STARS: Supercomputers for Trigger Analysis and Real-time Selections

Proposal for Ideas - FP VII

Alberto Annovi
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Outline

- STARS
- Trigger: we always need more power!
- CDF trigger problems/upgrades/solutions
- More for the next future?
- SVT & AM could survive after CDF at both
  level 1 (CMS @SLHC? SLIM5) and level 2 (ATLAS?)
  other applications?

STARS: Supercomputers for Trigger Analysis and Real-time Selections

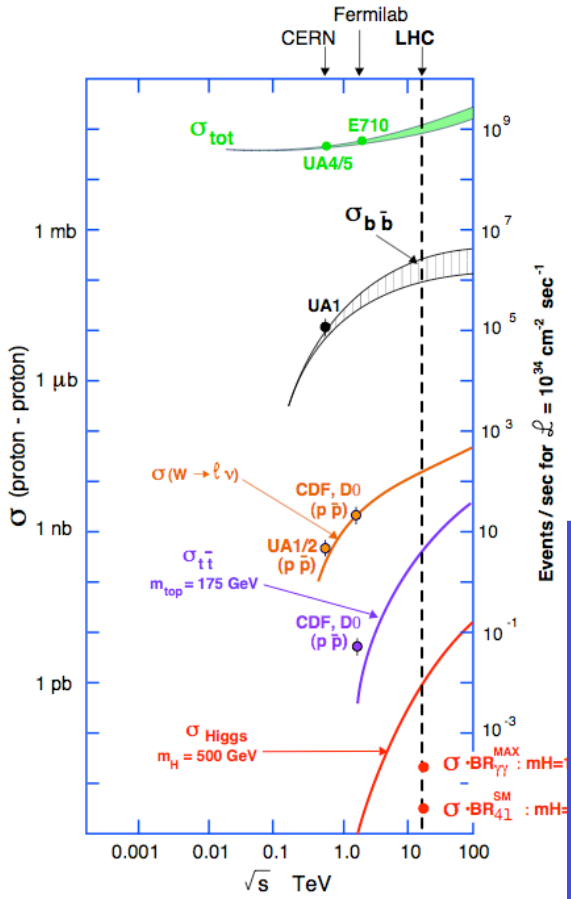
Current and future (HEP) experiments look for extremely rare processes hidden by severe background conditions.

The trigger dramatically affects our ability to extract these tiny signals from the huge backgrounds.

export the successful CDF trigger approaches to new experiments → Challenging: competition with Farm approach

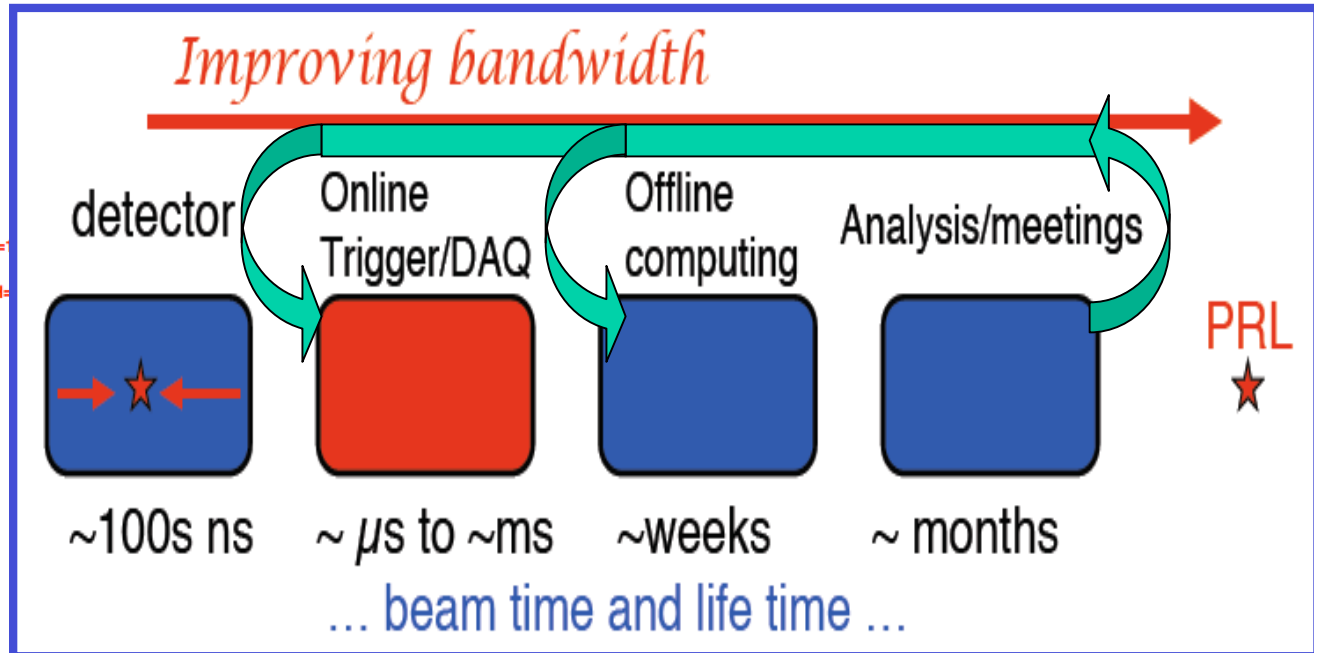
New experiments need powerful exclusive, high resolution triggers! The trigger cannot be "inclusive, low resolution" any more! → very large comupting power needed → time is critical

