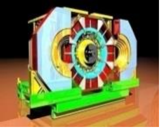
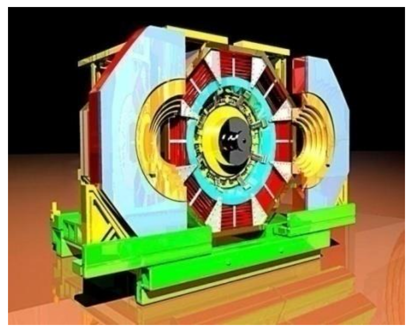


BESIII Collaboration



Piani per il futuro prossimo e meno prossimo

CSN1 – Roma **July 15, 2013**

Significativo incremento in tutte le sezioni!

TORINO: 6.0 FTE

1. 20% Bagnasco
2. 40% Bianchi
3. 50% De Mori
4. 50% Destefanis
5. 50% Fava
6. 20% Gaido
7. 50% Greco
8. 30% Lusso
9. 50% Maniscalco
10. 50% Maggiora
11. 50% Marcello
12. 10% Rivetti
13. 50% Spataro
14. 80% Sosio

+ 0.3FTE tecnici dei servizi

PG:

1. 30% Simone Pacetti

FE: 3.8 FTE

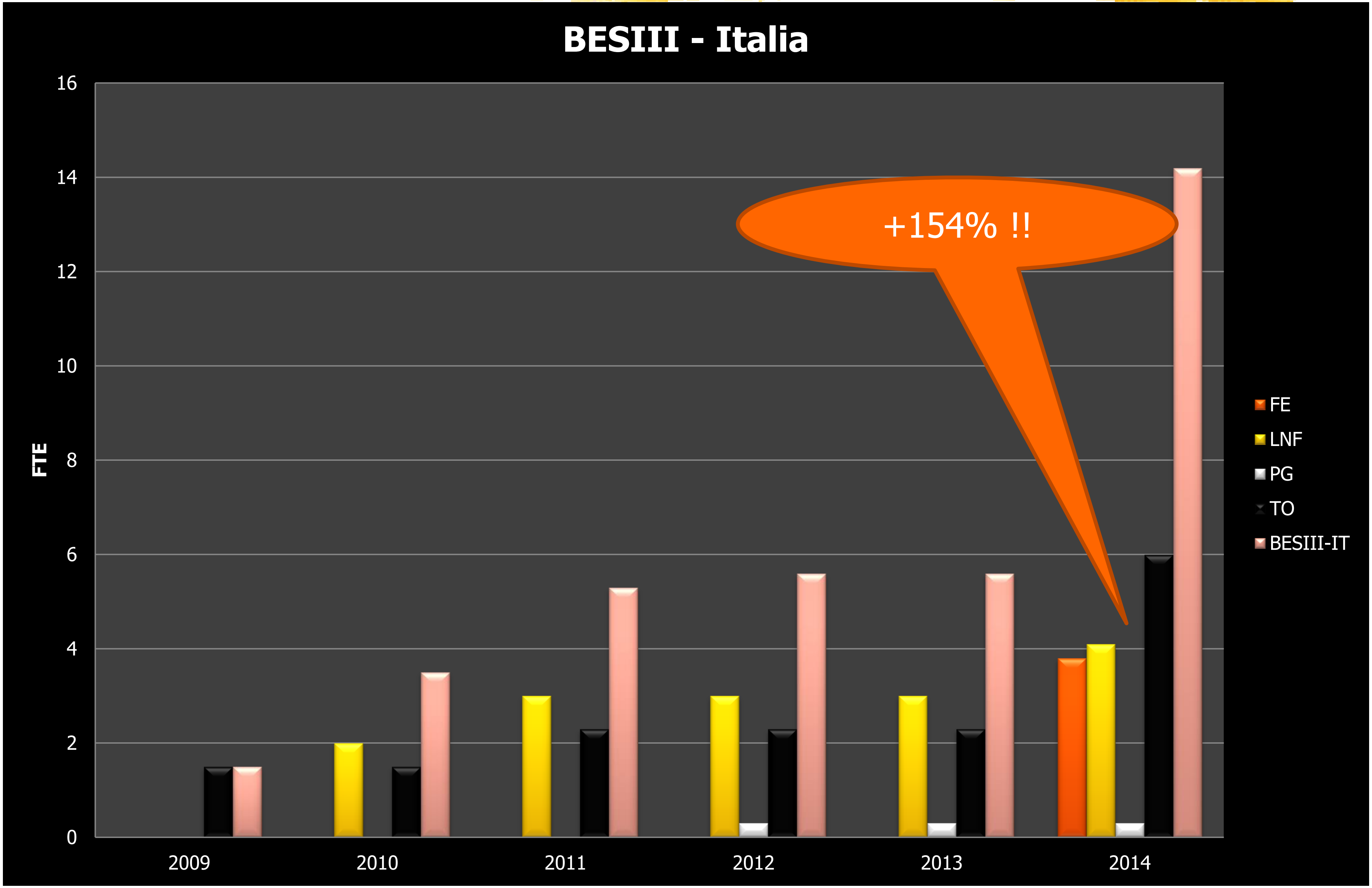
1. 50% Diego Bettoni
2. 30% Vito Carassiti
3. 70% Gianluigi Cibinetto
4. 10% Angelo Cotta Ramusino
5. 50% Elisa Fioravanti
6. 50% Isabella Garzia
7. 70% Valentina Santoro
8. 50% Mauro Savriè

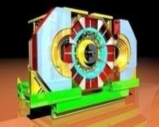
+ 0.9FTE tecnici dei servizi

LNF: 4.1 FTE

1. 0% Rinaldo Baldini
2. 100% Monica Bertani
3. 100% Alessandro Calcaterra
4. 30% Giulietto Felici
5. 80% Piero Patteri
6. 100% Yadi Wang
7. 0% Adriano Zallo

Significativo incremento in tutte le sezioni!





Scuola di Dottorato Interateneo di Torino

Scuola di Dottorato Interateneo:

"Integrated Electronic Devices and Sensors"

- INFN + Università + Politecnico di Torino
- LOI Scuola firmato il 28/6/2013
- Accreditamento MIUR richiede 3 borse per Istituto
- INFN finanzia 2 borse
- **1 borsa finanziata dall'IHEP tramite Virtual Laboratory**
- per il MIUR risulta borsa INFN
- **grande contributo IHEP 2013-2017 $\Rightarrow$ 200 K€!!**
- **LOI IHEP firmata il 5/7/2013**

Scuola di Dottorato Interateneo di Torino

Scuola di ...

"Inte... Sensors"

- INFN + Un...
- LOI Scuola...
- Accreditam...
- INFN finan...
- **1 borsa fi... ...ratory**
- per il MIUR...
- **grande co... !**
- **LOI IHEP ...**

Institute of High Energy Physics

Chinese Academy of Sciences

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Sezione di Torino
Via Pietro Giuria 1
10125 – Torino
ITALY

Object: Turin Doctoral School in "Integrated Electronic Devices"

INFN will soon found with Università di Torino and Politecnico di Torino a Doctoral School in "Integrated Electronic Devices", as declared in the Letter of Intent attached to the present letter.

I herewith declare that IHEP is willing to contribute to such a School, funding one doctoral grant per year, starting from the academic year 2013-2014, for a total of three full Ph.D. cycles, each full term being composed of three annuity.

The grant funded by IHEP should be reserved for a non-Italian candidate selected by IHEP and for academic activities agreed by the Turin Section of INFN with IHEP. The School Board should consider as a suitable Degree to access the Doctoral School, and hence equivalent to the Italian Master Degree, a declaration from the Ph.D. Supervisors Board of IHEP that the proposed candidate could access the Ph.D. three years term in a Doctoral School in the People's Republic of China.

IHEP is willing to abide to the following obligations:

1. each year, on September, IHEP will transfer to INFN funds corresponding to the gross cost of the annuities related to IHEP funded grants in the starting academic year (i.e. one in the first academic year, two in the second academic year, three in the third academic year and, if the Doctoral School Agreement won't be extended and IHEP and INFN won't extend their forthcoming MoU, two in the fourth academic year and one in the fifth academic year);
2. each year, on September, IHEP will transfer to INFN funds corresponding to the effective cost of the grant extensions due to the activities abroad of the students holding IHEP funded grants in the previous academic year, up to a maximum of 4K€ per grant and per annuity.

The present letter has to be considered as a Letter of Intent. The Agreement among IHEP and INFN on the above cited Doctoral School will be finalised by signing a proper Memorandum of Understanding between IHEP and INFN once the School Regulation will be signed and approved in Italy.

Beijing, 2013/07/5

Yifang WANG
Director of the Institute of High Energy Physics, Beijing

Scuola di Dottorato Università di Torino

- Esplicita richiesta BESIII & IHEP per l'attivazione di

  Borse di Dottorato in COTUTELA

  con l'Università di Torino

- Convenzioni con le

  singole Università P.R.R. legate all'IHEP e a BESIII

  in fase di studio

CLOUD di Sezione @ TO

Grande convergenza in Sezione a Torino

- **DG1 da Belle, BESIII e CMS investiti per 4WN condivisi**
- collaborazione anche con Alice

La CLOUD potrà partire prestissimo

- **prima CLOUD di Sezione per calcolo scientifico**
  (se non si considera il CNAF!)
- infrastruttura di sezione CONDIVISA
- possibili ulteriori contributi nei prossimi mesi

Stato dello ZDD

- Installato, funziona come (unico!) luminometro dell’esperimento
- Utilizzato dai macchinisti di BEPC-II durante tutto il run 2012-2013 per massimizzare la luminosità
- Dati acquisiti nel datastream di BESIII in modo ufficiale per l’ultimo 80% del run

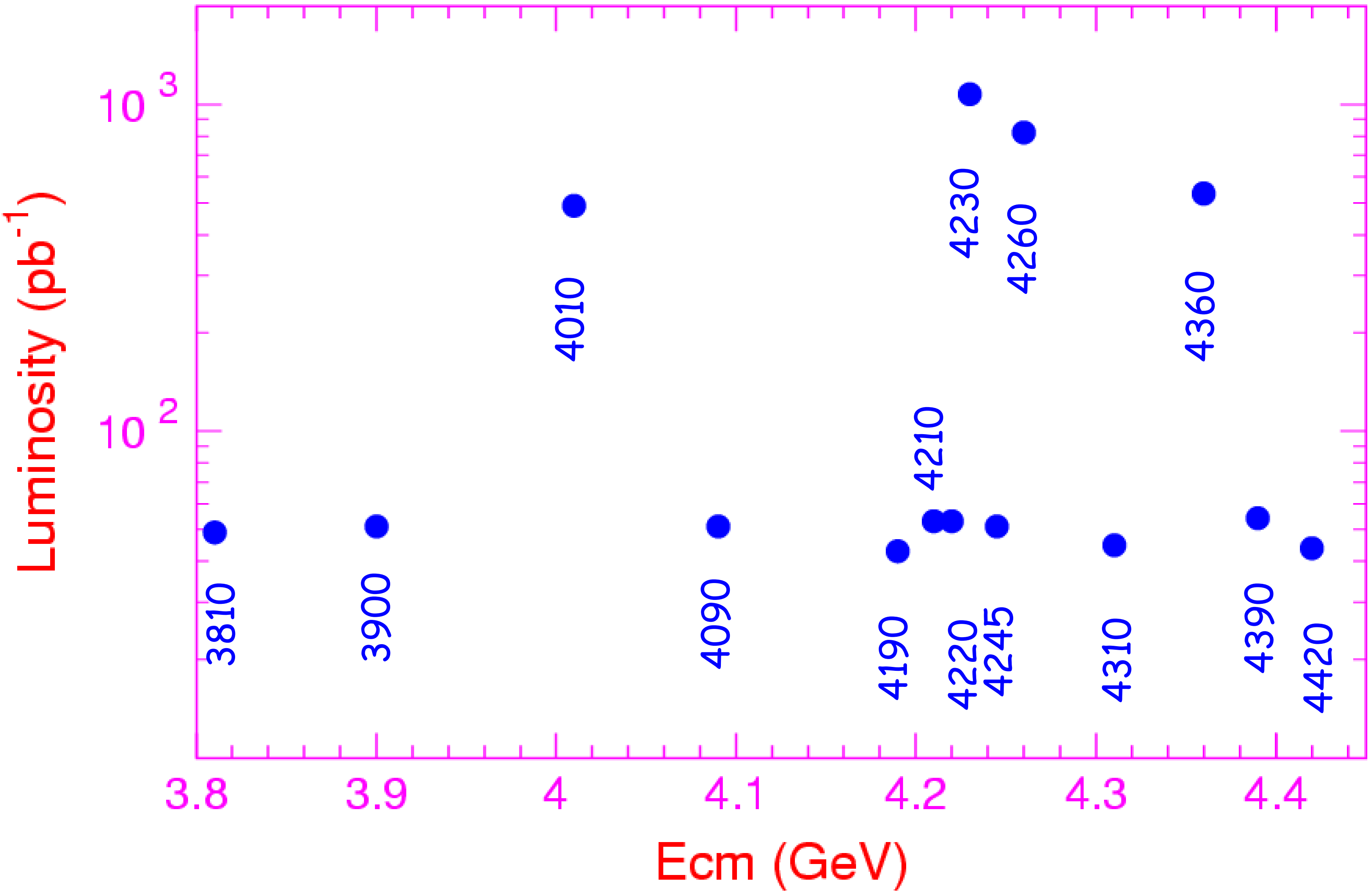
BESIII: Dati Raccolti

- Luglio 2008: prime collisioni e+e- in BESIII
- Nov 2008: ~14M y(2S) eventi per calibrazione
- 2009: 106M ψ(2S) 4xCLEOc
  225M J/ψ 4xBESII
- 2010-11: 2.9 fb^{-1} ψ (3770) 3.5xCLEOc
- 2011: 0.5 fb^{-1} @ 4.01GeV (Ds, XYZ)
- 2012: 0.4B ψ(2S)
  J/y: 1B eventi,
  lineshape scan sottosoglia per misura della fase relativa ampiezze e.m e forte della J/ψ , richieste dalla collab. italiana, 14pb^{-1}/pto, tot 5 punti
  R scan @ 2.4, 2.8, 3.4 GeV
- 2013: dati XYZ, see next page →

Il più grande set di J/ψ, ψ(2S) e ψ(3770) al mondo

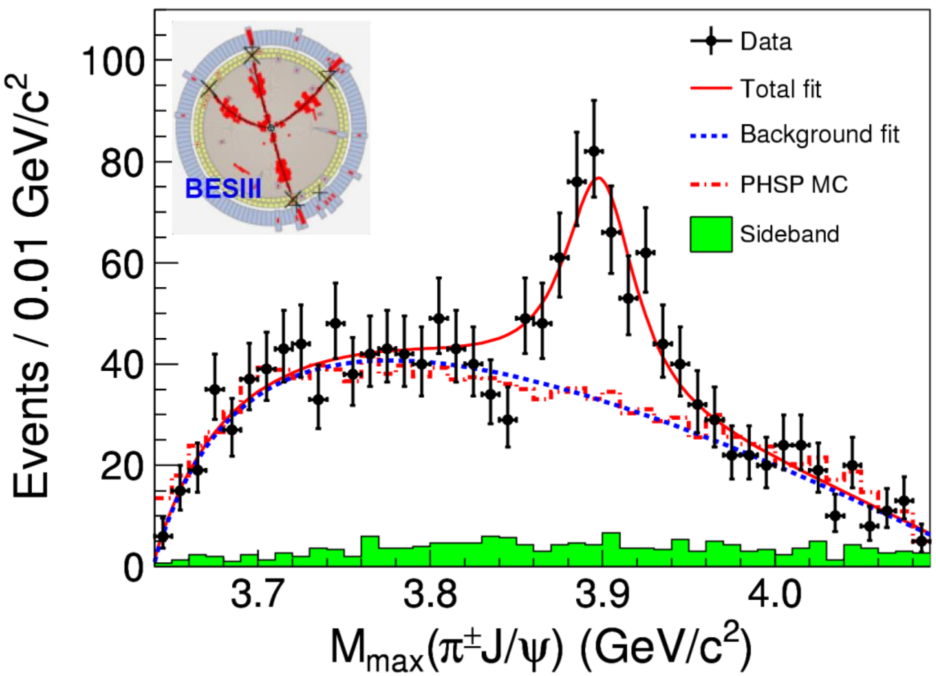
- Luminosità di picco raggiunta: $7x10^{32}$ $cm^{-2}s^{-1}$ @ 3770 MeV

BESIII collected 3.3/fb for XYZ study



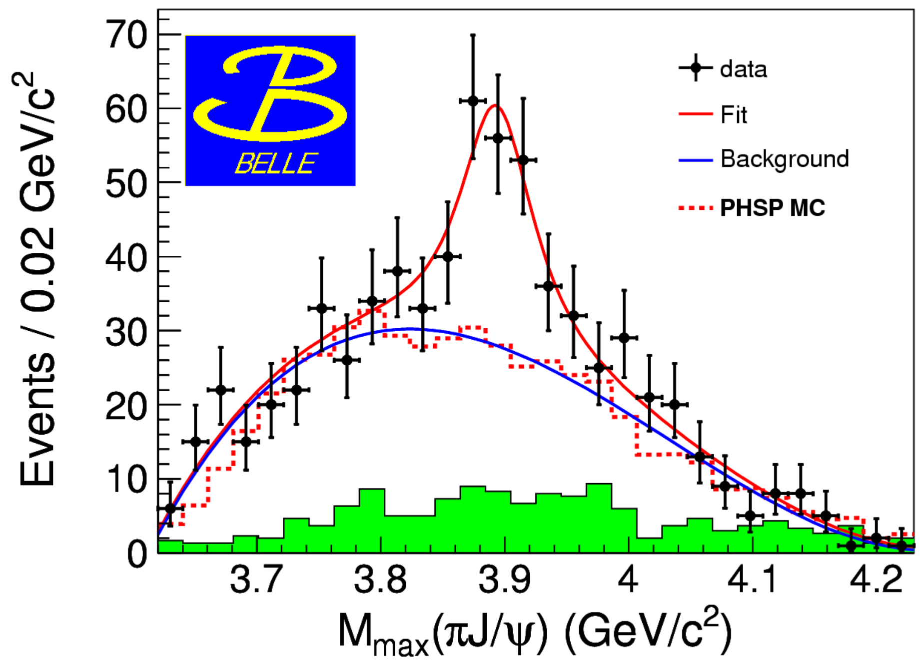
$Z_c(3900)$ observed in two experiments!

BES3 at 4.26 GeV: PRL 110(2013)252001



- M = 3899.0±3.6±4.9 MeV
- Γ = 46±10±20 MeV
- 307 ± 48 events
- >8σ

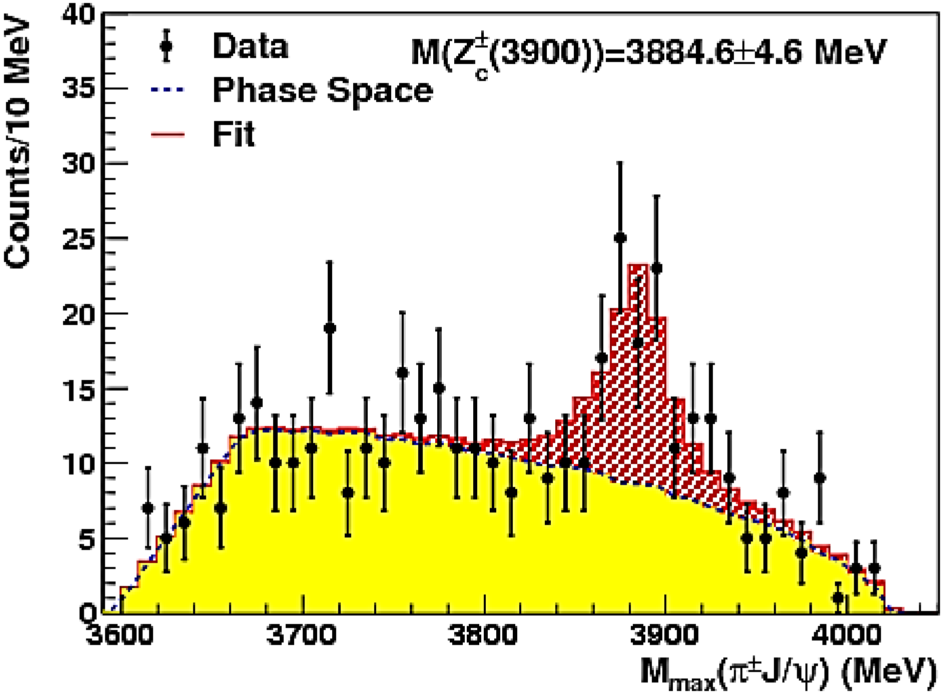
Belle with ISR: PRL 110(2013)252002



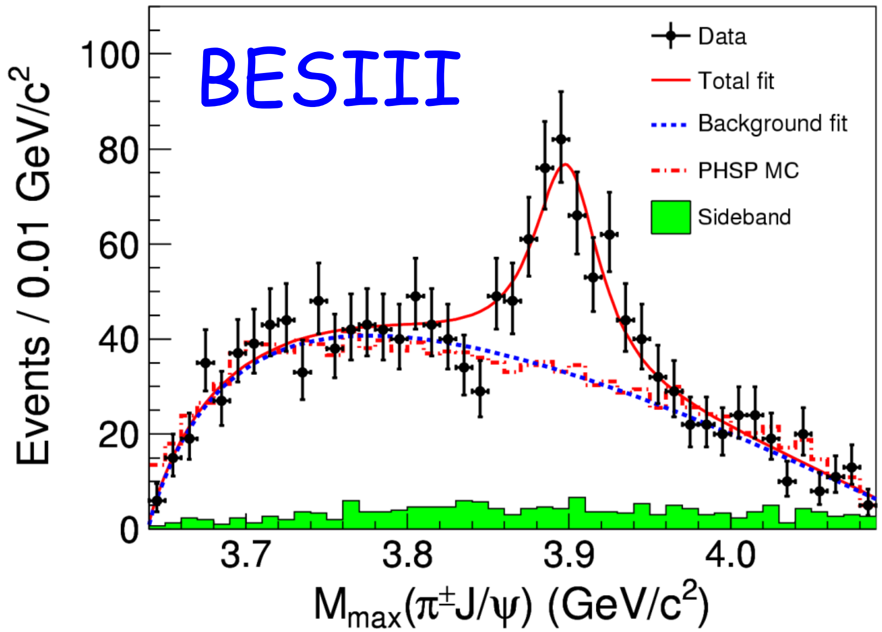
- M = 3894.5±6.6±4.5 MeV
- Γ = 63±24±26 MeV
- 159 ± 49 events
- >5.2σ

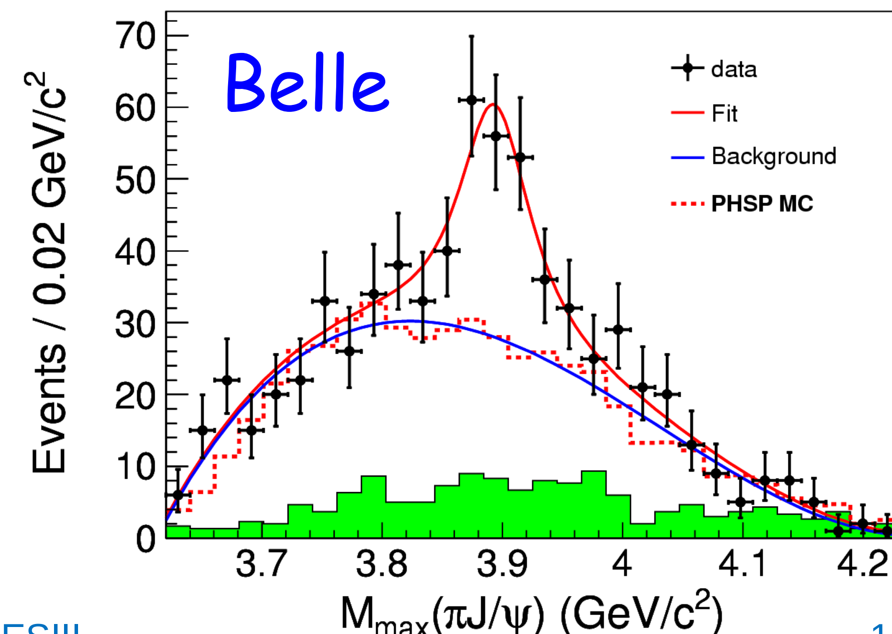
Confirmed with CLEOc data!