Looking for very rare phenomena



Hans Bethe: "Young man, if the cross section is so low, increase the luminosity !"

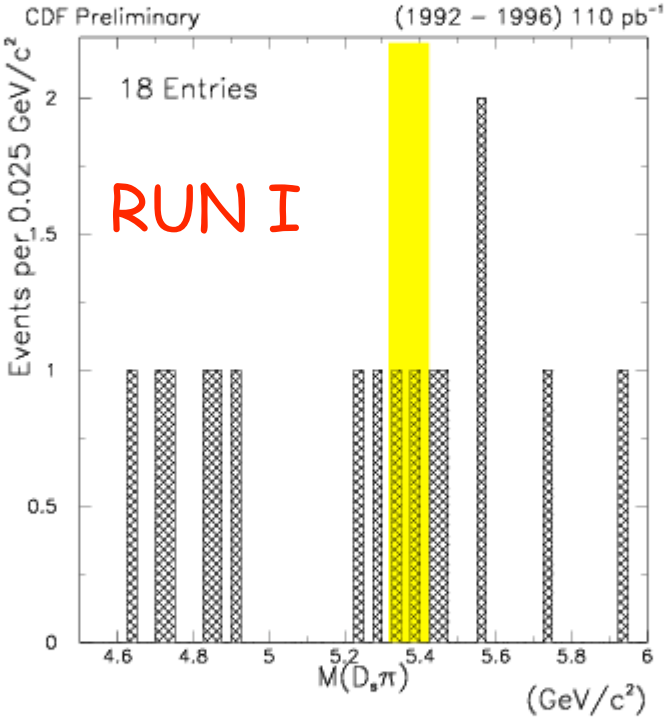
@hadronic collider not only the luminosity has to be increased, but also the bandwidth, the purity ... From collision point all the way to PRL editors Trigger is a critical part of this process: errors cause not-recoverable losses!



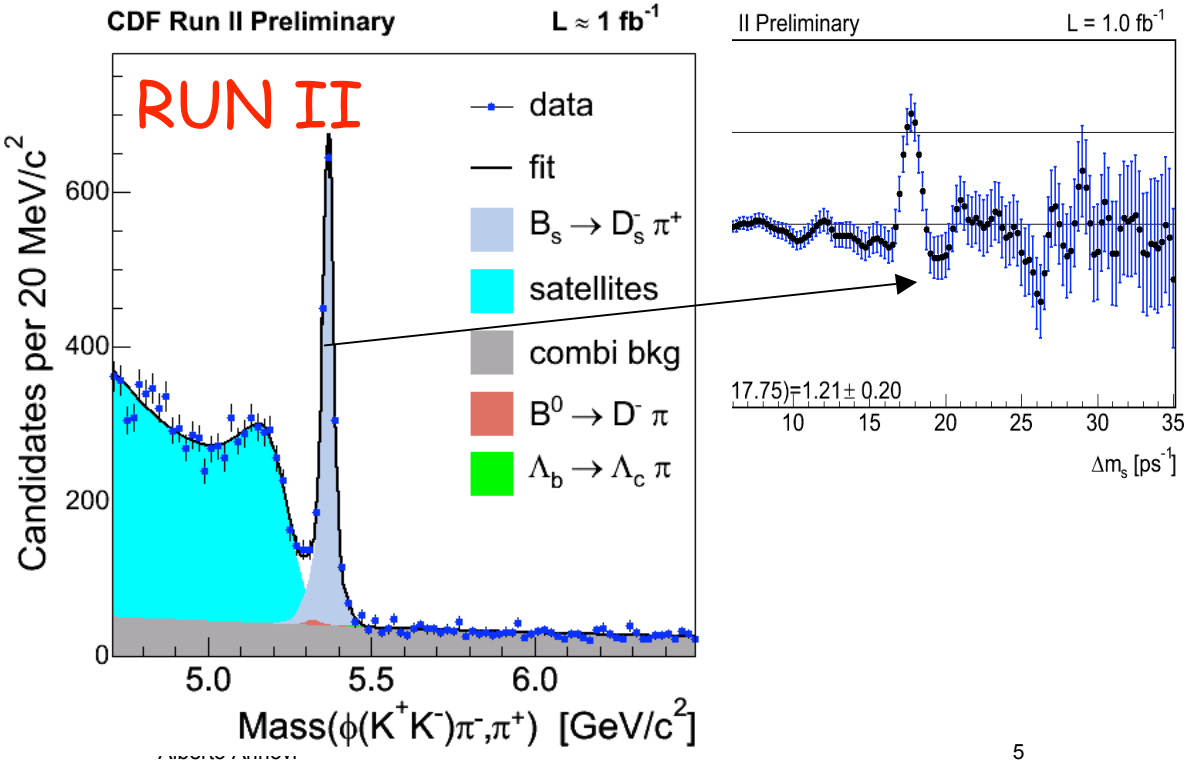
CDFTrigger power: (1) TTT: the displaced TrkTrigger but also Terrific Tracking (@ L1/L2)