CLEOc data at 4.17 GeV:
1304.3036

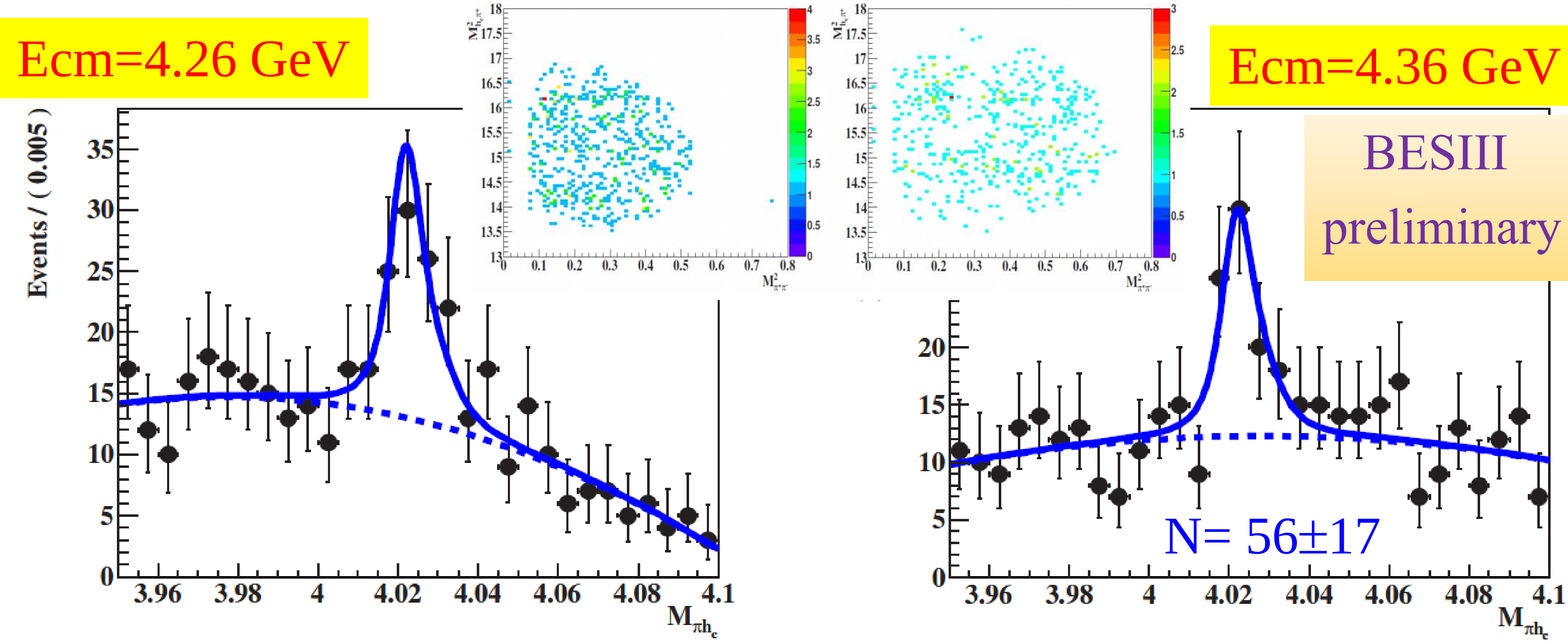


- M = 3885±5±1 MeV
- Γ = 34±12±4 MeV
- 81 ± 20 events
- 6.1σ





$e^+e^- \to \pi Z_c(4020) \to \pi^+\pi^- h_c(1P)$



Simultaneous fit to 4.26/4.36 GeV data and 16 η_c decay modes. 6.4σ

$M(Z_c(4020)) = 4021.8 \pm 1.0 \pm 2.5$ MeV; $\Gamma(Z_c(4020)) = 5.7 \pm 3.4 \pm 1.1$ MeV

$$R = \frac{\sigma(e^+e^- \to \pi^{\pm} Z_c^{\mp} \to \pi^+\pi^- h_c(1P))}{\sigma(e^+e^- \to \pi^+\pi^- h_c(1P))} = (16.2 \pm 4.1 \pm 0.7)\% \qquad (16.6 \pm 5.2 \pm 0.8)\%$$

J/ψ Strong and Electromagnetic Decay Amplitudes

Resonant contributions

$\Gamma_{J/\psi} \sim 93\text{KeV} \rightarrow$ pQCD

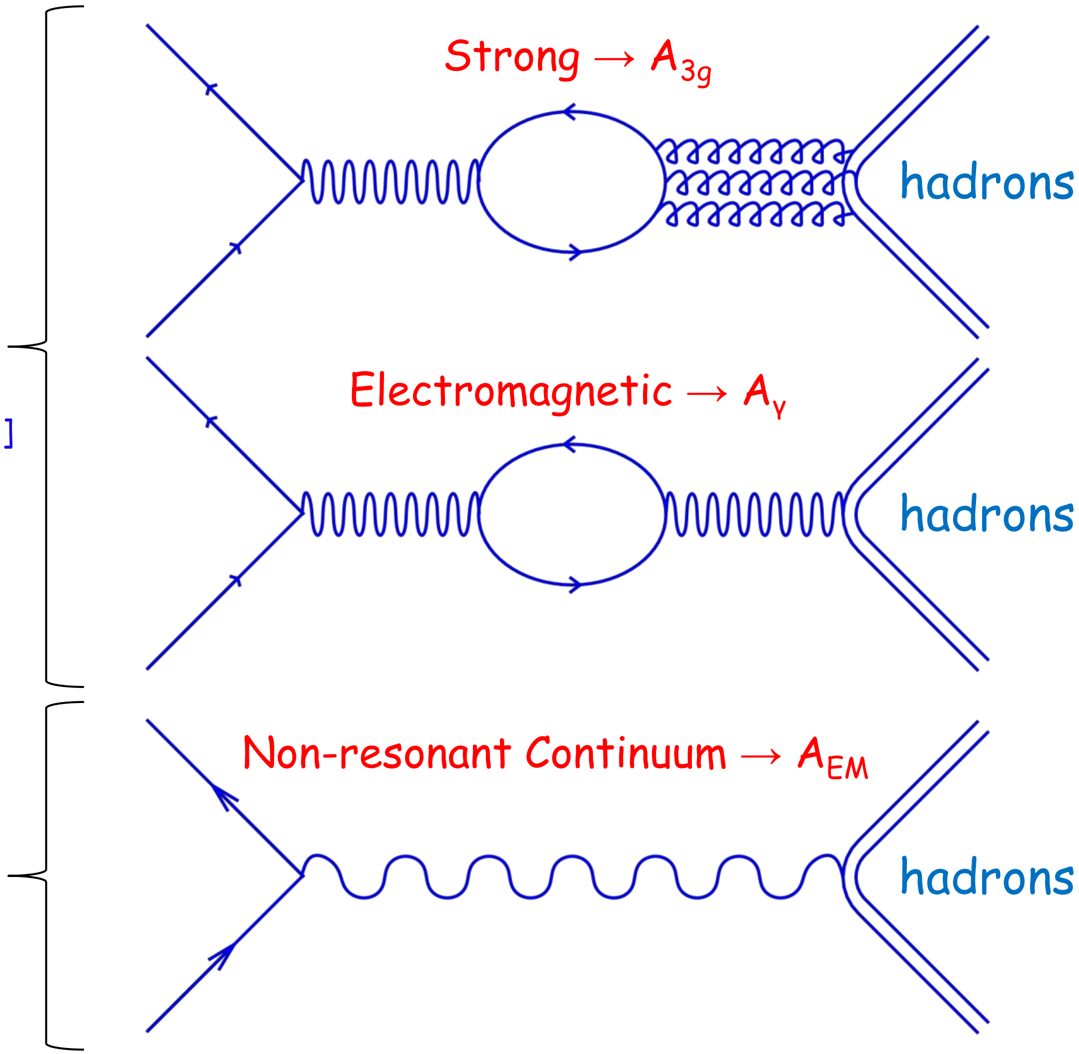
pQCD: all amplitudes almost real [1,2]

QCD -> $\Phi_p \sim 10°$ [1]

Non-resonant continuum

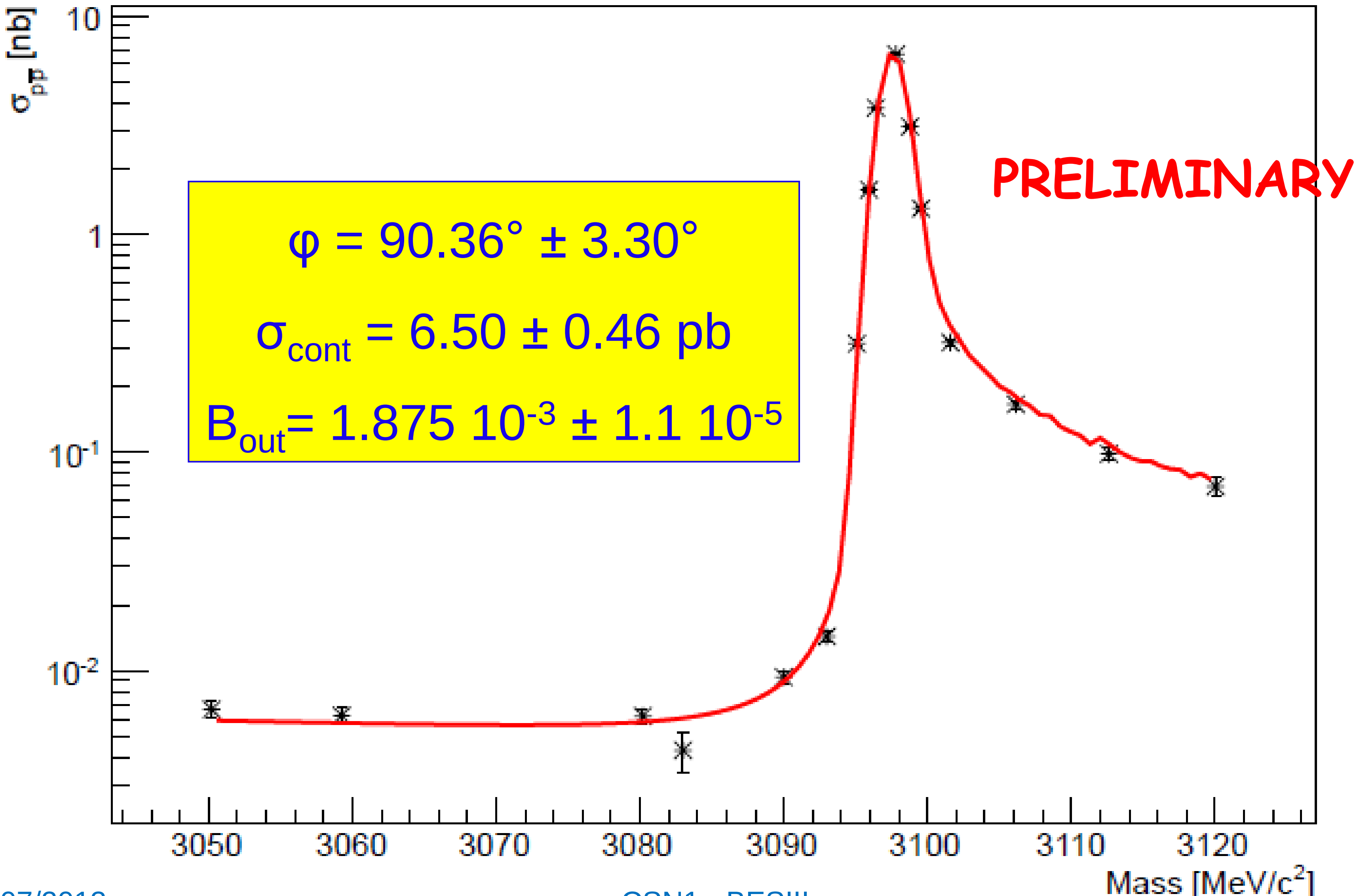
pQCD regime

$A_{EM} \in \Re$



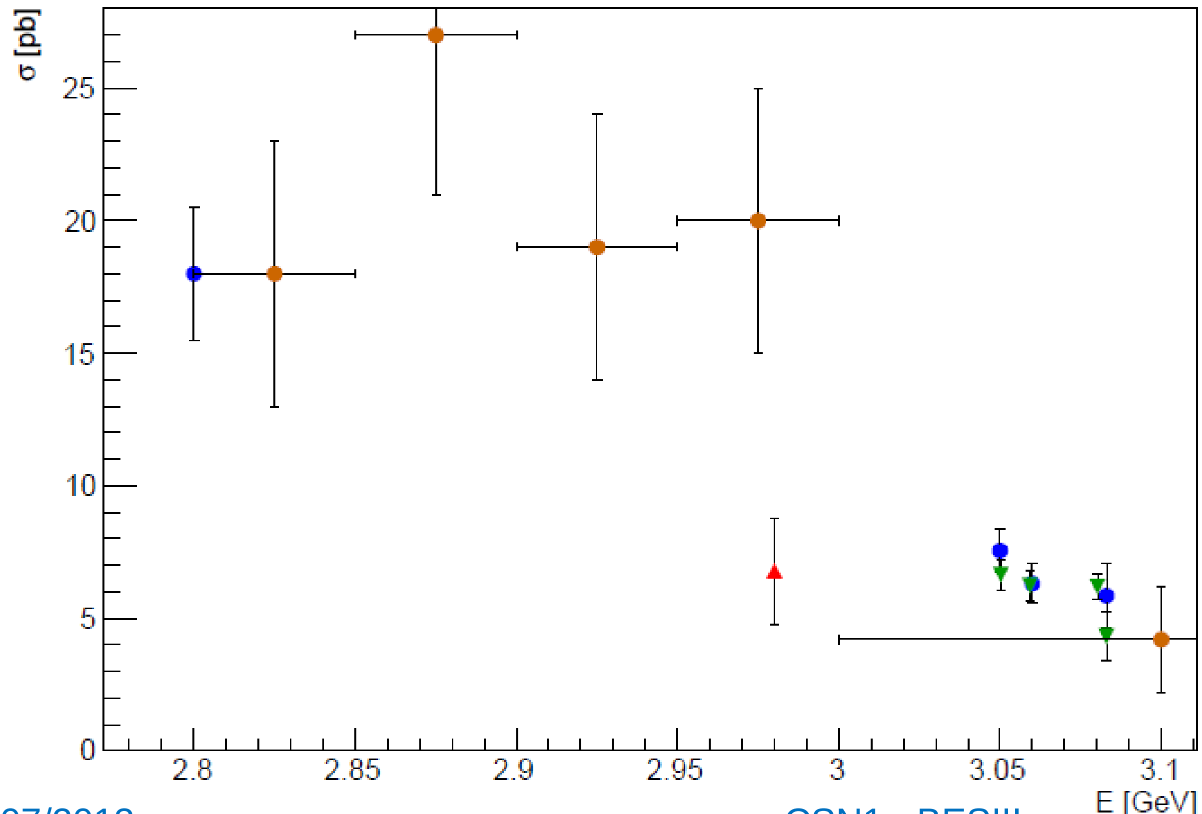
[1] J. Bolz and P. Kroll, WU B 95-35.
[2] S.J. Brodsky, G.P. Lepage, S.F. Tuan, Phys. Rev. Lett. 59, 621 (1987).

J/ψ → ppbar Phase



Jump in the cross section?

BESIII-IT	triangle	
Xiaorong Zhou	circle	Study of $e^+e^- \rightarrow$ ppbar, P&S Meeting 2013
Babar	circle	arXiv:1302.0055v1 [hep-ex] 1 Feb 2013
E760	triangle	Phys.Rev.Lett. 70, 1212, 1993



Further data

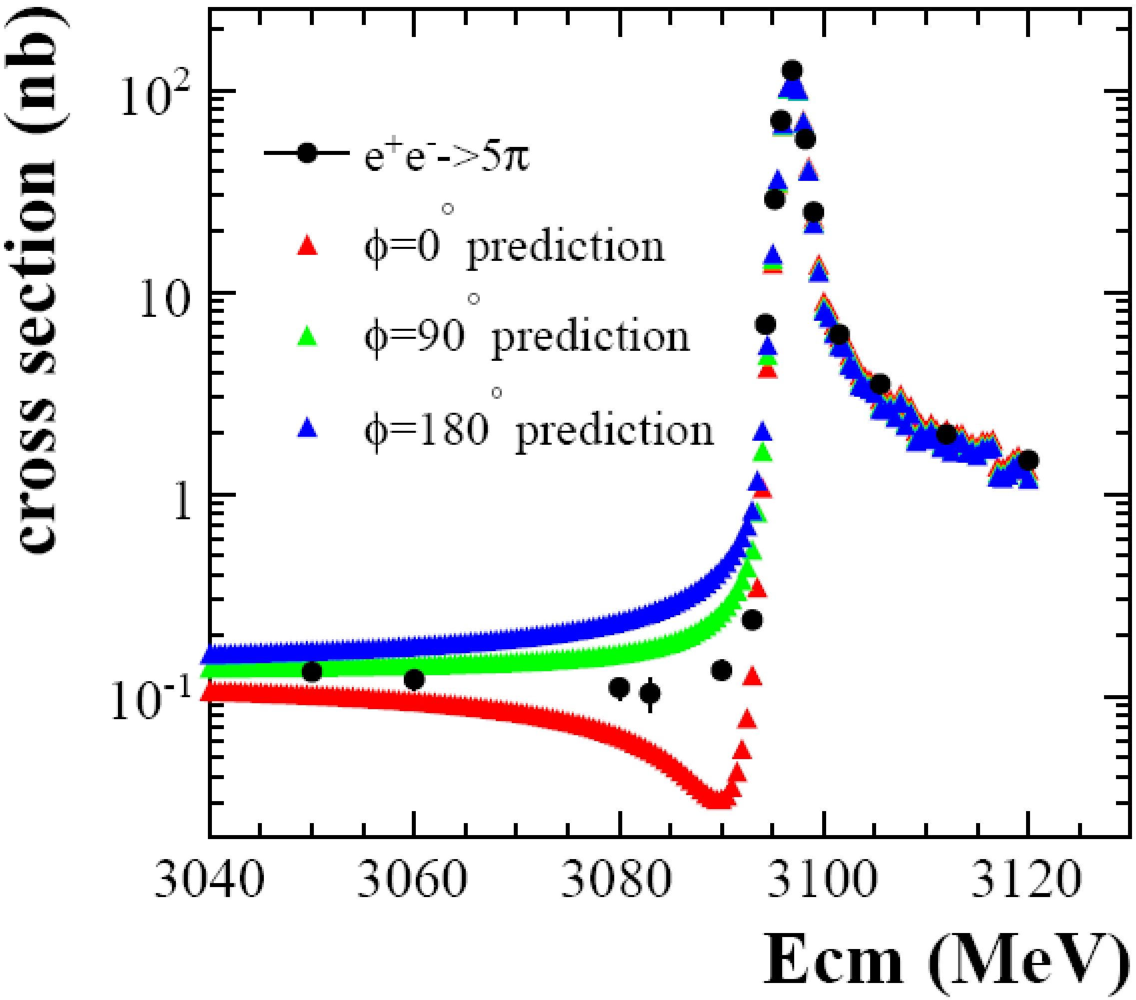
Between

2.8 and 3.0 GeV!