- Run I collected O(1) $B_s \to D_s\pi$ (all D_s modes)
- Run II collected ~2000 $B_s \to D_s\pi$ ($D_s \to \phi[\to K^+K^-]\,\pi$)
- Compare with only 10x integrated luminosity!
- The trigger had a much bigger impact than Tevatron upgrade!!!

Without SVT

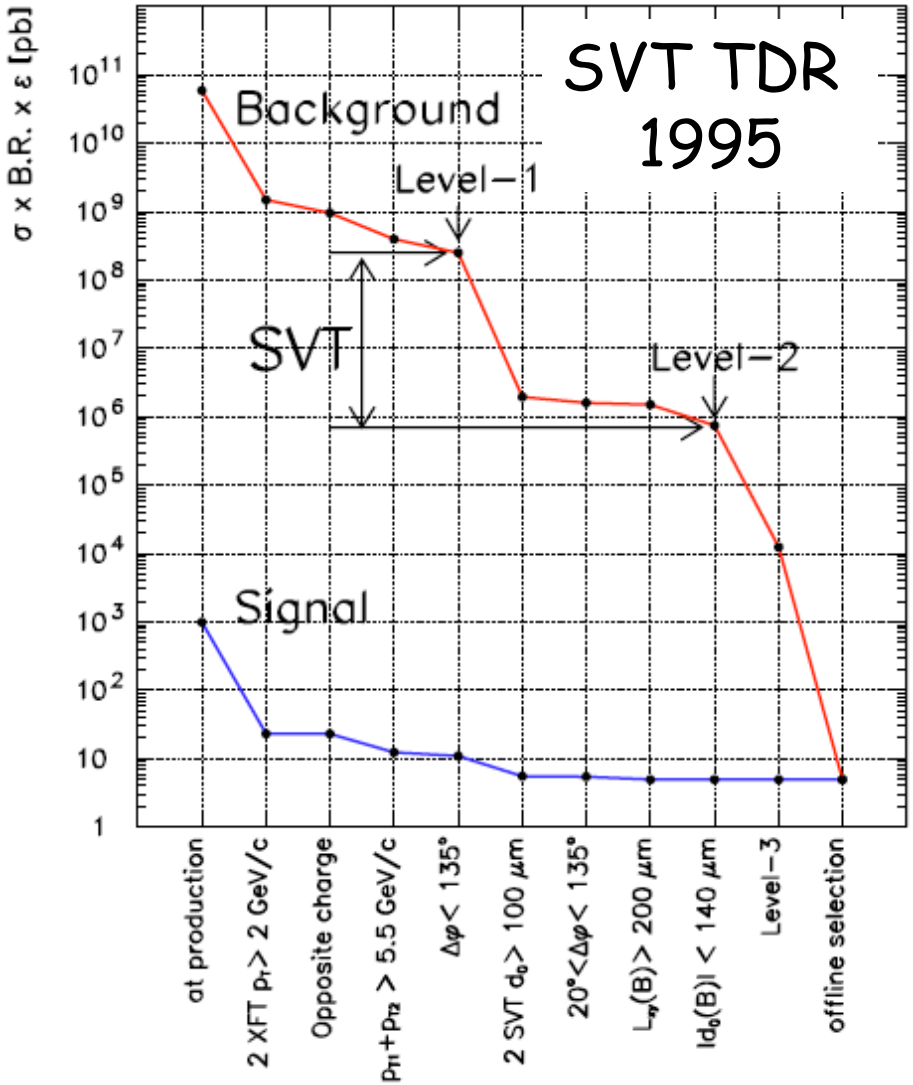


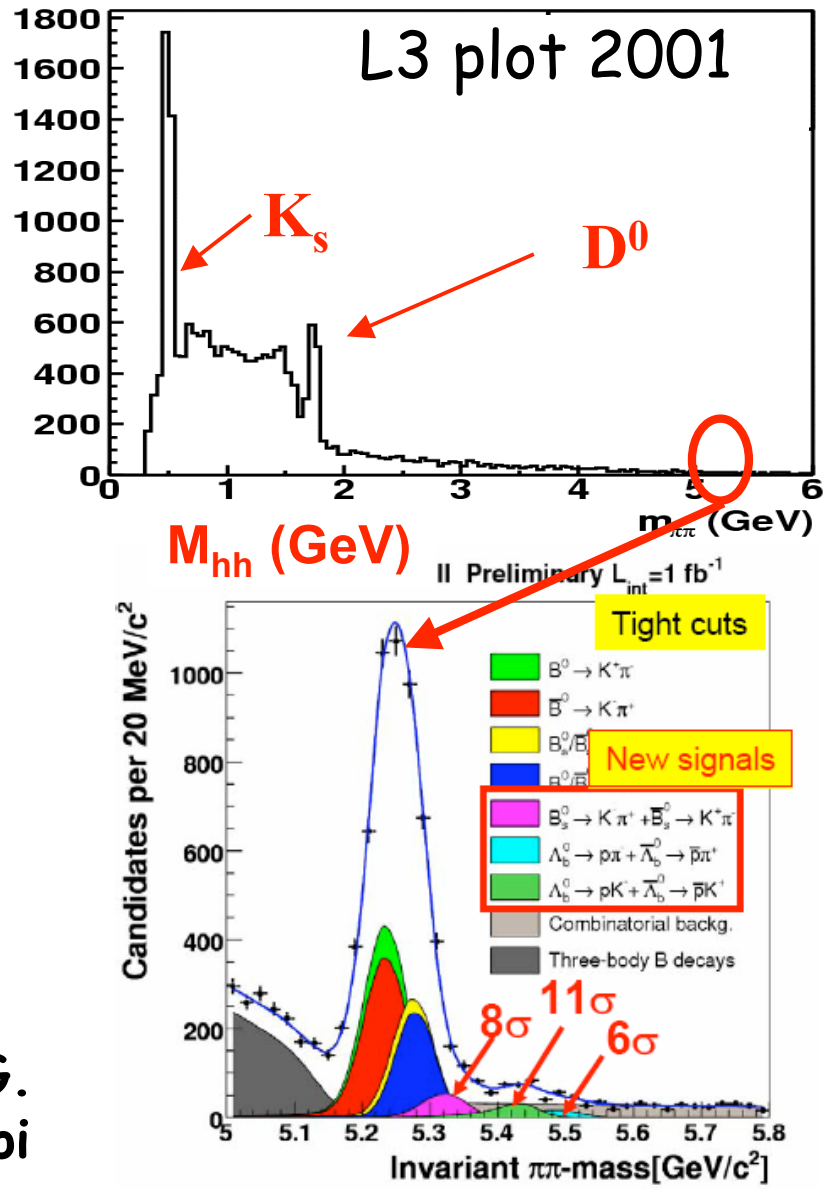
With SVT



$B^0 \rightarrow$ had + had Trigger

The SVT advantage: 3 orders of magnitude





S. Donati, M. Morello, G. Punzi, D. Tonelli, G. Volpi

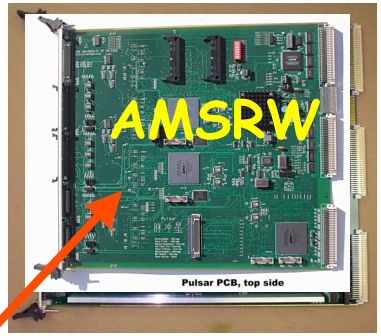
SVT: many different boards → 2 years for upgrade → PULSAR