GS Huang

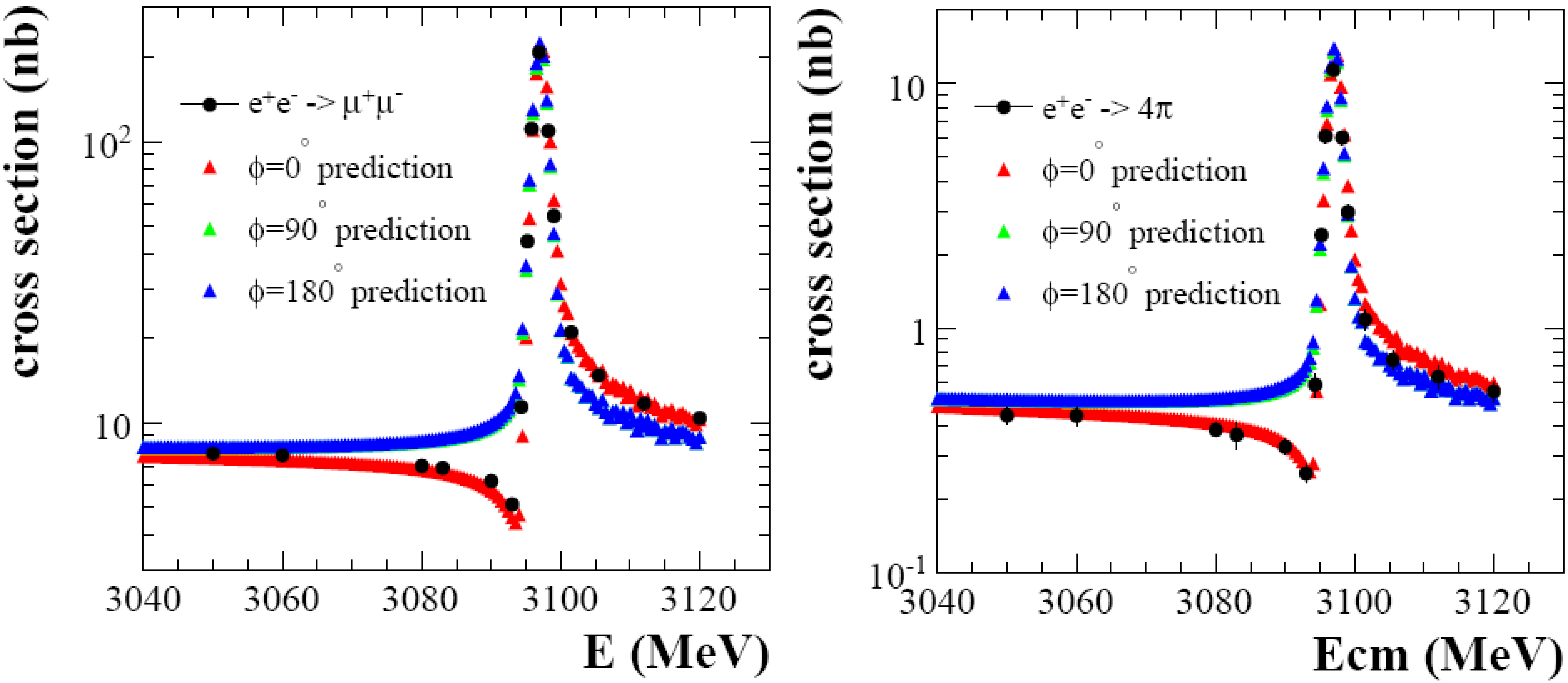
$J/\psi \to 5\pi$ Phase

PRELIMINARY



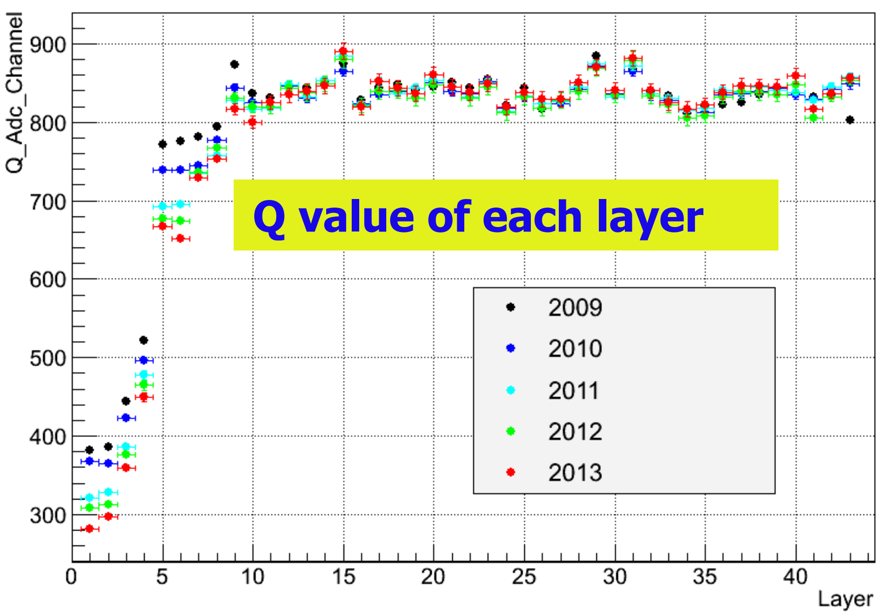
J/ψ → other channels Phase

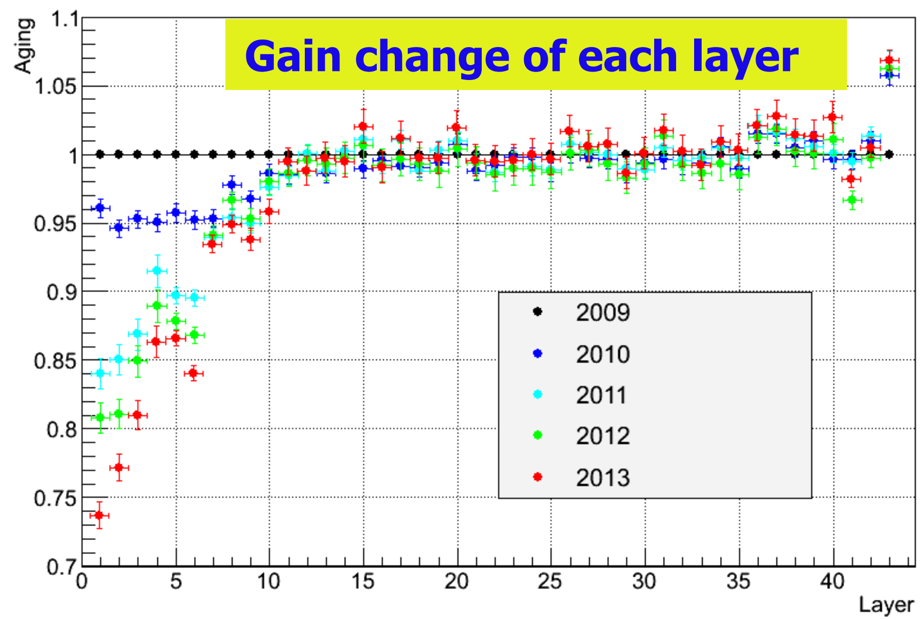
PRELIMINARY



BESIII Inner Tracker: MDC aging problems

Gain change from 2009-2013 with Bhabha events

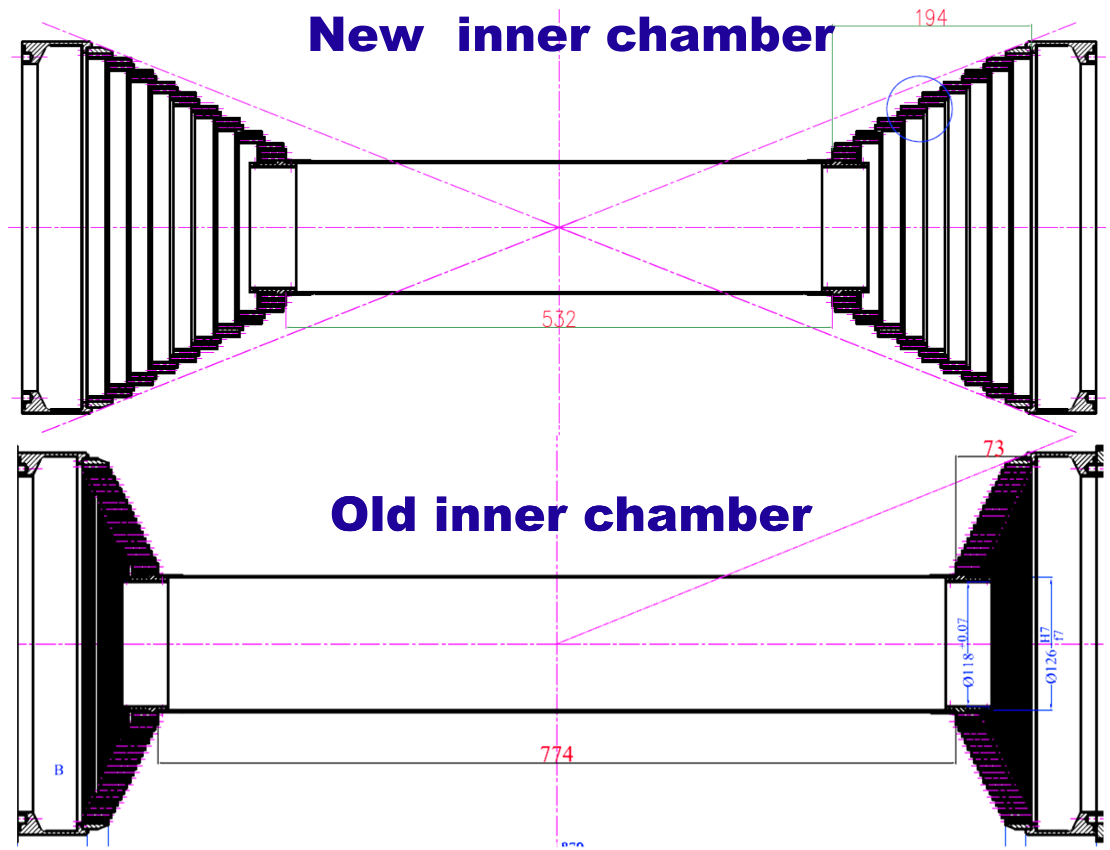




- Compared with 2009, now the gas gains of first 5 layers decrease about 26% —14%
- The gains of the first 10 layers have an obvious decrease
- The gains of the layers in the outer chamber have nearly no change

BESIII new Inner Tracker: one more DC

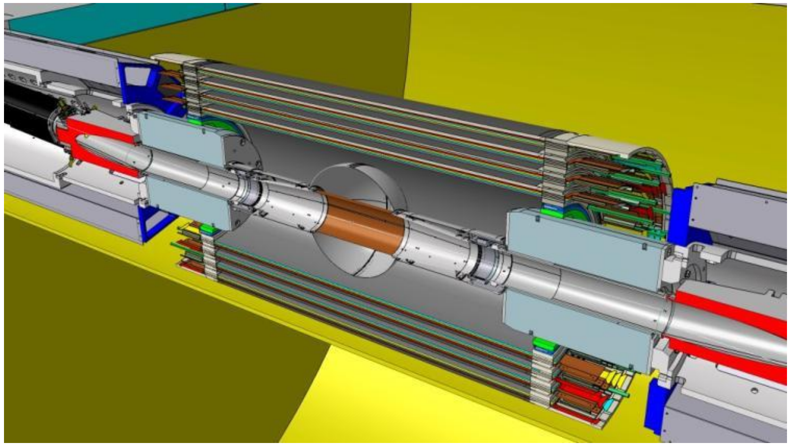
- A spare new inner drift chamber is under construction, which will be finished in next April
- Steped end plate is used to shorten the wire length beyond the effective solid angle



KLOE2 Inner Tracker

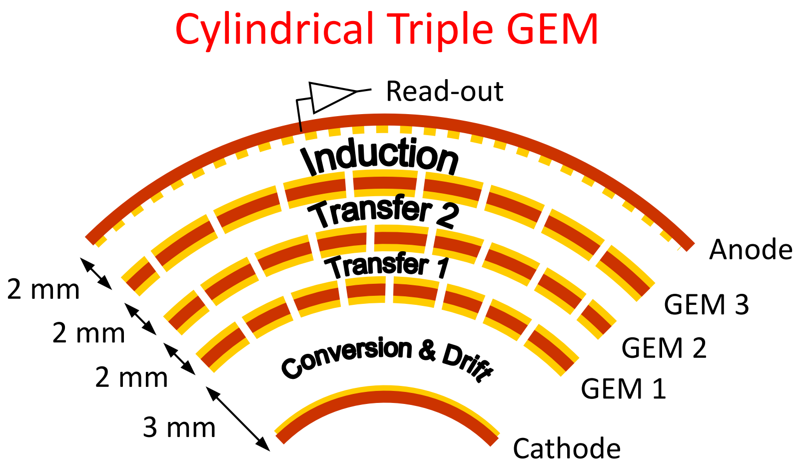
To improve vertex reconstruction of K_s , η and η' and K_s- K_L interference measurements:

1. $\sigma_{r\varphi} \sim 200\ \mu m$ and $\sigma_z \sim 350 \mu m$
2. low material budget: < 2% X_0



Cylindrical GEM detector is the adopted solution

- 4 CGEM layers :from IP to DC Inner wall
- 700 mm active length
- XV strips-pads readout (~40º stereo angle)
- <2%X_0 total radiation length in the active region

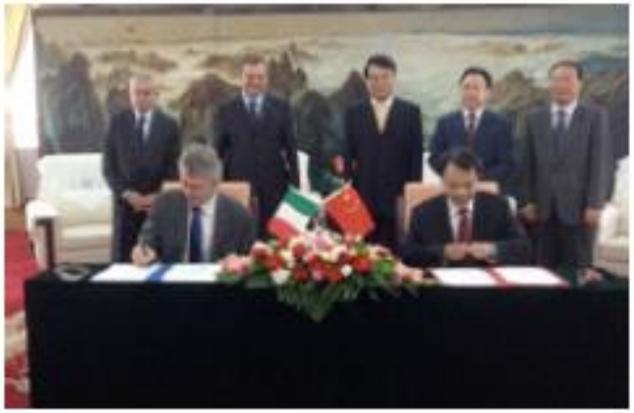


$K_S \rightarrow \pi^+ \pi^-$ vertex resolution will improve of about a factor 3 from present 6mm

First layer: construction goals

- Design,construction and test of a CGEM prototype, in case first layer of a new CGEM Inner Tracking
- Design,construction and test of an analog readout system to achieve < 100 μm xy and < 200 μm z resolutions
- Budget (euros) requested to Foreign Affairs Ministry, following the Agreement of scientific cooperation for a Joint laboratory "INFN-IHEP" :

INFN 1st year expenditure	40000	33.3%
Italian Ministry of FA expenditure	40000	33.3%
Foreign Institution expenditure	40000	33.3%
More funds	0	0%
1st year project cost	120000	


BESIII Winter Collaboration Meeting,Guilin

BESIII Inner Tracker

Requirements for the inners tracking detector

- Rate capability: ~10^4 Hz/cm^2
- Spatial resolution: s_{xy} =~100μm : s_z=~1mm
- Momentum resolution:: s_{pt}/P_t =~0.5% @1GeV
- Efficiency=~98%
- Material budget <= 1.5% all layers
- Coverage: 93% 4π
- Operation duration~ 5 years

BESIII Inner Tracker: CGEM

KLOE2

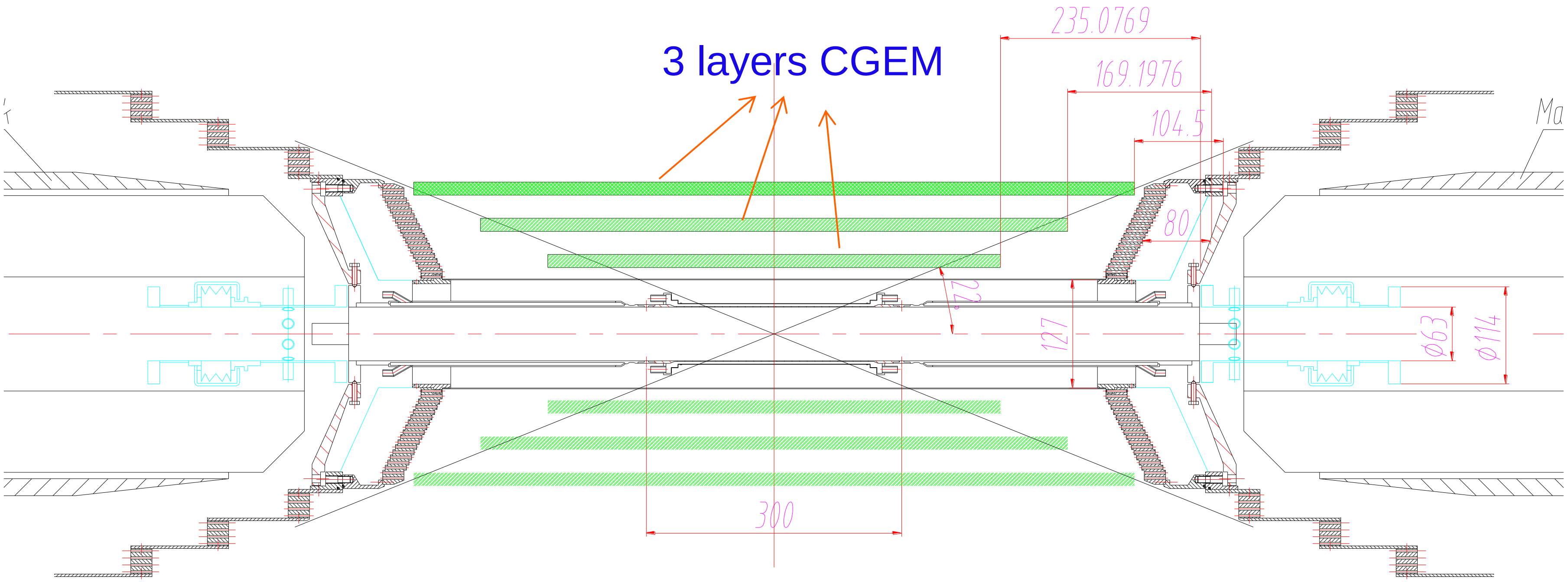
Anodo: not clear to G.B.
CF Carbon Fiber

		% of X_0
CATHODE	Copper: 2*3 *1 Kapton: 2*50*1 Honeycomb: 1*3000*1	0.0420 0.0350 0.0240 Total= 0.101
GEM foils	Copper: 6*3 *0.8 Kapton: 3*50 *0.8	0.1007 0.0420 Total= 0.143
ANODE	Copper: 3.5+1.5+3 Kapton: 1*225 *1 Gold : 2*0.1 *1 Epoxy: 2*10 *1	0.0559 0.0787 0.0061 0.0060 Total=0.147
CF Shield	CF: 2*90 *1 Honeycomb: 1*5000*1	0.0429 0.0400 Total=0.0829
		1 Layer:0 .48 4 Layers:1.92

BESIII

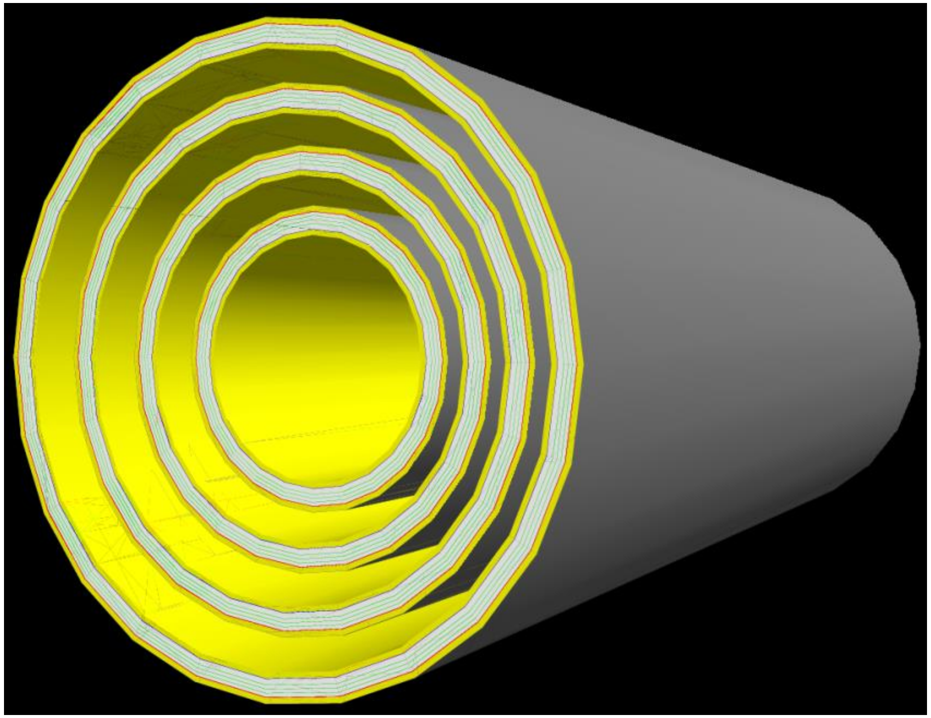
		% of X_0
CATHODE	Copper: 2*2 *1 Kapton: 2*50*1 Honeycomb: 1*3000*1	0.0280 0.0350 0.0240 Total= 0.0870
GEM foils	Copper: 6*2 *0.8 Kapton: 3*50 *0.8	0.0671 0.0420 Total= 0.109
ANODE	Copper: 2.5+1.5+2 Kapton: 1*225 *1 Gold : 2*0.1 *1 Epoxy: 2*10 *1	0.0420 0.0787 0.0061 0.0060 Total= 0.133
Shield	Kapton: 2*50 *1 Honeycomb: 1*3000*1	0.0350 0.0240 Total= 0.0590
		1 Layer: 0.39 4 Layer:**<u>1.56</u>**

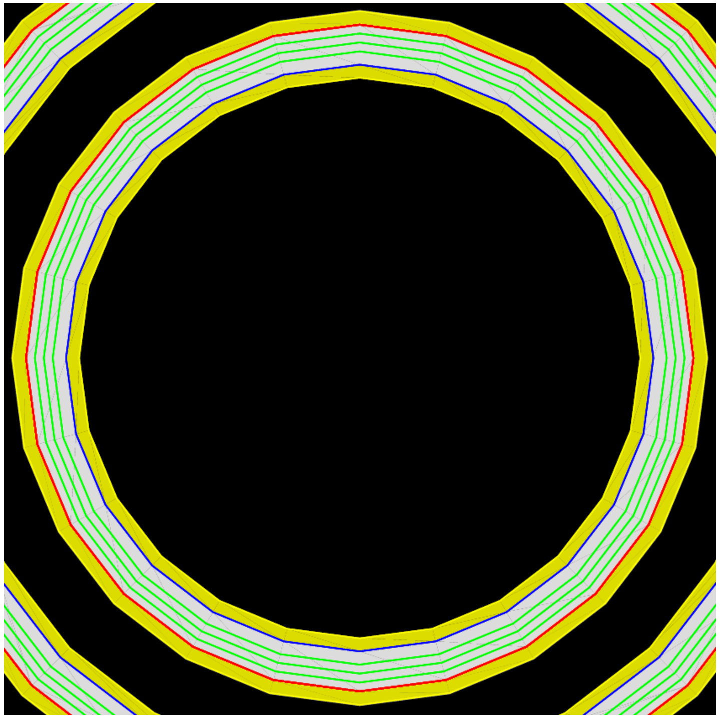
BESIII Inner Tracker: space available in z direction



- The gap is about 80mm~100mm between the end plate of MDC inner chamber and the mechanical support of beam pipe
- 105mm~235mm in z direction is available for the support structure, readout electronics, cables of CGEM on each side

BESIII Inner Tracker: CGEM GEANT4 model





Yellow: Honeycomb Support (Nomex)

Blue: Cathode (Cu, Kapton)

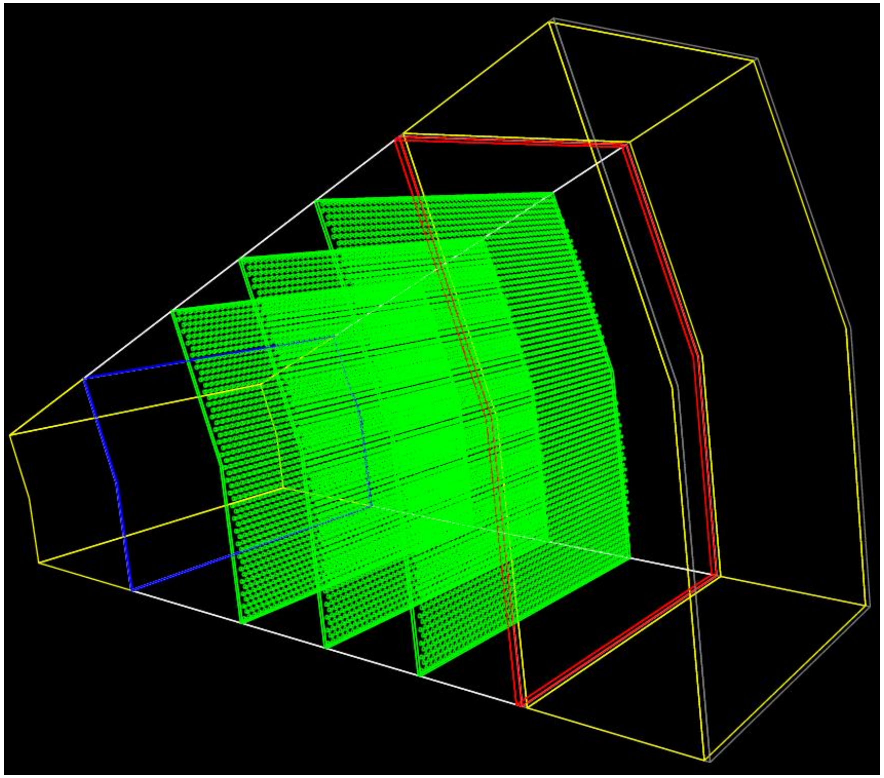
White: Work Gas of Gem ($Ar:CO_2$=70:30)

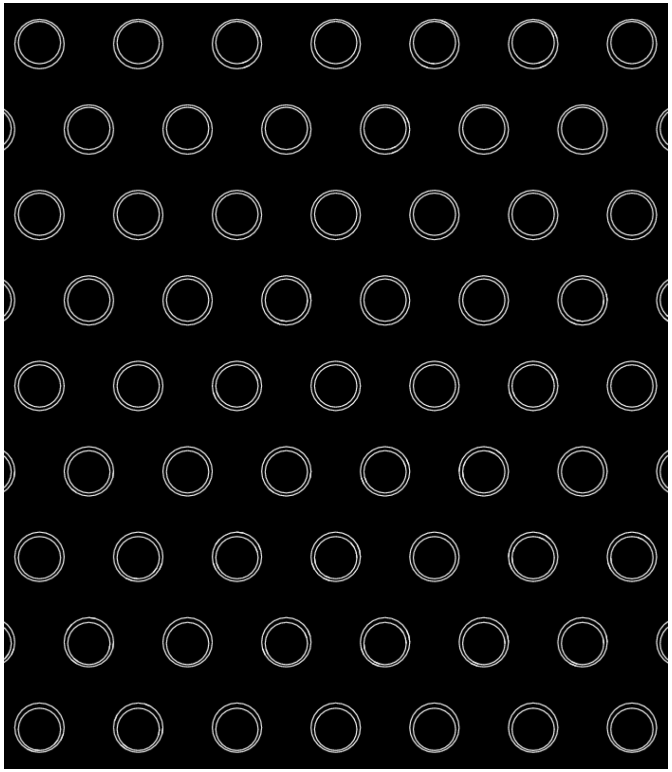
Green: Gem Foil (Cu, Kapton)

Red: Readout Anode (Cu, Kapton, Al Shielding)

Grey: Carbon Fiber Support

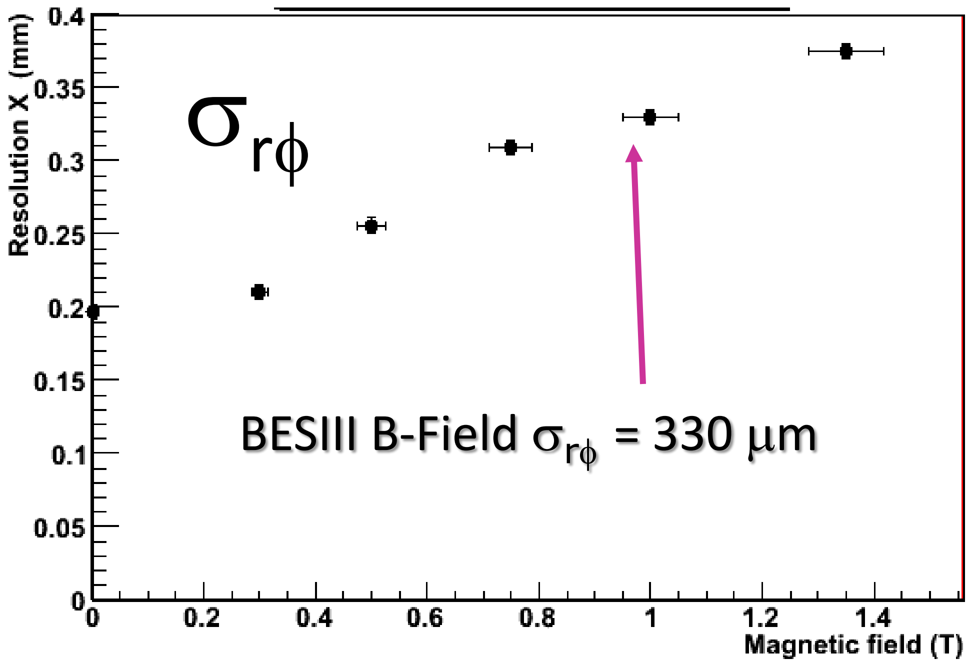
BESIII Inner Tracker: CGEM layer structure

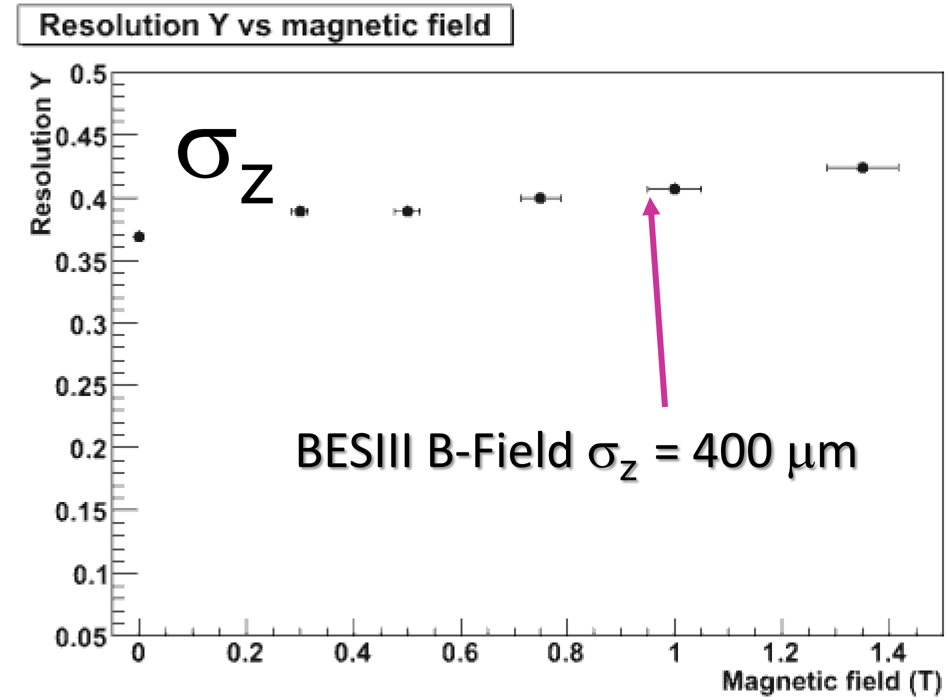




Single Mask Gem Foil, Single conical hole structure
Hole diameter: 70-60 μm
The larger section of the holes facing the cathode.
Hole Pitch: 140 μm

CGEM expected spatial resolution





Readout	$\sigma_{r\phi}$ (μm)	σ_z (μm)
Digital readout (Beam test @2009)	330	400
Analog readout (magnetic field effect avoided)*	80	150

* Taken as expected spatial resolution

CGEM resolutions

CGEM inner detector (**VS** MDC inner detector)

- **Improves dz resolution significantly**
  (by a factor of 2.6~6)

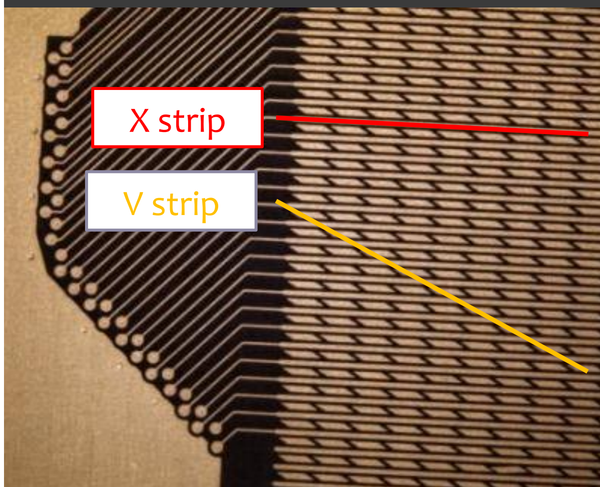
- **Comparable dr resolution**
  (~5% poorer for low momentum tracks)

- **Comparable momentum resolution**
  (~5% better for high momentum tracks)

CGEM: new anode design

KLOE2 IT – Readout Plane (no more available)

Readout'Plane'

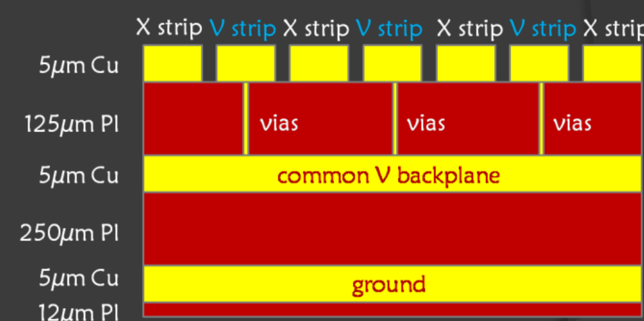


Readout plane is realized at CERN TE-MPE-EM

It is a kapton/copper multilayer flexible circuit

Provides 2-dimensional readout with XV strips on the same plane

- X are realized as longitudinal strips
- V are realized by connection of pad through conductive holes and a common backplane
- Pitch is 650 µm for both



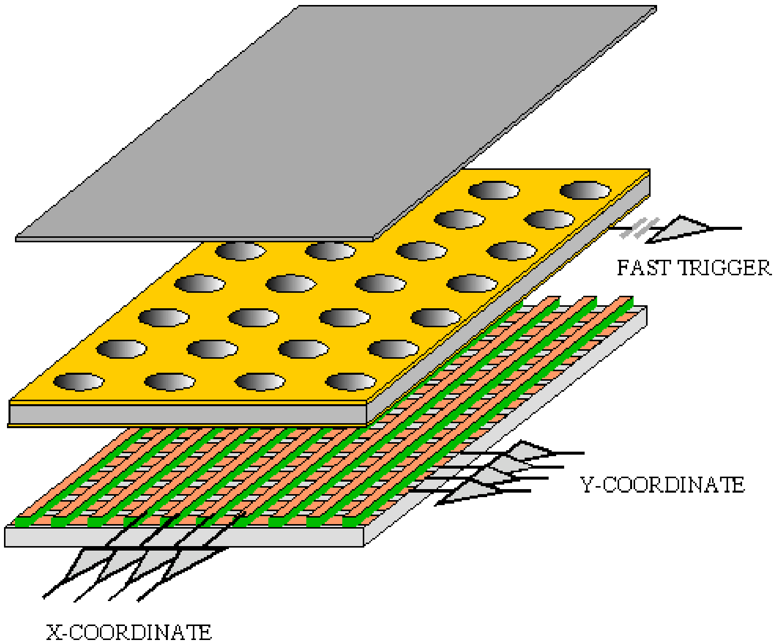
X pitch 650µm → X res 190µm

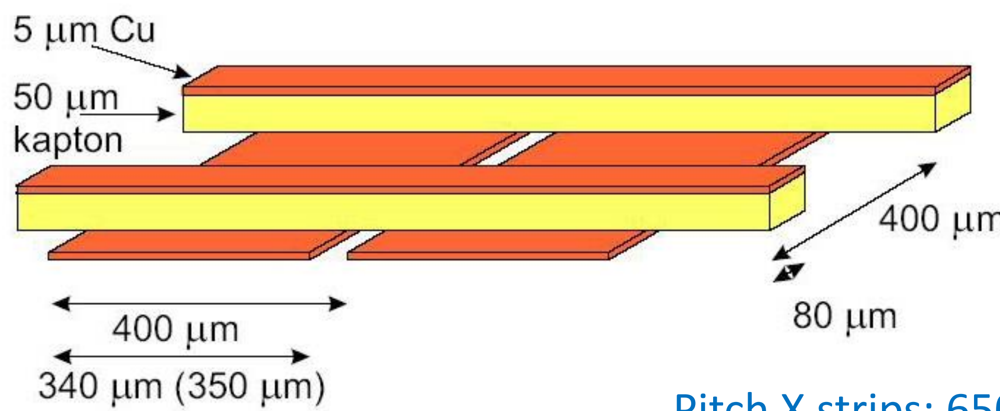
V pitch 650µm → Y res 350µm

D.Domenici - LNF

32

CGEM: COMPASS-type solution, new readout





Pitch X strips: 650 μm
Width X strips: 350 μm
Width V strips: 80 μm
Kapton: 50 μm
Cu: 5 μm

- *Due to diffusion the charge cloud collected on the readout board is bigger than the strip width (≈ 3.5 x pitch) and a weighting method is used for calculate the exact track position in two dimensions*
- *Every single strip versus the other readout coordinate acts as a plate capacitor. With the permittivity ε=3.9 of Kapton and an area of $2.27 \cdot 10^{-1} cm^2$, this capacitance is 15.7 pF*

CGEM: a new support

Rohacell

- Poli-Methacrylimide from hot foaming of of methacrylic acid and Methacrylonitrile Copolymer sheets
- Grades :

  31(30 kg/m^3); 51(50 kg/m^3); 71(70 kgm^3);

  110 (110 kg/m^3); 170(170 kg/m^3); 190(190 kgm^3)
- Availability(mm):

  2500*1250 *(2-65)
- Very good mechanical properties
- Very easy to work on milling machine & Lathe

CGEM: Rohacell

BESIII -Rohac-Compass Anode

		% of X_0
CATHODE	Copper: 2*3 *1 Kapton: 3*25*1 Rohacell: 2*1000*1 Epoxy: 2*10*1	0.0440 0.0200 0.0140 0.0060 Total= 0.0800
GEM foils	Copper: 6*3 *0.8 Kapton: 3*50 *0.8	0.1007 0.0420 Total= 0.1430
ANODE	Copper: 3+5+3 Kapton: 2*50 *1 Gold : 2*0.1 *1 Epoxy: 2*10 *1 Rohacell 2*1000*1	0.008 0.034 0.006 0.006 0.014 Total=0.068
		1 Layer:0 .24 3 layers:**<u>0.72</u>** 4 layers:0.96

BESIII-Kloe like

		% of X_0
CATHODE	Copper: 2*2 *1 Kapton: 2*50*1 Honeycomb: 1*3000*1	0.0280 0.0350 0.0240 Total= 0.0870
GEM foils	Copper: 6*2 *0.8 Kapton: 3*50 *0.8	0.0671 0.0420 Total= 0.109
ANODE	Copper: 2.5+1.5+2 Kapton: 1*225 *1 Gold : 2*0.1 *1 Epoxy: 2*10 *1	0.0420 0.0787 0.0061 0.0060 Total= 0.133
Shield	Kapton: 2*50 *1 Honeycomb: 1*3000*1	0.0350 0.0240 Total= 0.0590
		1 Layer: 0.39 4 Layer:**<u>1.56</u>**

CGEM IT FrontEnd electronics

- Readout ASIC for CGEM:
  - Modify/adapt the existing TOF-PET ASIC

    (Rolo, Rivetti et al http://iopscience.iop.org/1748-0221/8/02/C02050)

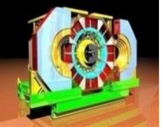
    in IBM 130nm for PET applications

- Re-design a **new analogue FE** (suited for CGEM signals)

- Use of the **same BackEnd** of TOF-PET

- Migration to a newer and cheaper technology:
  IBM 130nm $\rightarrow$ **UMC 110 nm**
  should be exportable in China (implemented in Italy)

- Integration and Development of the new ASIC for CGEM



TOF-PET: Basic Features

Features of an ASIC for SiPM readout in PET applications

Parameter	Value
Number of channels	64
Clock frequency	80 – 160 MHz
Dynamic range of input charge	**300 pC**
SNR (Q_{in} = 100 fC)	> 20-25 dB
Amplifier noise (in total jitter)	< 25 ps (FWHM)
TDC time binning	**50 ps**
Coarse gain	G_0, $G_0/2$, $G_0/4$
Max. channel hit rate	100 kHz
Max. output data rate	320 Mb/s (640 w/ DDR)
Channel masking	programmable
SiPM fine gain adjustment	**500 mV (5 bits)**
SiPM	up to 320pF term. cap., 2MHz DCR
Calibration BIST	internal gen. pulse, 6-bit prog. amplitude
Power	**< 10 mW per channel**

⇒ GEM Input charge : 5 - 20 fC

⇒ GEM Power cons. < 7 mW

How these specs impact the choice of the readout chip architecture?

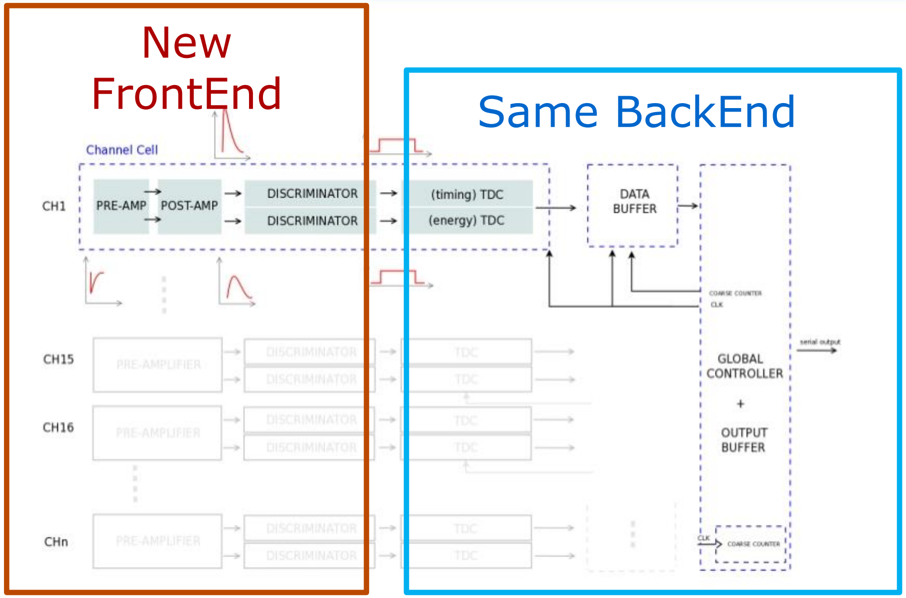
Manuel D. Rolo (LIP, Unito, INFN) | IC Design for TOF-PET with SiPMs | XXVI cycle Seminar | 9 / 31

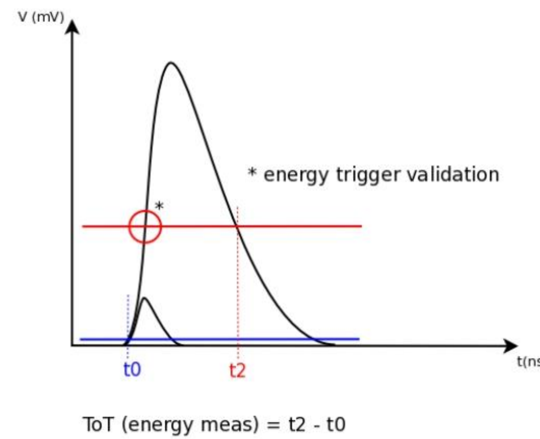
Front End not suited for GEM signals

TOFPET to the New ASIC

Overview of the channel architecture

64 Channels





- Time and charge measurements with independent TDCs
- TDC time binning 50 ps
- Charge measured with Time-over-threshold
- Typ. power consumption is 7mW p/channel (**trigger 0.5 p.e.** w/ $SNR > 23dB$ for 9 mm^2 MPPC, 40 KHz event rate, 1MHz DCR)

NEW ASIC : Basic Features

- UMC 110 nm technology

  (limited power consumption, to be tested for radiation tolerance)

  - Time and Charge measurements by independent TDCs
  - TDC 50 ps time binning
  - Double threshold discrimination $\Rightarrow$ CGEM needed time resolution ~ 1 ns
  - Time over Threshold (ToT) to measure the charge
  - Power consumption < 7 mW p/channel $\Rightarrow$ 4 mW p/channel feasible

CGEM first layer: cosmic test setup (LNF-FE-TO)

- The COMPASS-type readout layer is substantially different from the KLOE2 one
- It must be tested, before employ in a full-scale cylindrical prototype
- KLOE2 can give us a cosmic-ray telescope
  (3 complete and working planar GEM chambers of KLOE2 type)
- To these we will add a small (10x10 cm^2) planar chamber with GEMs, and a COMPASS-type readout layer
- Buy planar GEM chamber kit from CERN
- Prepare support for readout layer
- Design and order COMPASS-type small readout layer
- Procure TOFPET and design its board
- Test COMPASS-type readout plane using an amplifier
- Start taking cosmic data, beam if possible
- Small rate if few channels: will take time

CGEM mechanics: FE-LNF-IHEP

- Refurbish clean room, repair toolings etc
- Evaluate KLOE2 machine for inserting cylindrical layers (BESIII layers will be longer); modify in the near future…
- Take as a reference inner KLOE2 molds for BESIII middle layer. Rebuild of the molds necessary!
- Study to optimise COMPASS-type readout layer
- Start drawings for readout layer

CGEM: Electronics, DAQ, Offline, HV, gas system

- ASIC development for BESIII (TO-LNF)
- Design off-detector electronics (LNF)

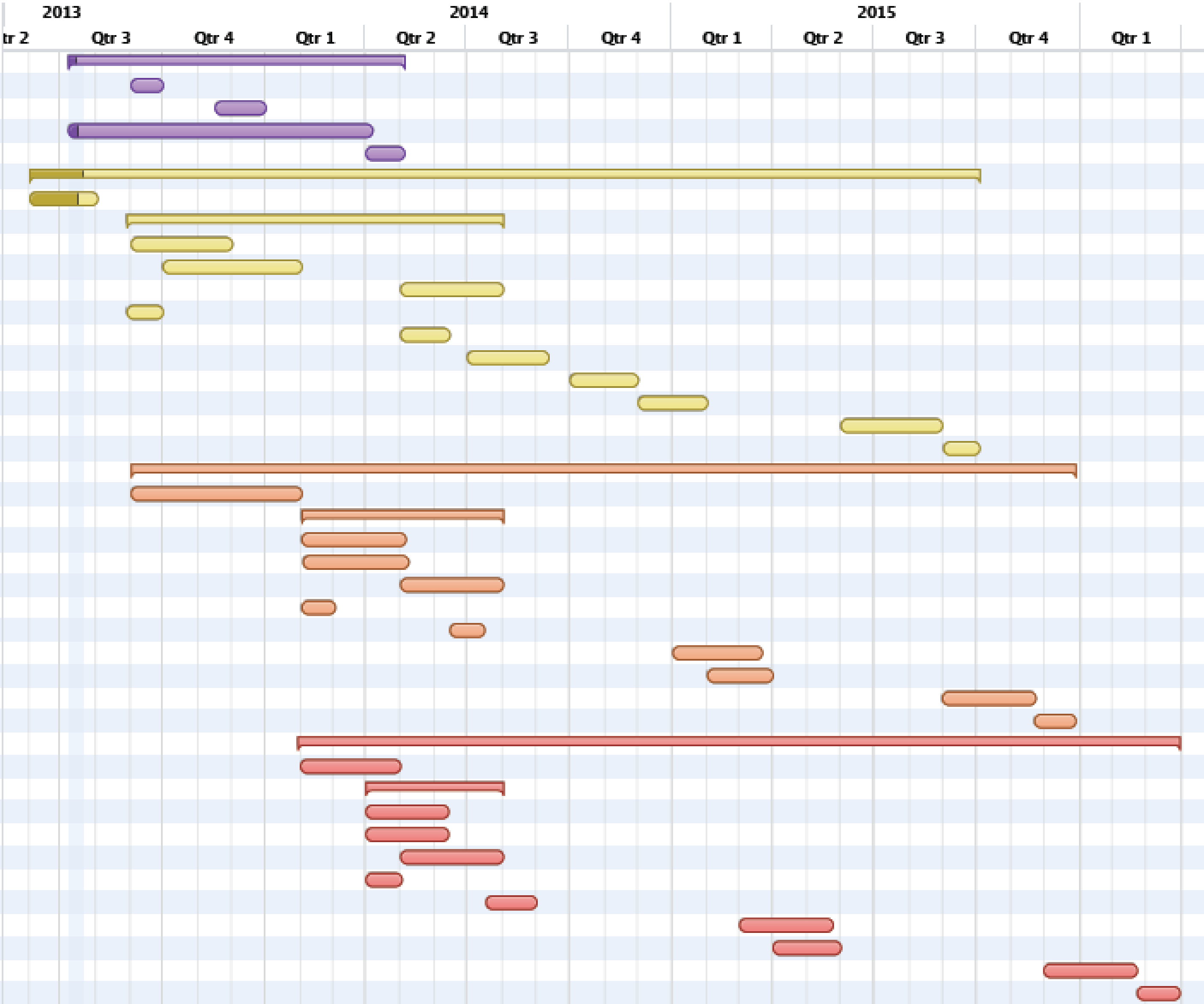
- Studying impact on BESIII DAQ and L1 trigger (IHEP)
- Monte Carlo and Offline Reconstruction (IHEP, LNF, FE, TO)
- Plan additions to HV, Gas systems, Slow Controls (IHEP)