x12 wedges

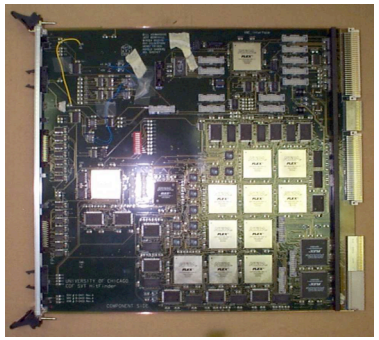
AM Sequencer

Super Strip

AM Board



Hit Finder

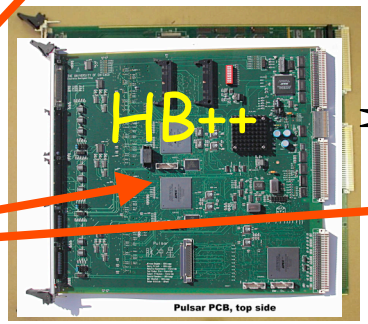


Hits

Detector Data

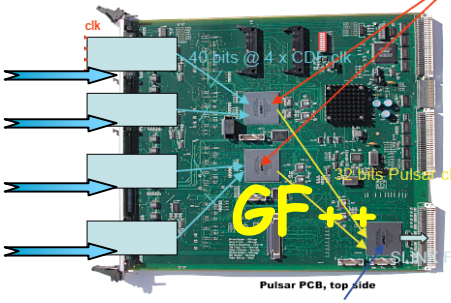
Roads

Matching Patterns



Hit Buffer

Roads + Correspond Hits



Powerful flexible PULSARS

Just add Firmware

L2 CPU

Tracks + Corresponding Hits

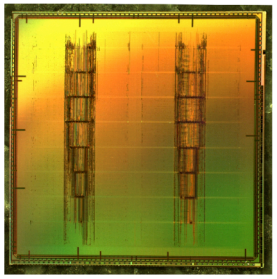
AM chips from 1992 to 2005

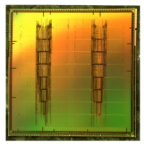
- (90's) **Full custom VLSI chip -** 0.7μm (INFN-Pisa)
- **128 patterns, 6x12bit words each**
- **32k roads / wedge**

F. Morsani et al., "The AMchip: a Full-custom MOS VLSI Associative memory for Pattern Recognition", IEEE Trans. on Nucl. Sci., vol. 39, pp. 795-797, **(1992).**

On the opposite side: **FPGA** for the same AMchip

P. Giannetti et al. "A Programmable Associative Memory for Track Finding", Nucl. Intsr. and Meth., vol. A413/2-3, pp.367-373, **(1998).**





NEXT: NEW VERSION For both L1 & L2

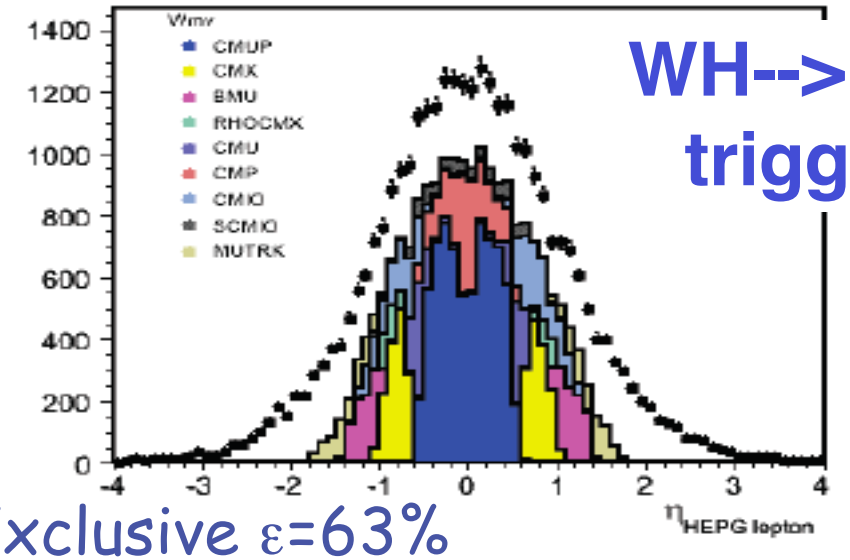
In the middle: **Standard Cell 0.18** μm (INFN Ferrara, Pisa)→ 5000 pattern/chip AMchip

L. Sartori, A. Annovi et al., "A VLSI Processor for Fast Track Finding Based on Content Addressable Memories", **IEEE Transactions on Nuclear Science**, Volume 53, Issue 4, Part 2, Aug. **2006** Page(s):2428 - 2433