CGEM BESIII IT: roadmap from BESIII

- **2013**
  - start R&D program (cosmic setup, simulations)
  - write a Letter of Intent
- **2014**
  - build prototype with IT middle layer layout
- **2015**
  - Prototype test and validation
  - TDR
  - IT design and material procurement
- **2016**
  - start IT construction
- **2017**
  - complete IT, test and validation

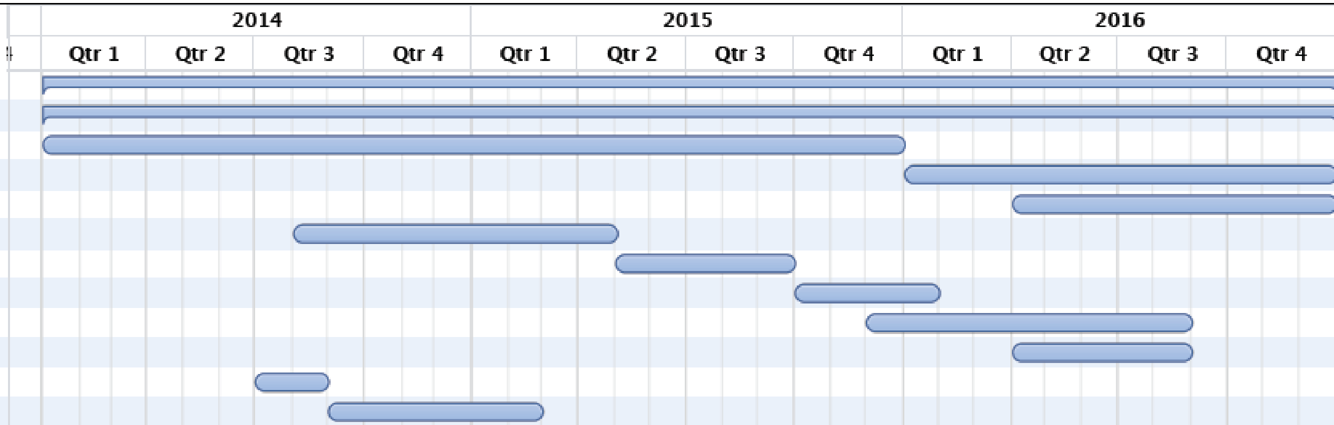
CGEM BESIII IT: schedule rivelatore

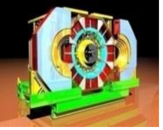
Task	Effort
1) **R&D**	274d
1.1) FE – Roahcell fake cathode	21d
1.2) FE – Assembly tests	33d
1.3) FE/LNF – Anode Simulation	195d
1.4) LNF – Anode finalization and design	25d
2) **Layer I**	547d
2.1) FE – Technical design	44d
2.2) **Material procurement**	243d
2.2.1) Cylinders	65d
2.2.2) GEM foils	89d
2.2.3) Anode	66d
2.2.4) Other material	23d
2.3) FE – Cathode construction	32d
2.4) LNF – GEM assembly	52d
2.5) Anode assembly	43d
2.6) LNF – Detector test and validation	45d
2.7) LNF – Full detector assembly	65d
2.8) LNF – Detector test and QA	23d
3) **Layer II**	539d
3.1) FE – Technical design	110d
3.2) **Material procurement**	221d
3.2.1) Cylinders	67d
3.2.2) GEM foils	67d
3.2.3) Anode	66d
3.2.4) Other material	21d
3.3) FE – Cathode construction	22d
3.4) LNF/FE – GEM and anode assembly	57d
3.5) LNF – Detector test and validation	42d
3.6) LNF – Full detector assembly	60d
3.7) LNF – Detector test and QA	27d
4) **Layer III**	482d
4.1) FE – Technical design	64d
4.2) **Material procurement**	195d
4.2.1) Cylinders	53d
4.2.2) GEM foils	53d
4.2.3) Anode	66d
4.2.4) Other material	23d
4.3) FE – Cathode construction	32d
4.4) LNF/FE – GEM and anode assembly	60d
4.5) LNF – Detector test and validation	43d
4.6) LNF – Full datector assembly	60d
4.7) LNF – Detector test and QA	28d



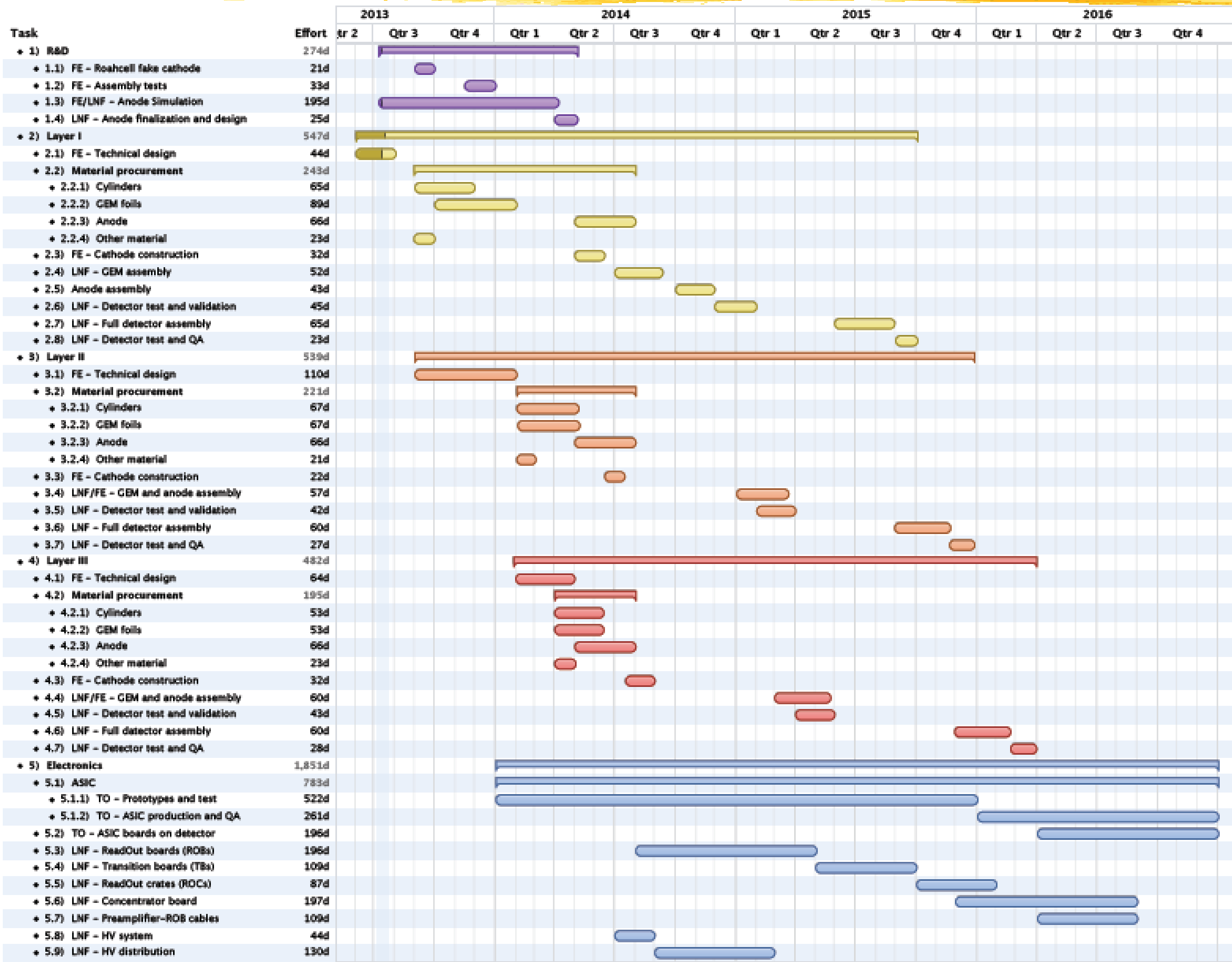
CGEM BESIII IT: schedule elettronica

Task	Effort
• 1) Electronics	1,851d
• 1.1) ASIC	783d
• 1.1.1) TO – Prototypes and test	522d
• 1.1.2) TO – ASIC production and QA	261d
• 1.2) TO – ASIC boards on detector	196d
• 1.3) LNF – ReadOut boards (ROBs)	196d
• 1.4) LNF – Transition boards (TBs)	109d
• 1.5) LNF – ReadOut crates (ROCs)	87d
• 1.6) LNF – Concentrator board	197d
• 1.7) LNF – Preamplifier-ROB cables	109d
• 1.8) LNF – HV system	44d
• 1.9) LNF – HV distribution	130d





CGEM BESIII IT: schedule



Task	Effort
1) R&D	274d
1.1) FE – Roahcell fake cathode	21d
1.2) FE – Assembly tests	33d
1.3) FE/LNF – Anode Simulation	195d
1.4) LNF – Anode finalization and design	25d
2) Layer I	547d
2.1) FE – Technical design	44d
2.2) Material procurement	243d
2.2.1) Cylinders	65d
2.2.2) GEM foils	89d
2.2.3) Anode	66d
2.2.4) Other material	23d
2.3) FE – Cathode construction	32d
2.4) LNF – GEM assembly	52d
2.5) Anode assembly	43d
2.6) LNF – Detector test and validation	45d
2.7) LNF – Full detector assembly	65d
2.8) LNF – Detector test and QA	23d
3) Layer II	539d
3.1) FE – Technical design	110d
3.2) Material procurement	221d
3.2.1) Cylinders	67d
3.2.2) GEM foils	67d
3.2.3) Anode	66d
3.2.4) Other material	21d
3.3) FE – Cathode construction	22d
3.4) LNF/FE – GEM and anode assembly	57d
3.5) LNF – Detector test and validation	42d
3.6) LNF – Full detector assembly	60d
3.7) LNF – Detector test and QA	27d
4) Layer III	482d
4.1) FE – Technical design	64d
4.2) Material procurement	195d
4.2.1) Cylinders	53d
4.2.2) GEM foils	53d
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4.5) LNF – Detector test and validation	43d
4.6) LNF – Full datector assembly	60d
4.7) LNF – Detector test and QA	28d
5) Electronics	1,851d
5.1) ASIC	783d
5.1.1) TO – Prototypes and test	522d
5.1.2) TO – ASIC production and QA	261d
5.2) TO – ASIC boards on detector	196d
5.3) LNF – ReadOut boards (ROBs)	196d
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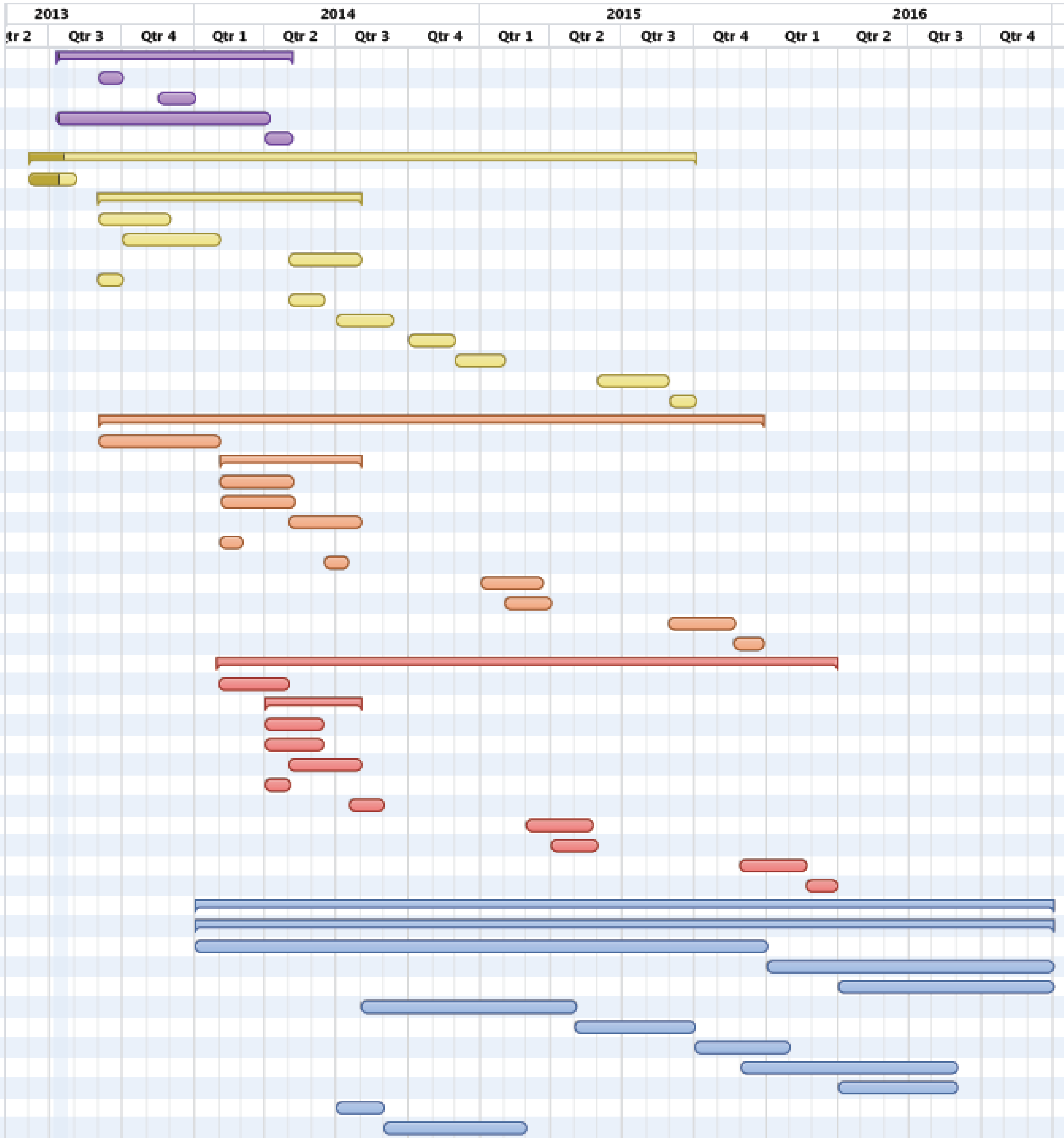
5.5) LNF – ReadOut crates (ROCs)	87d
5.6) LNF – Concentrator board	197d
5.7) LNF – Preamplifier-ROB cables	109d
5.8) LNF – HV system	44d
5.9) LNF – HV distribution	130d

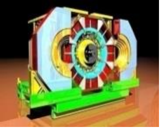


CGEM BESIII IT: prospetto finanziario 2013

	LNF (kE) (INFN+MAE)	FE (kE) (CSN1)	TO (kE) (CSN1)
HV	10		
Cameretta Planare Rui	5		
Sistema lettura prototipo planare	25		
Catodo e gems 1t	11		
Prime attrezzature sala	10		
Modifiche totem	10		
Consumi gas e altro	9		
Mola rettifica		7	
Rohacell per catodo fake		2	
Consumo catodo fake		0,5	
Catodo fake rohacell		0,5	
Mandrini 1t		9**(14)**	
Accessori mandrini 1t		6**(10)**	
Rohacell 1t		2	
Consumo 1t		1	
Somma	**80**	**28(37)**	

CGEM BESIII IT: prospetto finanziario 2014

	LNF (kE) (INFN+MAE)	LNF (kE) (CSN1)	FE (kE) (CSN1)	TO (kE) (CSN1)
Catodo e gems 2t	11			
Catodo e gems 3t			11	
Anodo 1t	10			
HV schedine 1t	5			
Consumi gas e altro	8			
Lavori e materiali assemblaggio 1t	30			
Elettronica provvisoria 1t	15			
Anodo 2t			10	
Anodo 3t			10	
Mandrini 2t			9**(14)**	
Accessori mandrini 2t			6**(10)**	
Rohacell 2t			2	
Consumo 2t			1	
Attrezzatura laboratorio			4	
Licenza 1y ANSIS Maxwell Edu			4,5	
I Fonderia ASIC (sj)				38
PCB per test ASIC				5
consumo ASIC				2
Licenza Cadence				0,5
2 PC per sviluppo ASIC				4
Somma	**79**	**0**	**57,5(66.5)**	**49,5**



CGEM BESIII IT: prospetto finanziario 2015

PRELIMINARY

	LNF (kE) (INFN+MAE)	LNF (kE) (CSN1)	FE (kE) (CSN1)	TO (kE) (CSN1)
HV schedine 2t	5			
HV schedine 3t	5			
Consumi gas e altro	10			
Lavori e materiali per assemblaggio 2t	10			
Lavori e materiali per assemblaggio 3t	10			
Mandrini 3t			9**(14)**	
Accessori mandrini 3t			6**(10)**	
Rohacell 3t			2	
Consumo 3t			1	
Licenza 1y ANSIS Maxwell Edu			4,5	
Elettronica Off-detector layer 1t, 2t e 3t		146		
HV system (power supply e distribuzione)		75		
II Fonderia ASIC (sj)	38			
PCB test ASIC				5
Somma	**78**	**221**	**22,5(31.5)**	**5**

CGEM BESIII IT: prospetto finanziario 2016

	LNF (kE) (CSN1)	FE (kE) (CSN1)	TO (kE) (CSN1)
Elettronica on-Detector			28
Assemblaggio IT	30		
Produzione ASIC			236
Somma	**30**	**0**	**264**

PRELIMINARY

CGEM BESIII IT: prospetto finanziario

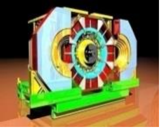
Anno	LNF-MAE	LNF-CSN1	FE-CSN1	TO-CSN1	**CSN1**	**Somma**
2013	80		28(37)	0	**28(37)**	**108(117)**
2014	79	0	57,5(66.5)	49,5	**107(116)**	**186(195)**
2015	78	221	22,5(31.5)	5	**248,5(257.5)**	**326,5(335,5)**
2016		30	0	264	**294**	**294**
2017		0	0	0	**0**	**0**
	237	**251**	**108(135)**	**318,5**	**677,5(704.5)**	**914,5(941.5)**

PRELIMINARY

Oggetti	Riassetto sala	Prot. planare	Layer 1t	Layer 2t	Layer 3t	Elett off-det	Elett on-det	ASIC	IT	**Somma**
2013	20	49	29(38)	0	0	0	0	0		**98(107)**
2014		8	68	39(48)	21	0	0	45		**181(190)**
2015		10	0	20	38(47)	146	43	0		**257(264)**
2016			0	0	0	0	28	236	30	**294**
2017										**0**
	20	**67**	**97(106)**	**59(68)**	**59(68)**	**146**	**71**	**281**	**30**	**830(857)**

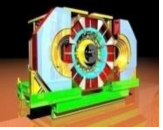
CGEM BESIII IT: prospetto finanziario 2013

	LNF (kE) (INFN+MAE)	FE (kE) (CSN1)	TO (kE) (CSN1)
HV	10		
Cameretta Planare Rui	5		
Sistema lettura prototipo planare	25		
Catodo e gems 1t	11		
Prime attrezzature sala	10		
Modifiche totem	10		
Consumi gas e altro	9		
Mola rettifica		7	
Rohacell per catodo fake		2	
Consumo catodo fake		0,5	
Catodo fake rohacell		0,5	
Mandrini 1t		9**(14)**	
Accessori mandrini 1t		6**(10)**	
Rohacell 1t		2	
Consumo 1t		1	
Somma	**80**	**28(37)**	



CGEM BESIII IT: prospetto finanziario 2014

	LNF (kE) (INFN+MAE)	LNF (kE) (CSN1)	FE (kE) (CSN1)	TO (kE) (CSN1)
Catodo e gems 2t		11		
Catodo e gems 3t		11		
Anodo 1t			10	
HV schedine 1t	5			
Consumi gas e altro	8			
Lavori e materiali assemblaggio 1t	30			
Elettronica provvisoria 1t	15			
HV System (pw sup e distribuzione)	22			
Anodo 2t			10	
Anodo 3t			10	
Mandrini 2t			9**(14)**	
Accessori mandrini 2t			6**(10)**	
Rohacell 2t			2	
Consumo 2t			1	
Attrezzatura laboratorio			4	
Licenza 1y ANSIS Maxwell Edu			4,5	
I Fonderia ASIC (sj)				38
PCB per test ASIC				5
consumo ASIC				2
Licenza Cadence				0,5
2 PC per sviluppo ASIC				4
Somma	**80**	**22**	**57,5(66.5)**	**49,5**



CGEM BESIII IT: prospetto finanziario 2015

	LNF (kE) (INFN+MAE)	LNF (kE) (CSN1)	FE (kE) (CSN1)	TO (kE) (CSN1)
HV schedine 2t	5			
HV schedine 3t	5			
Consumi gas e altro	10			
Lavori e materiali per assemblaggio 2t	10			
Lavori e materiali per assemblaggio 3t	10			
Mandrini 3t			9**(14)**	
Accessori mandrini 3t			6**(10)**	
Rohacell 3t			2	
Consumo 3t			1	
Licenza 1y ANSIS Maxwell Edu			4,5	
Elettronica Off-detector layer 1t, 2t e 3t		146		
HV system (power supply e distribuzione)		53		
II Fonderia ASIC (sj)	38			
PCB test ASIC				5
Somma	**78**	**199**	**22,5(31.5)**	**5**

PRELIMINARY

CGEM BESIII IT: prospetto finanziario 2016

	LNF (kE) (CSN1)	FE (kE) (CSN1)	TO (kE) (CSN1)
Elettronica on-Detector			28
Assemblaggio IT	30		
Produzione ASIC			236
Somma	**30**	**0**	**264**

PRELIMINARY

CGEM BESIII IT: prospetto finanziario

Anno	LNF-MAE	LNF-CSN1	FE-CSN1	TO-CSN1	**CSN1**	**Somma**
2013	80		28(37)	0	**28(37)**	**108(117)**
2014	80	22	57,5(66.5)	49,5	**128(137)**	**208(217)**
2015	78	199	22,5(31.5)	5	**226,5(235.5)**	**304,5(333,5)**
2016		30	0	264	**294**	**294**
2017		0	0	0	**0**	**0**
	238	**251**	**107(136)**	**318,5**	**676,5(704.5)**	**914,5(941.5)**

PRELIMINARY

Oggetti	Riassetto sala	Prot. planare	Layer 1t	Layer 2t	Layer 3t	Elett off-det	Elett on-det	ASIC	IT	**Somma**
2013	20	49	29(38)	0	0	0	0	0		**98(107)**
2014		8	68	39(48)	21	0	0	45		**181(190)**
2015		10	0	20	38(47)	146	43	0		**257(264)**
2016			0	0	0	0	28	236	30	**294**
2017										**0**
	20	**67**	**97(106)**	**59(68)**	**59(68)**	**146**	**71**	**281**	**30**	**830(857)**