CDFTrigger power: (2) also Terrific Calorimeter selection (@L2)

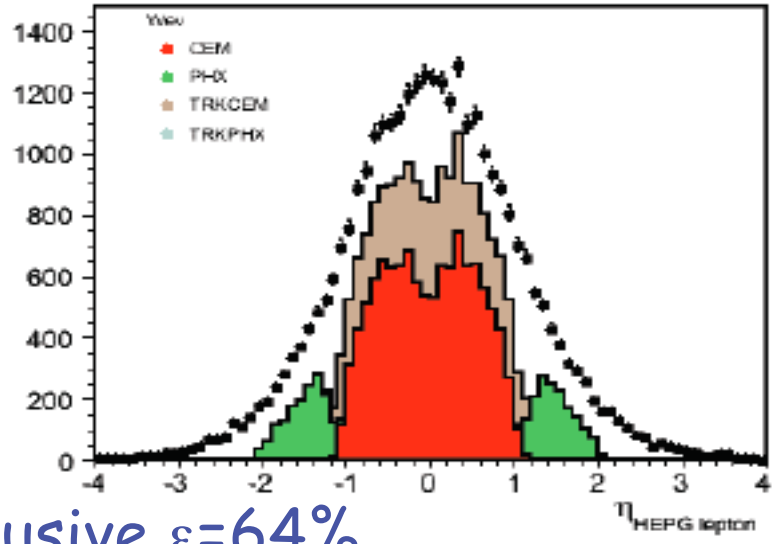
SVT

Muon acceptance

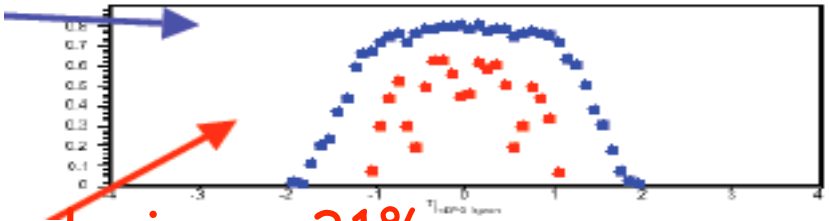


WH--> lvbb triggers

Electron acceptance

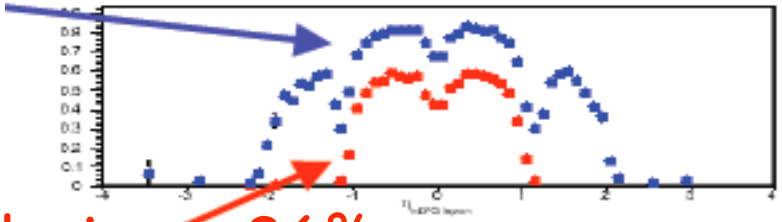


Exclusive ε=63%



Inclusive ε=31%

Exclusive ε=64%



Inclusive ε=36%

Release lepton quality cuts --> gain acceptance x2

Control rate with jet/MET requirements --> exclusive triggers

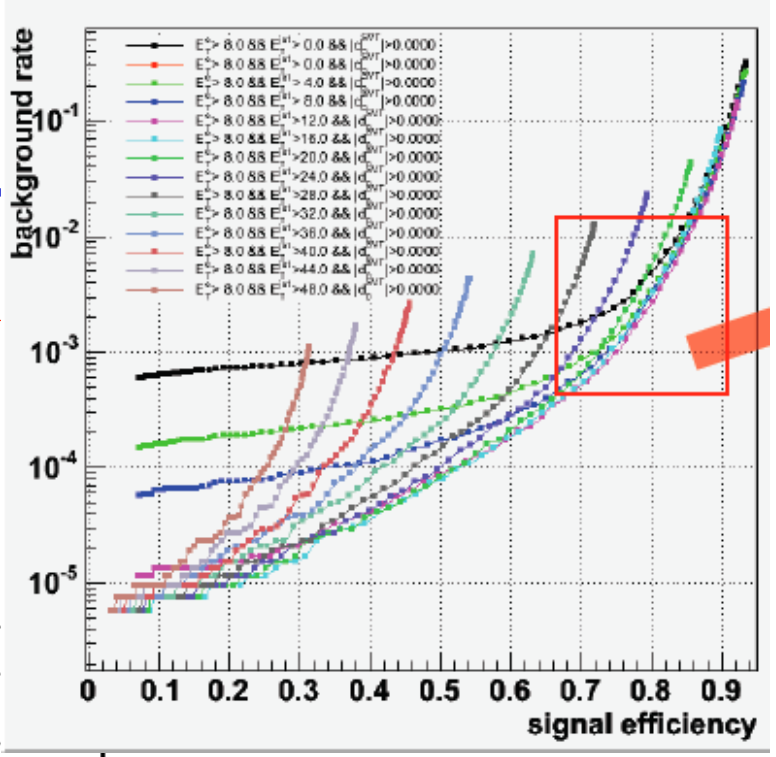
Need high-quality jet/MET trigger --> under upgrade!

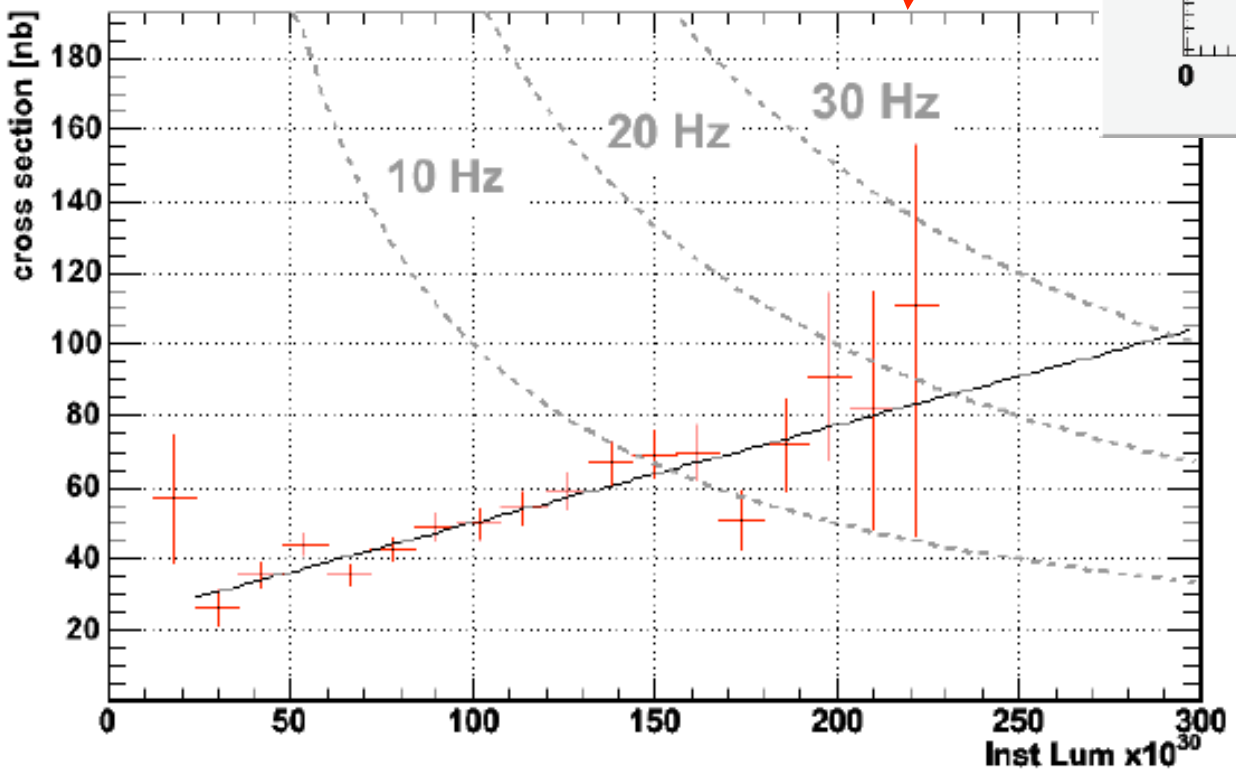
Example: New exclusive WH-> evbb trigger

M. Casarsa et al. (in progress)

A real >80% efficient trigger
with low rate @ peak lumi
Using L2 clustering upgrade