Richieste straordinarie Luglio 2013

	Sezione	Capitolo	Descrizione Richiesta	Richiesto		Commento Assegnazione	Assegnato			
					SJ			SJ	Dot.	
Luglio	TO	missioni	2p x 2v x 2K€: meeting collaborazione giugno e novembre e physics workshop	8.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	missioni	2p x 1v x 2K€: 2w uomo per 2 persone ai LNF per test prototipo planare	4.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	missioni	1p x 1v x 2K€: workshop cgem a ihep	2.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	missioni	2p x 2v x 2K€: FE su sede resp. nazionale: meeting collaborazione giugno e novembre e physics workshop	8.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	missioni	2p x 1v x 2K€: FE su sede resp. nazionale: workshop cgem a ihep	4.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	missioni	FE su sede resp. nazionale: missioni in Italia per interazione con gruppo italiani	4.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	inventario	FE su sede resp. nazionale: mola rettifica	7.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	consumo	FE su sede resp. nazionale: consumo per catodo fake	1.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	apparati	FE su sede resp. nazionale: rohacell catodo fake	2.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	apparati	FE su sede resp. nazionale: mandrino layer 1t	9.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	apparati	FE su sede resp. nazionale: accessori mandrino 1t	6.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	apparati	FE su sede resp. nazionale: rohacell layer 1t	2.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	consumo	FE su sede resp. nazionale: consumo laboratorio	1.0	0.0		0.0	0.0	0.0	canc
Luglio	TO	apparati	FE su sede resp. nazionale: mandrino layer 1t, s.j. alla definizione delle specifiche costruttive	9.0	0.0		0.0	0.0	0.0	canc
Luglio	LNF	missioni	2p x 1v x 2K€: workshop cgem a ihep	4.0	0.0		0.0	0.0	0.0	canc
Luglio	LNF	missioni	1p x 1v x 2K€: meeting novembre	2.0	0.0		0.0	0.0	0.0	canc
Luglio	LNF	missioni	1p x 1v x 2K€: validazione analisi a ihep per inizio procedura di pubblicazione	2.0	0.0		0.0	0.0	0.0	canc
Luglio	LNF	missioni	1p x 1v x 2K€: missione per ZDD ad agosto	2.0	0.0		0.0	0.0	0.0	canc

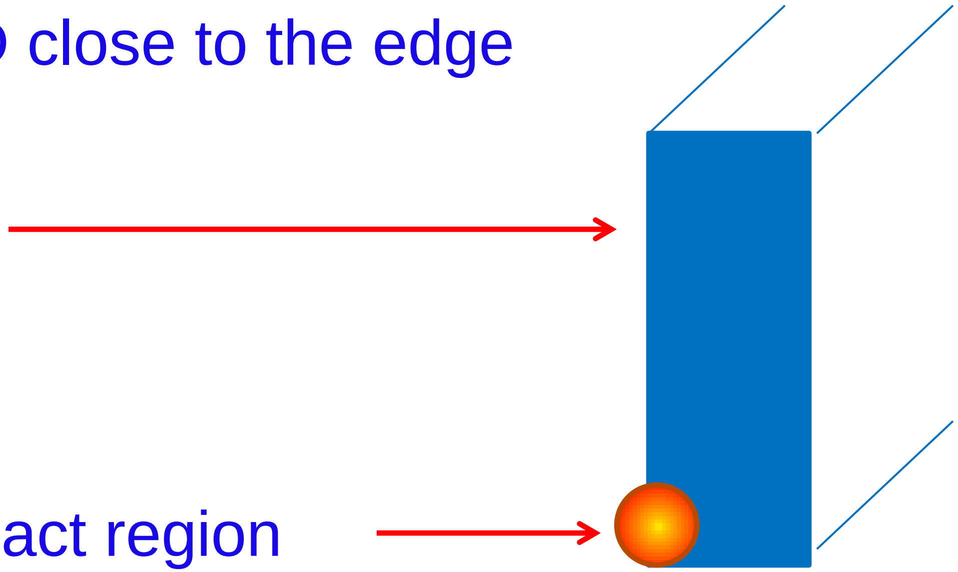
Question time

Question time

ZDD

ZDD upgrade

- ISR photons hit the ZDD close to the edge
  - ZDD face (top half)
  - Photon expected impact region



- Showers are not fully contained, and energy resolution will be worse than expected

What can be done?

- Unfortunately this effect can not always be corrected, the γ impact point is unknown
- Some γ's (1/3 → 1/2 of the total) will convert in the beam pipe window
- The (narrow opening angle) resulting e^+e^- pair could be detected by an array of small scintillators

The array

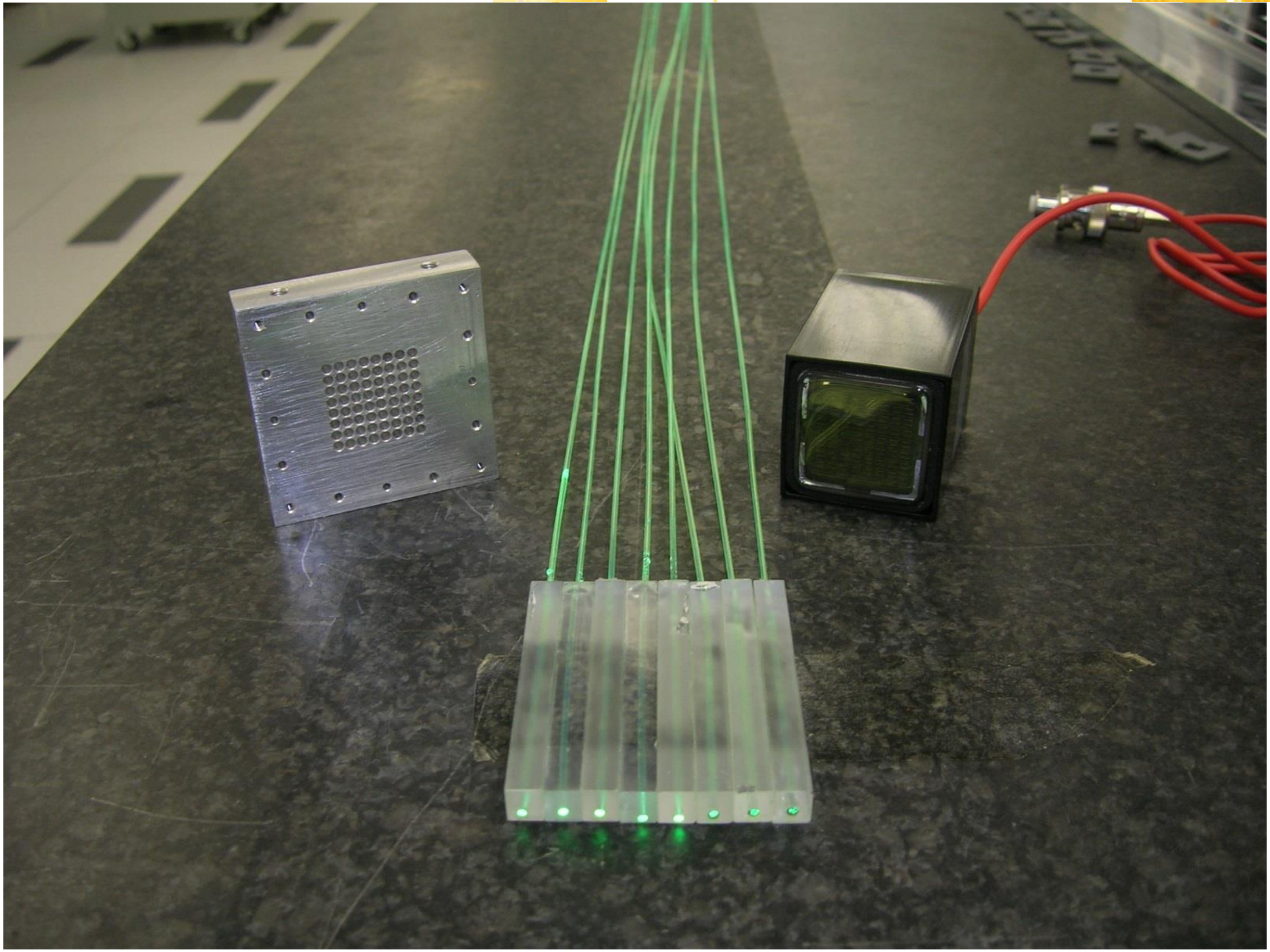
- Two arrays of 8 scintillators each, (5 x 6 x 100) mm^3, read by 2 m long green scintillating fibers, built by M. Anelli and “Servizio Supporto Esperimenti” in LNF

- The fibers are connected to a multianode Hamamatsu PM, H7546-200, with 64 channels (gains equal within ~20%)

- The 16 channels with most similar gains are chosen, 8 for the bottom ZDD and 8 for the top ZDD

- It will be installed in front of ZDD beginning of September 2013

The scintillators



The electronics

- The multianode PM is connected to a local group of electronic boards made in Frascati (SEL group) for amplifying and CF-discriminating signals

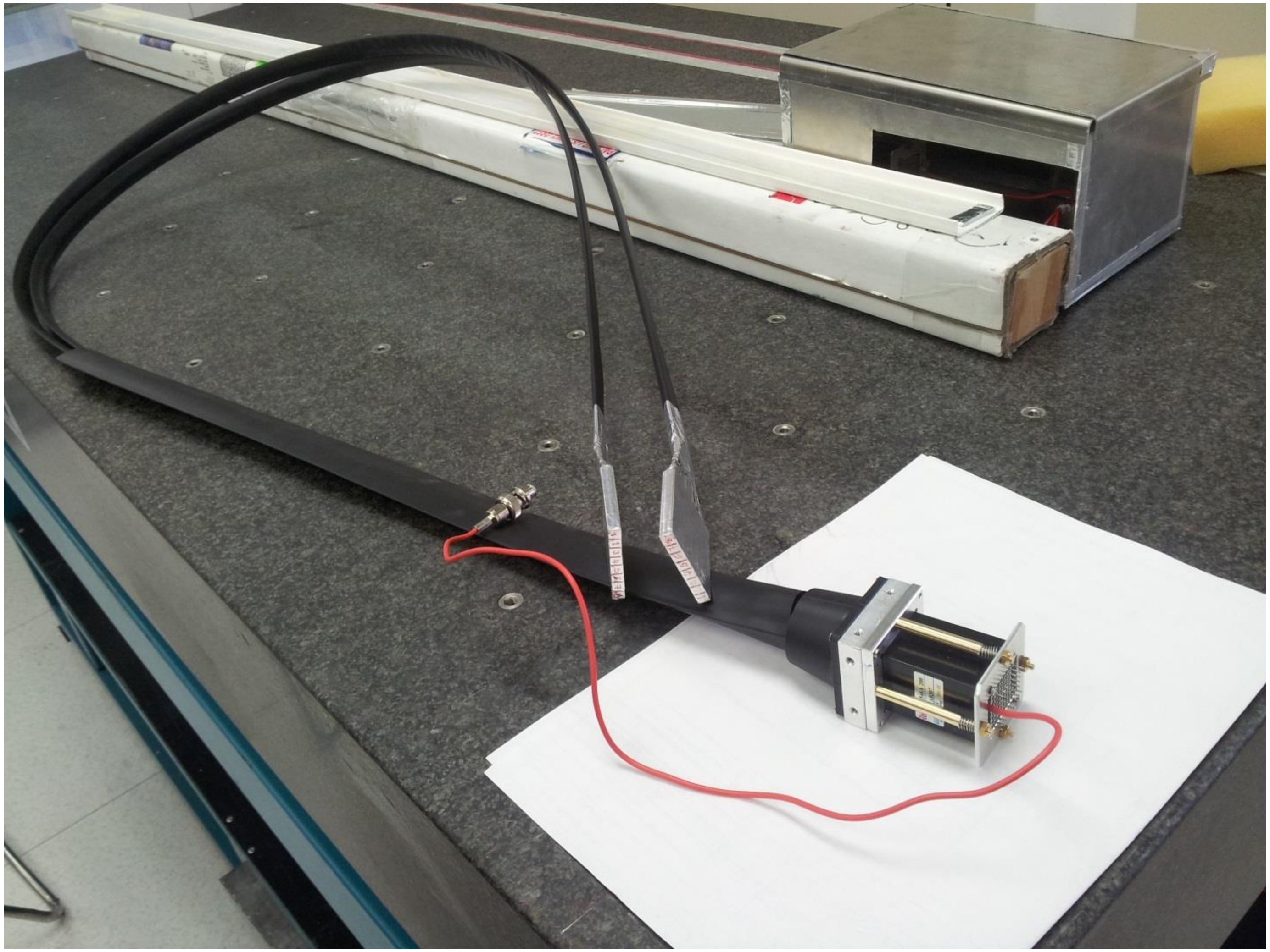
- Tests have been successfully made with a β source looking at LVDS signals on a scope

- An electron-beam test just concluded at the BTF in Frascati: all channels functional!

The scintillator arrays

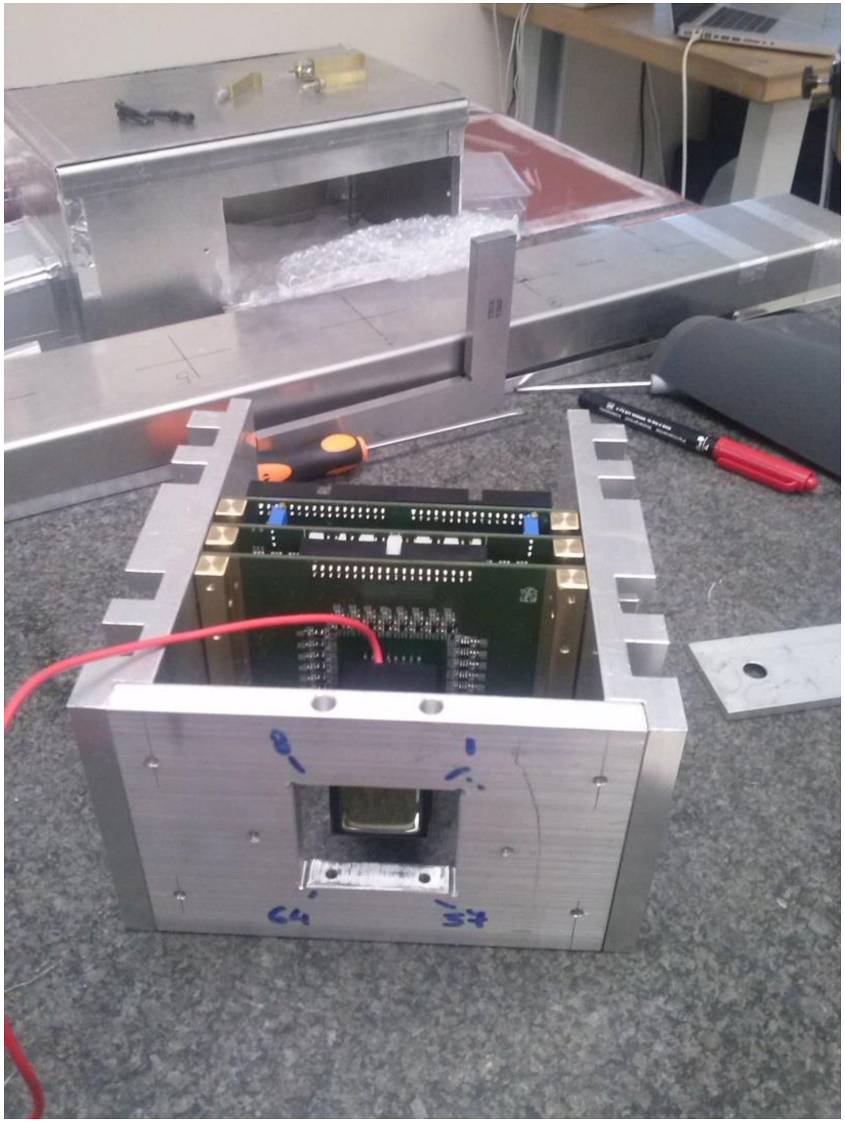
The completed device

(M.Anelli, R. Rosellini, and Servizio supporto Esperimenti of LNF)

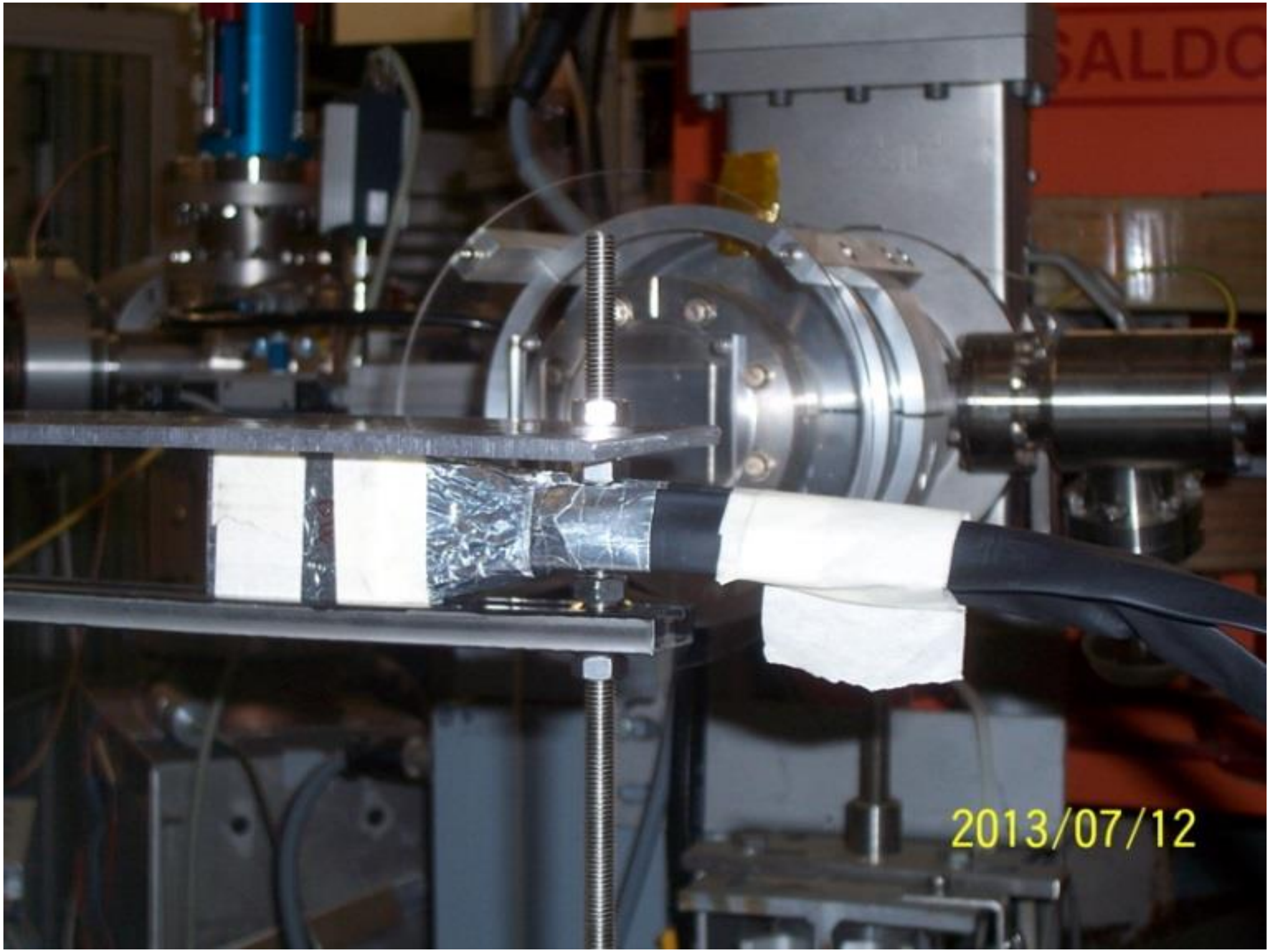


The electronics

(Servizio Elettronica e Automazione of LNF)



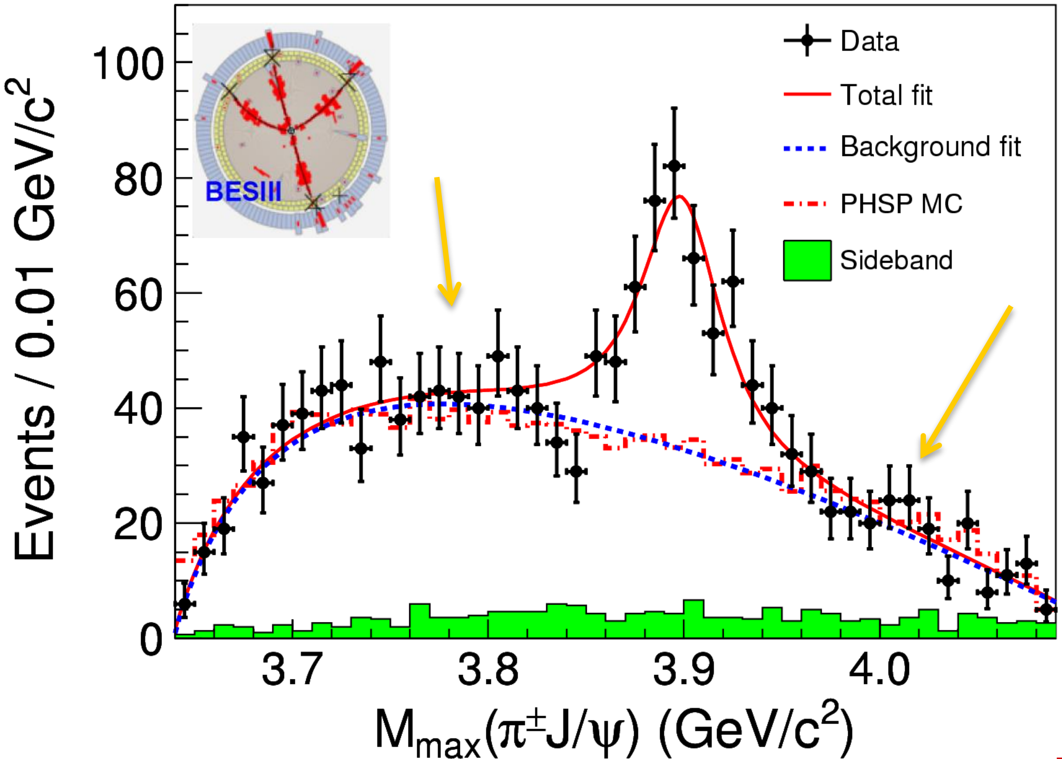
At the BTF, 8 → 14 July 2013



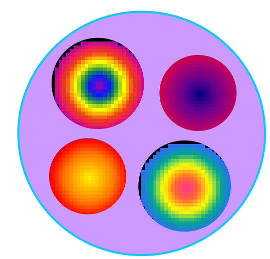
Question time

Physics

What is $Z_c(3900)$?



- Couples to $c\bar{c}$
- Has electric charge
- At least 4-quarks
- What is its nature?

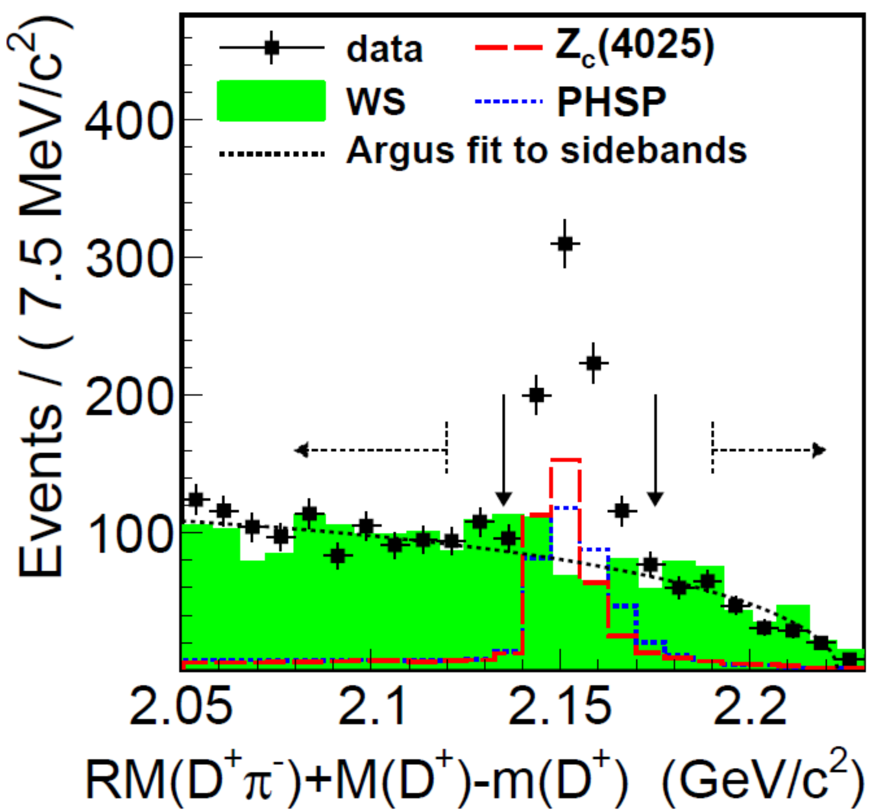


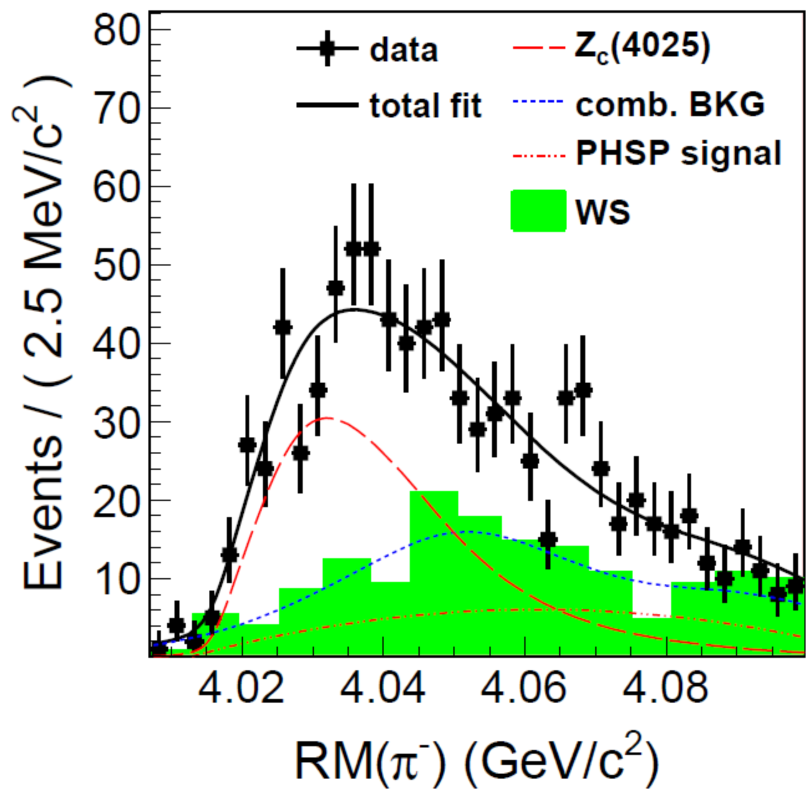
- $\bar{D}D^*$ molecule?
- Tetraquark state?
- Cusp?
- Threshold effect?
- …

Predictions and more experimental information will be essential to understand its nature.

➔ A partner <u>below/above</u> Z_c?

$e^+e^- \to \pi Z_c(4025) \to \pi^- (D^*\underline{D}^*)^+ + c.c.$





Fit to $\pi^\pm$ recoil mass yields 401±47 $Z_c(4025)$ events. >10σ

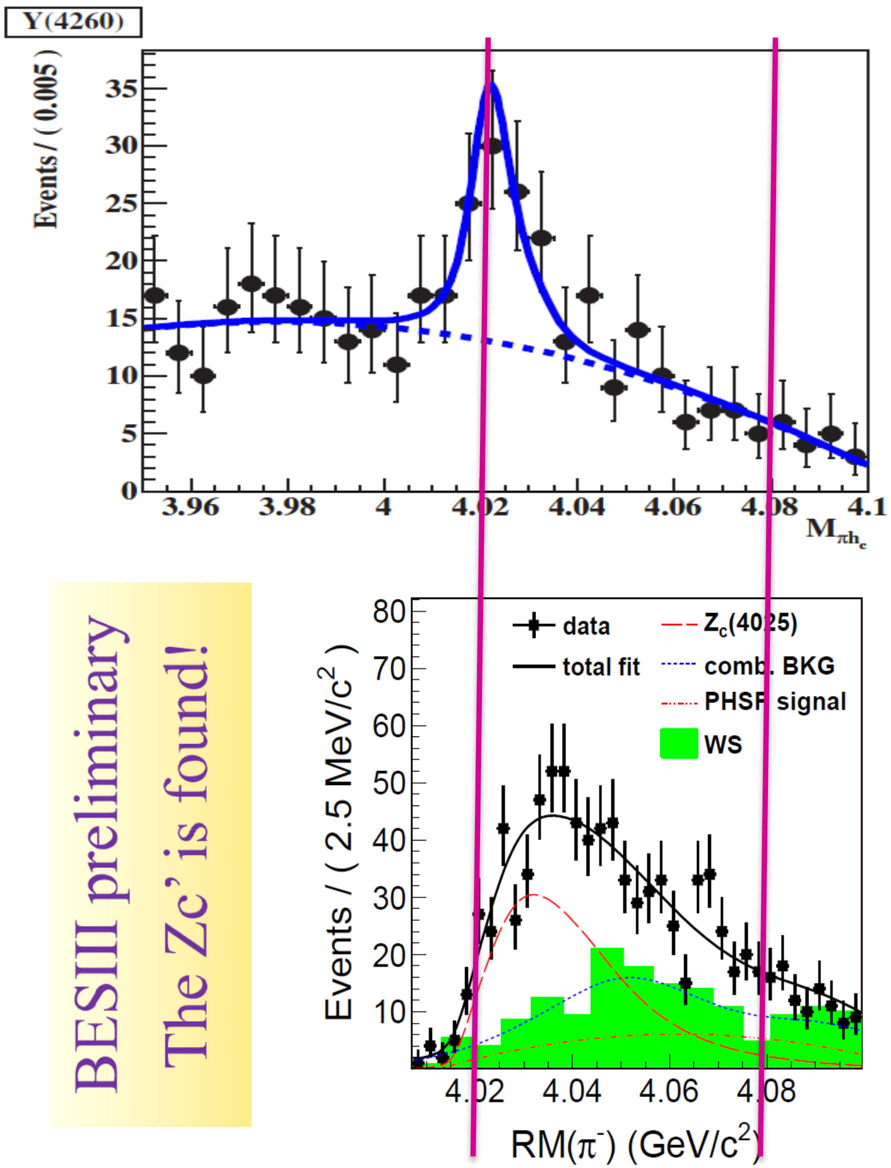
$M(Z_c(4025)) = 4026.3\pm2.6\pm3.7$ MeV; $\Gamma(Z_c(4025)) = 24.8\pm5.7\pm7.7$ MeV

$$\sigma(e^+e^- \to \pi^\pm (D^*\overline{D}^*)^\mp) = (137\pm9\pm15)\ \text{pb}$$

$$R = \frac{\sigma(e^+e^- \to \pi^\pm Z_c^\mp \to \pi^\pm (D^*\overline{D}^*)^\mp)}{\sigma(e^+e^- \to \pi^\pm (D^*\overline{D}^*)^\mp)} = (65\pm9\pm6)\,\%$$

BESIII preliminary

$Z_c(4020)=Z_c(4025)$?



- M(4020) = 4021.8±1.0±2.5 MeV
- M(4025) = 4026.3±2.6±3.7 MeV
- Γ(4020) = 5.7±3.4±1.1 MeV
- Γ(4025) = 24.8±5.7±7.7 MeV

Close to D*D* threshold=4017 MeV

Mass consistent with each other but width ~2σ difference

Interference with other amplitudes may change the results

Coupling to $\bar{D}$*D* is much larger than to πh_c if they are the same state

Will fit with Flatte formula

J/ψ Phase – Real Data

Ecm(GeV)	$\mathcal{L}$ (pb^{-1})
3.0500	14.895±0.029
3.0600	15.056±0.030
3.0830	4.759±0.017
3.0856	17.507±0.032
3.0900	15.552±0.030
3.0930	15.249±0.030
3.0943	2.145±0.011
3.0952	1.819±0.010

Ecm(GeV)	$\mathcal{L}$ (pb^{-1})
3.0958	2.161±0.011
3.0969	2.097±0.011
3.0982	2.210±0.011
3.0990	0.759±0.007
3.1015	1.164±0.010
3.1055	2.106±0.011
3.1120	1.719±0.010
3.1200	1.261±0.009
3.0969	79.6

B.X. Zhang, Luminosity measurement for J/psi phase and lineshape study.

Online Beam Energy Measurement

Ecm [MeV]	E meas [GeV]
3050.0	3050.22±0.03
3060.0	3059.26±0.03
3083.0	3083±0.09
3085.6	3080.20±0.02
3090.0	3090±0.09
3093.0	3093±0.09
3094.3	3095.08±0.07
3095.2	3095.93±0.08

Ecm [GeV]	E meas [GeV]
3.0958	3096.40±0.07
3.0969	3097.82±0.08
3.0982	3098.79±0.07
3.0990	3099.54±0.09
3.1015	3101.59±0.10
3.1055	3106.14±0.09
3.1120	3112.61±0.09
3.1200	3120.03±0.13

Question time

CGEM

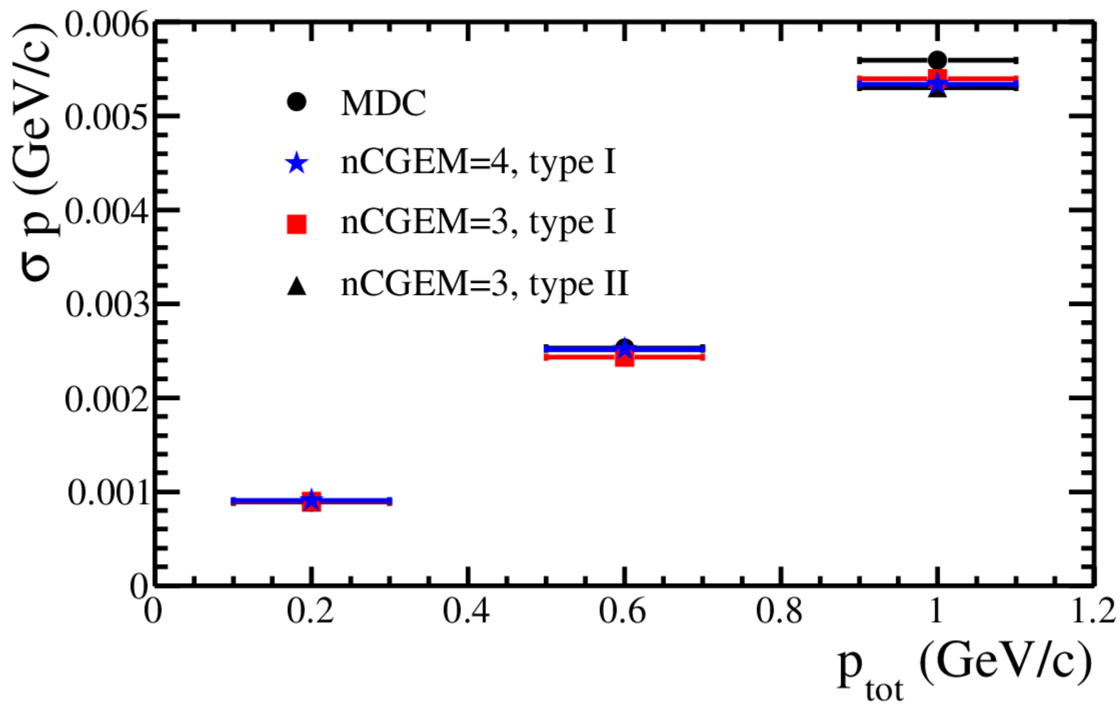
BESIII Inner Tracker: 3 layers of CGEM

Component	L1(Rin/Rout)	L2(Rin/Rout)	L3(Rin/Rout)	Material
Cathode	78.0/81.0	120.5/123.5	163.0/166.0	3 mm Honeycomb
Conversion + drift	81.0/84.0	123.5/126.5	166.0/169.0	3 mm gas
Transfer 1	84.0/86.0	126.5/128.5	169.0/171.0	2 mm gas
Transfer 2	86.0/88.0	128.5/130.5	171.0/173.0	2 mm gas
Induction	88.0/90.0	130.5/132.5	173.0/175.0	2 mm gas
Readout	90.0	132.5	175.0	
Outer shield	90.0/93.0	132.5/135.5	175.0/178.0	3 mm Honeycomb

- L1 length: 532mm , L2 length: 690mm
- L3 length: 847mm

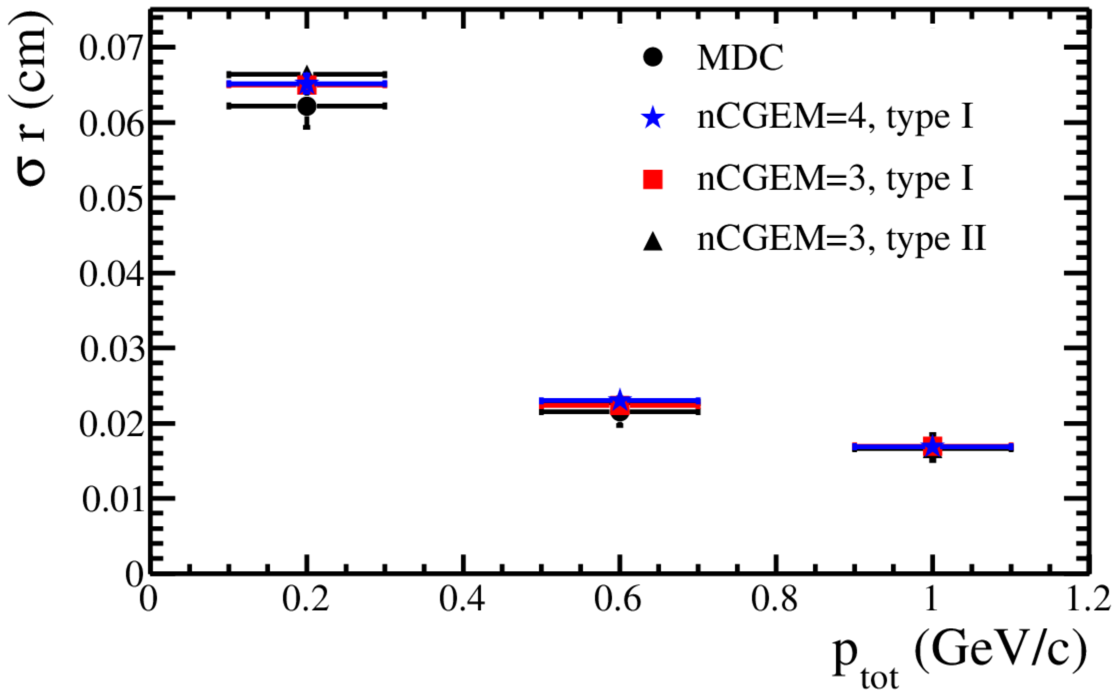
CGEM expected momentum resolution

type I and II refer to different layer configurations (cathode/anode reversed)



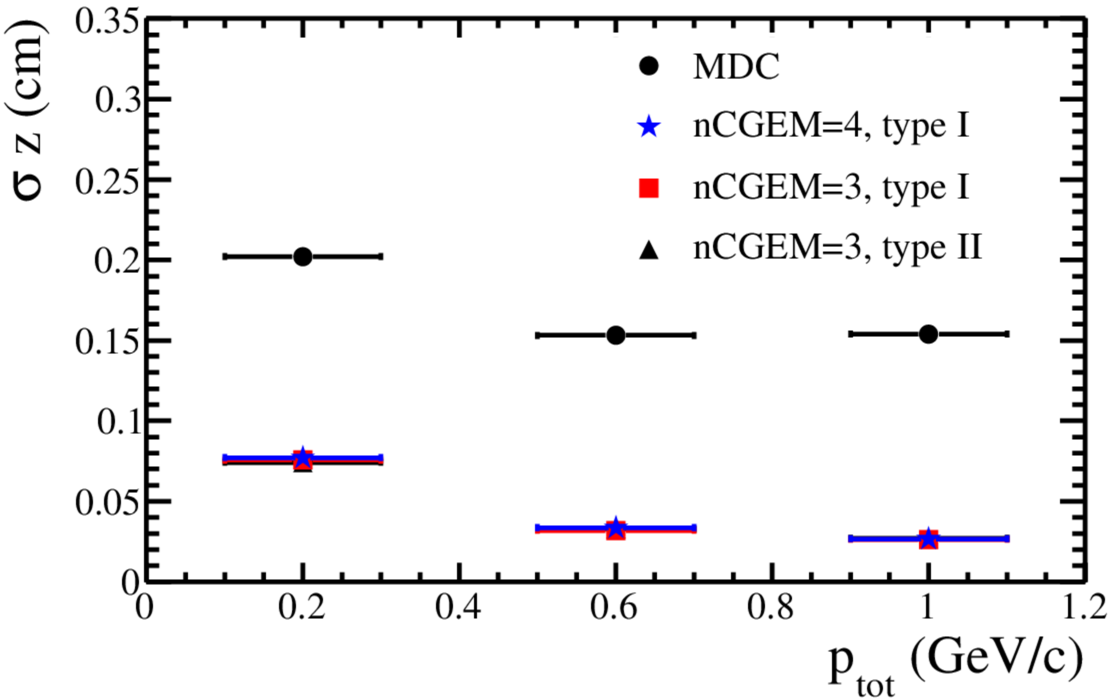
P_{tot}(GeV/c)	0.2	0.6	1.0
σ_p(MDC) (MeV)	**0.89** (100%)	**2.53** (100%)	**5.59** (100%)
σ_p(CGEM 4 layers, type I)	**0.91**(+2.2%)	**2.52** (-0.4%)	**5.34**(-4.5%)
σ_p(CGEM 3 layers, type I)	**0.89**(+0%)	**2.43** (-3.9%)	**5.40**(-3.4%)
σ_p(CGEM 3 layers, type II)	**0.89**(+0%)	**2.51** (-0.8%)	**5.30**(-5.2%)

CGEM expected vertex resolution in r



P_{tot}(GeV/c)	0.2	0.6	1.0
σ_r(MDC) (μm)	**622** (100%)	**215**(100%)	**168**(100%)
σ_r(CGEM 4 layers, type I)	**652**(+4.8%)	**230**(+7.0%)	**169**(+0.6%)
σ_r(CGEM 3 layers, type I)	**650**(+4.5%)	**224**(+4.2%)	**170**(+1.2%)
σ_r(CGEM 3 layers, type II)	**664**(+6.7%)	**228**(+6.0%)	**166**(-1.2%)

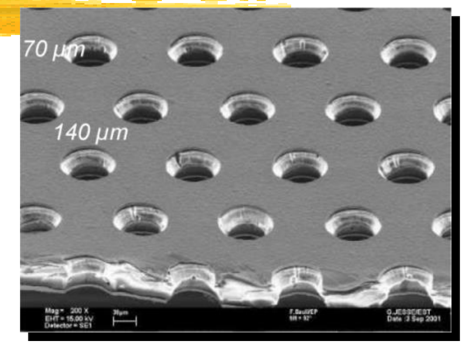
CGEM expected vertex resolution in z

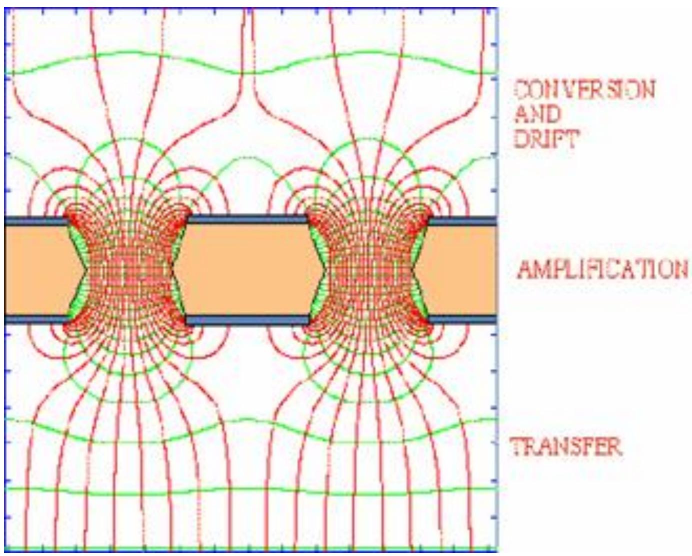


P_{tot}(GeV/c)	0.2	0.6	1.0
σ_z(MDC) (μm)	**2020** (100%)	**1531**(100%)	**1539**(100%)
σ_z(CGEM 4 layers, type I)	**772**(-61.8%)	**336**(-78.1%)	**266**(-82.7%)
σ_z(CGEM 3 layers, type I)	**757**(-62.5%)	**319**(-79.2%)	**263**(-82.9%)
σ_z(CGEM 3 layers, type II)	**742**(-63.3%)	**327**(-78.6%)	**270**(-82.5%)

GEM: principle of operation

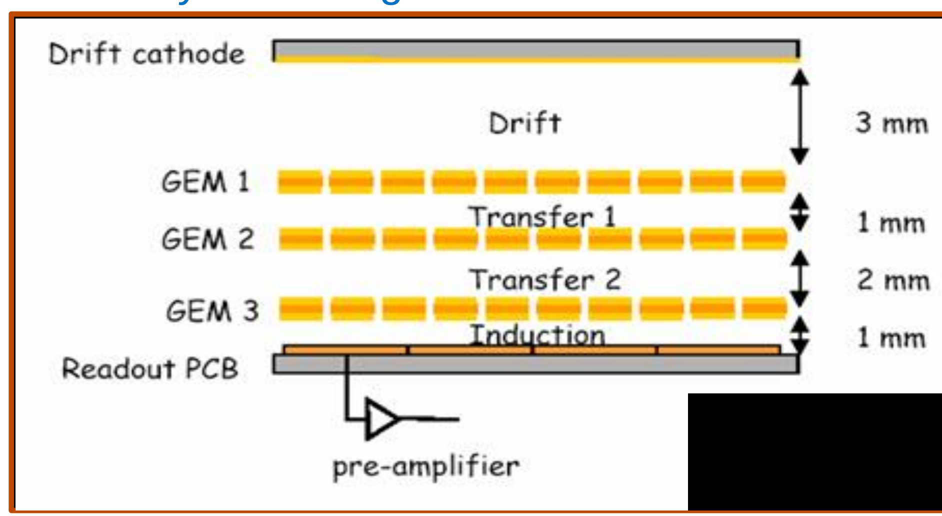
The GEM (Gas Electron Multiplier) [F.Sauli, NIM A386 (1997) 531] is a thin (50 μm) metal coated by a kapton foil perforated by a high density of holes (70 μm diameter, pitch of 140 μm) → standard photo-lithographic technology.





By applying 400-500 V between the two copper sides, an electric field as high as ~100 kV/cm is produced into the holes which act as multiplication channels for electrons produced in the gas by a ionizing particle.

Gains up to 1000 can be easily reached with a single GEM foil. Higher gains (and/or safer working conditions) are usually obtained by cascading two or three GEM foils.



A Triple-GEM detector is built by inserting three GEM foils between two planar electrodes, which act as the cathode and the anode.

GEM detector features

- flexible geometry → arbitrary shape: rectangular, cylindrical …
- ultra-light structure → very low material budget: <0.5% X0/chamber
- gas multiplication separated from readout stage → arbitrary readout pattern: pad, strips (XY, UV), mixed …
- high rate capability: >50 MHz/cm2
- high safe gains: > 10^4
- high reliability: low discharge, $P_d < 10^{-12}$ per incoming particle
- rad hard: up to 2.2 C/cm^2 integrated over the whole active area without permanent damages (corresponding to 10 years of operation at LHCb1)
- high spatial resolution: down to 60µm (COMPASS with analog readout Nucl.Phys.Proc.Suppl. 125 (2003) 368-373)
- good time resolution: down to 3 ns (with CF_4)

Rohacell

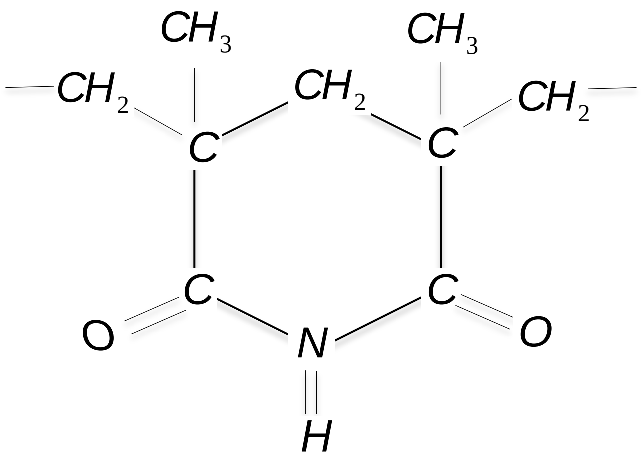
ROHACELL® IG/IG-F Properties

Property	Standard	Unit	ROHACELL® 31 IG/IG-F	ROHACELL® 51 IG/IG-F	ROHACELL® 71 IG/IG-F	ROHACELL® 110 IG/IG-F
Density	ISO 845	kg/m³	32	52	75	110
	ASTM D 1622	lbs/ft³	2.00	3.25	4.68	6.87
Compressive Strength	ISO 844	MPa	0.4	0.9	1.5	3.0
	ASTM D 1621	psi	58	130	217	435
Tensile Strength	ISO 527-2	MPa	1.0	1.9	2.8	3.5
	ASTM D 638	psi	145	275	406	507
Shear Strength	DIN 53294	MPa	0.4	0.8	1.3	2.4
	ASTM C 273	psi	58	116	188	348
Elastic Modulus	ISO 527-2	MPa	36	70	92	160
	ASTM D 638	psi	5,220	10,150	13,340	23,200
Shear Modulus	DIN 53294	MPa	13	19	29	50
	ASTM C 273	psi	1,885	2,755	4.205	7,250

Technical data of our products are typical values for the nominal density.

Rohacell

Rohacell 31



$$\frac{1}{X_0} = \sum_j \frac{w_j}{X_{0j}} \qquad \begin{cases} w_j = weight \;\; fraction \\ X_{0,j} = radiation \;\; length \;\; of \;\; element \end{cases}$$

$$X_0 \cong 41.67\,gcm^{-2} \qquad \rho = 3 \cdot 10^{-2}\,gcm^{-3}$$

$$L_0 \cong 1389\,cm\,(4\%\,air)$$

$$1mm(Rohacell\,31) = 7 \cdot 10^{-5}\,X_0$$

Kapton

$$X_0 = 40.58\,gcm^{-2};\ \rho = 1.42\,gcm^{-3}$$

$$25\,\mu m(Kapton) = 0.01\%\,X_0$$

$$50\,\mu m(Kapton) = 0.02\%\,X_0$$

Copper

$$X_{0,cu} = 12.86\,gcm^{-2};\ \rho = 8.96\,gcm^{-3}$$

$$3\,\mu m(Copper) = 0.022\%\,X_0$$

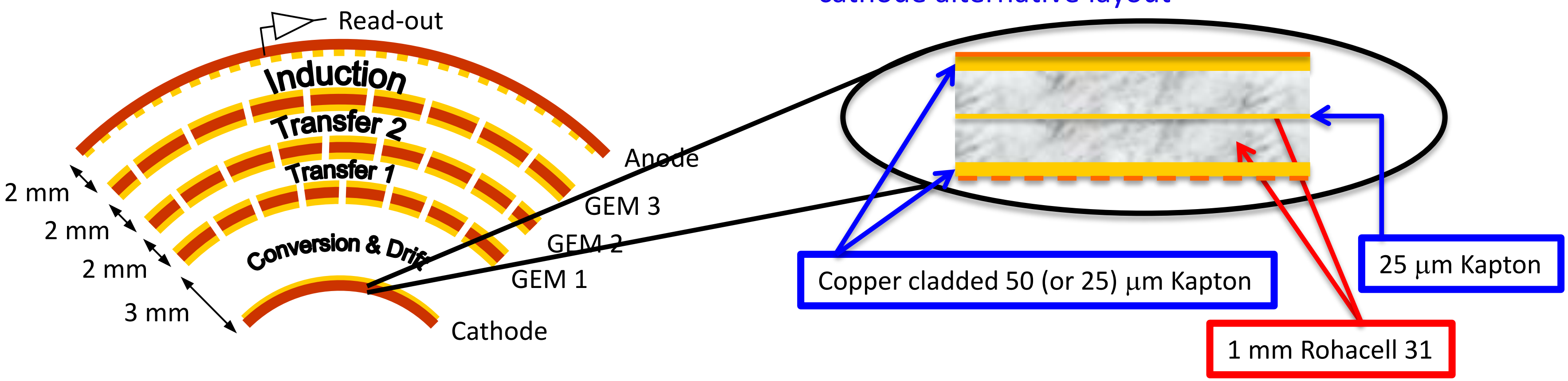
$$18\,\mu m(Copper) = 0.13\%\,X_0$$

$$35\,\mu m(Copper) = 0.24\%\,X_0$$

CGEM layer layout

Cylindrical Triple GEM

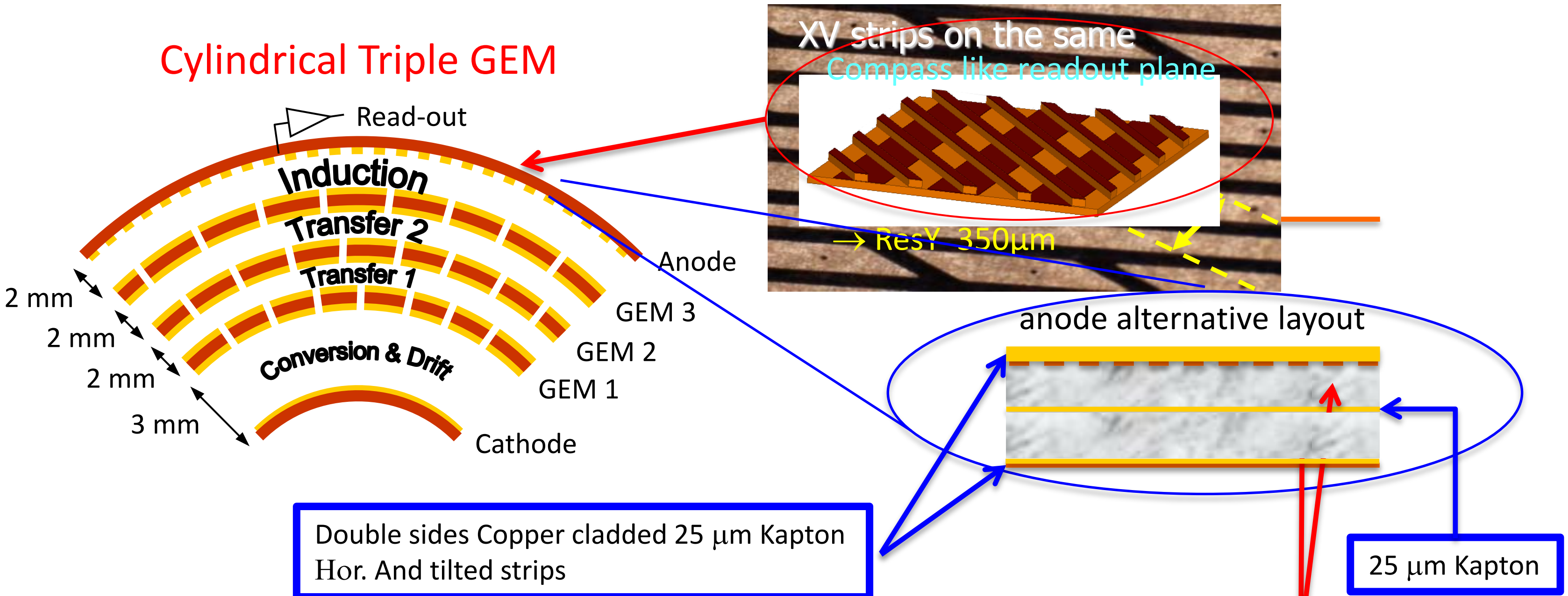
cathode alternative layout



With this technique:

2 layers Roh ~ 1mm each:
2 layers Kapt. 25μm:
1 layer Kapt. 50 (25) μm:
2 layer Cu 3μm:
$\text{TOTAL}_{\text{cath.}}$.:

CGEM layer layout



Typical Anode with this technique:

2 layers Roh. ~ 1 to 3 mm each:	$(0.014 - 0.04)\% X_0$
1 layers Kapt. 50µm:	$0.017\% X_0$
2 layer Kapt. 25 µm:	$0.017\%(0.01) X_0$
2 layer Cu 3 µm:	$0.043\% X_0$
1 layer Cu 5 µm:	$0.036\% X_0$
2 layer gold	0.006
TOTAL$_{cath.}$.:	$(0.14 - 0.17)\% X_0$

One CGEM layer thickness: <13mm (Kloe:15mm)

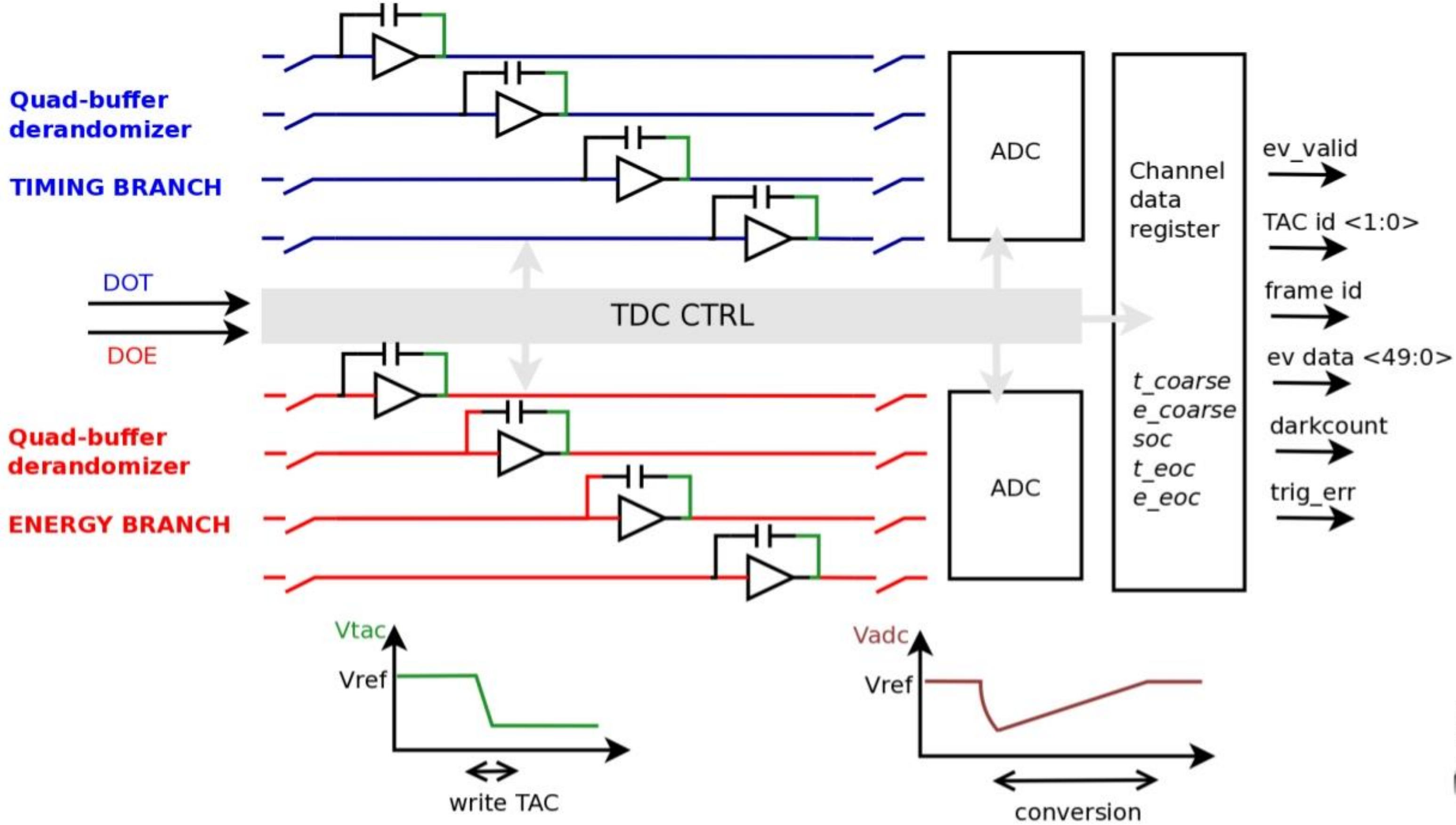
Question time

ASIC

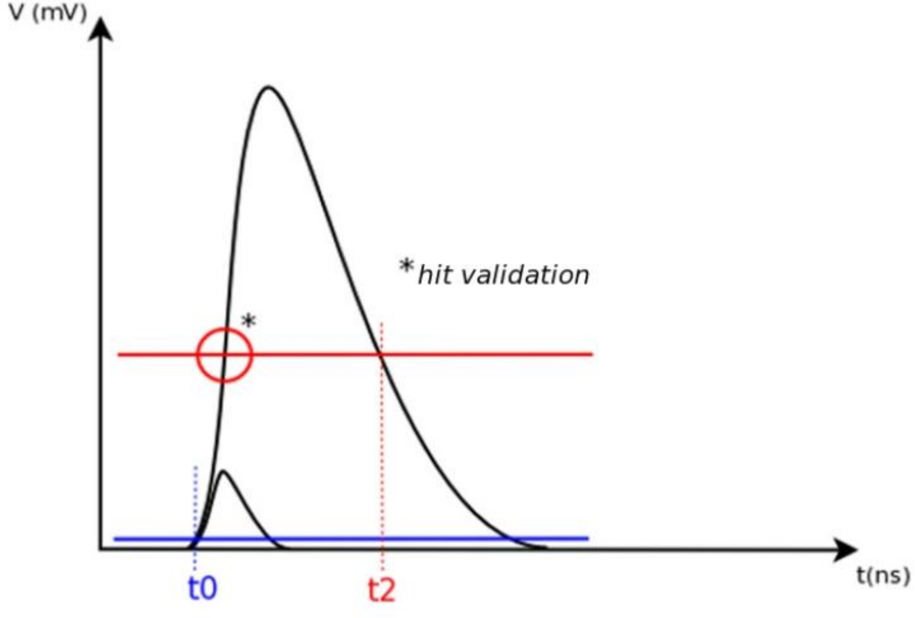
Time-to-Digital Converter

Analogue TDC with 50 ps time binning - based on Time-to-Amplitude Conversion [Stevens89, Rivetti09]

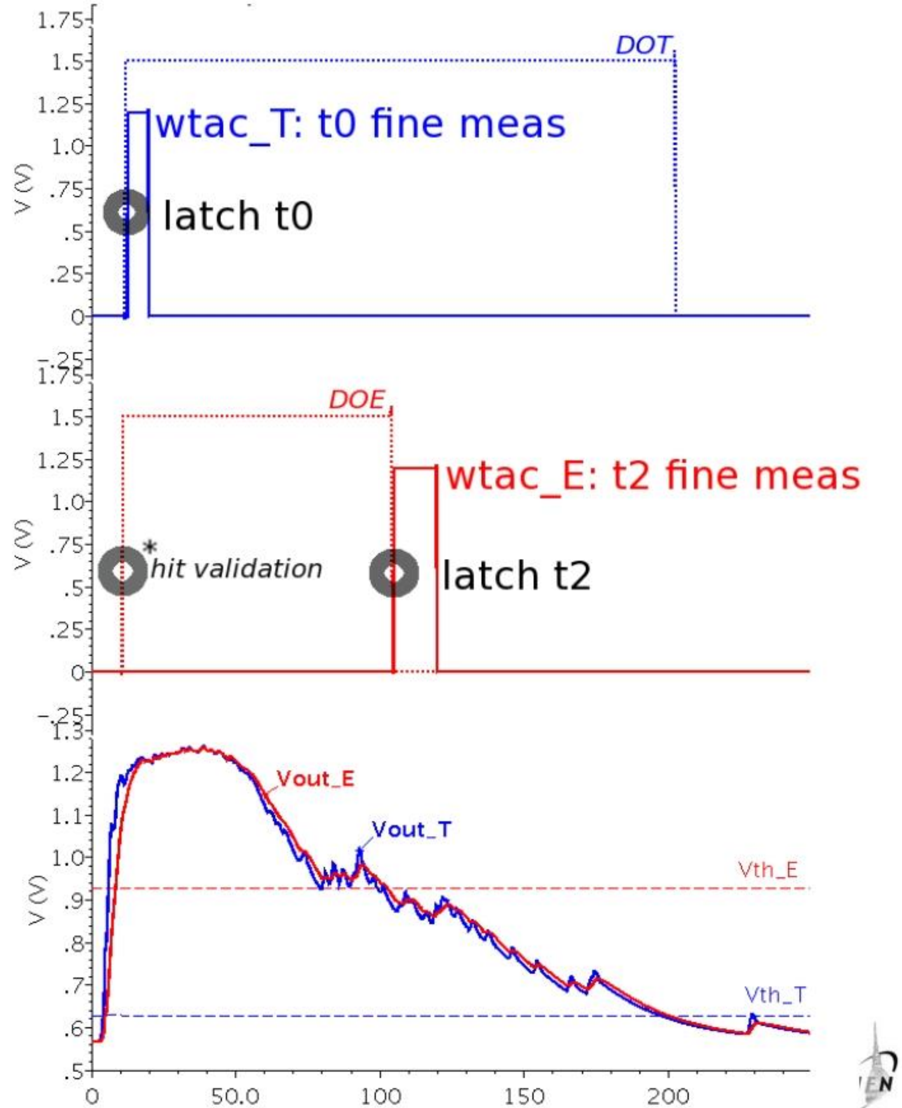
- TDC Control: switching, hit validation, buffer allocation, data reg.
- Time stamp: 10-bit master clock count + Fine time measurement



TDC operation for a valid event



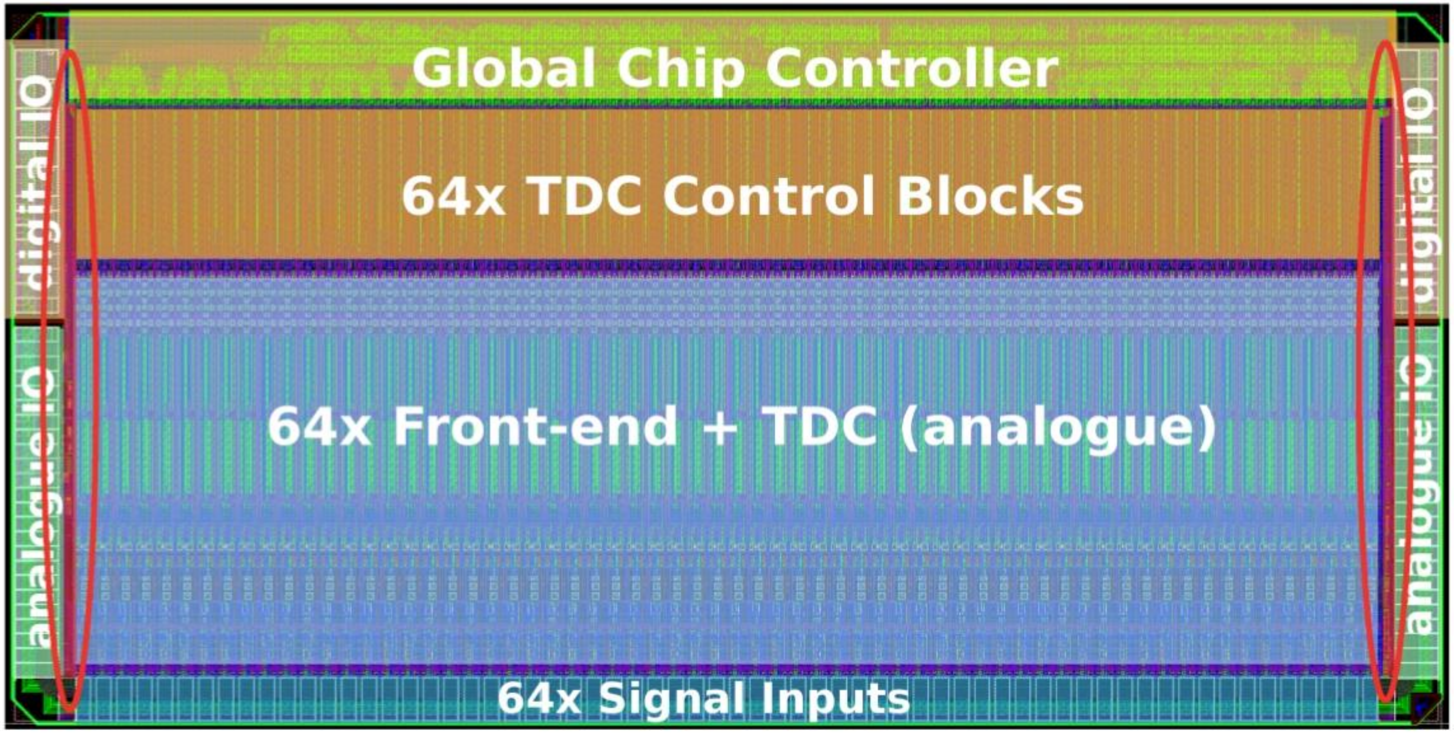
a)



b)

Floorplan of the 64-channel mixed-mode chip

- CMOS 130nm 25mm^2 64-channel ASIC
- Highlight shows the allocated area for bias and calibration circuitry.
- One pad-free edge to allow abutting two twin chips into a 128-channel BGA package.



ASIC characteristics

• Input charge: 5-20 fC • Cstrip 5-50 pF • Input rate (single strip): 7-15 kHz	Detector Spec
• Trigger latency: 8-9 μs - Dead time. 4 μs • Trigger rate: 1-2 kHz	Readout section
• Input impedance 120-300 Ω • Charge sensitivity 20-40 mV/fC • Shaping time: 50-100 ns • ENC : 400e+40e/pF to 600e+60e/pF	Input section (pre+shaper)
• Charge meas resolution: 7-8 bits • Time meas resolution: 10-20 ns	Data conversion section

• Power consumption < 7 mW p/channel ⇒ 4 mW p/channel feasible