Tools →





$L1\_ET_{TOW}$>10 GeV

L1_MET >15 GeV

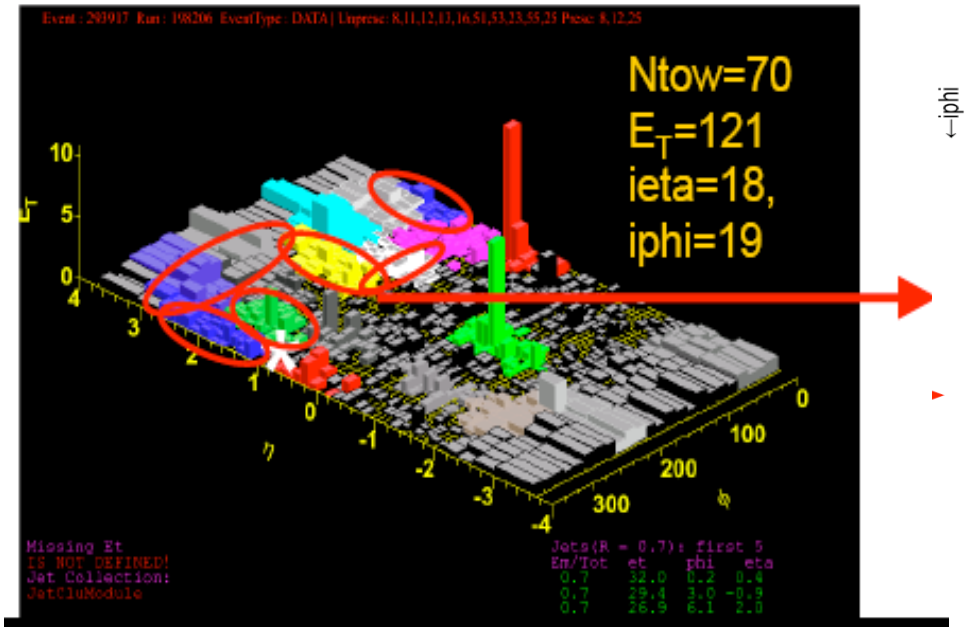
L2_MET > 20 GeV

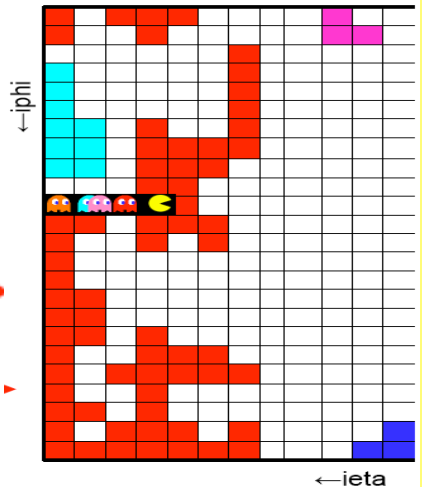
$L2\_Et_e$ > 8 GeV

L2_2Jet> 12 GeV

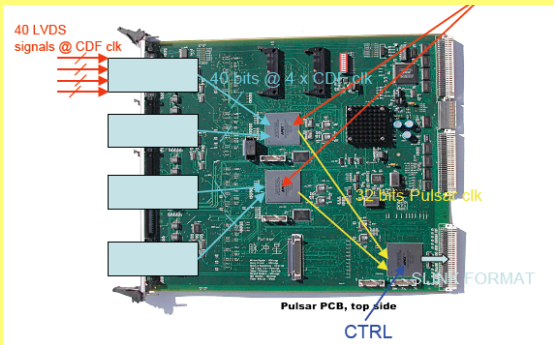
CDF LVL2 Calo upgrade

Need a cone algorithm!

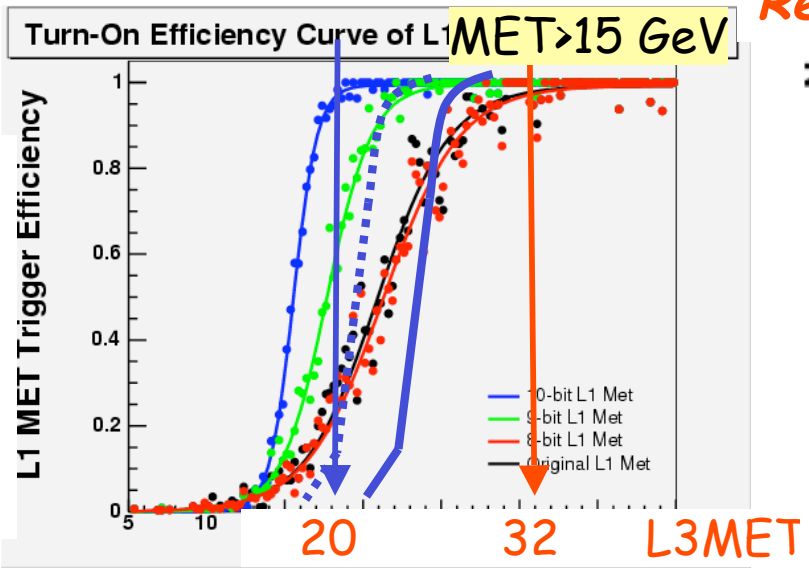




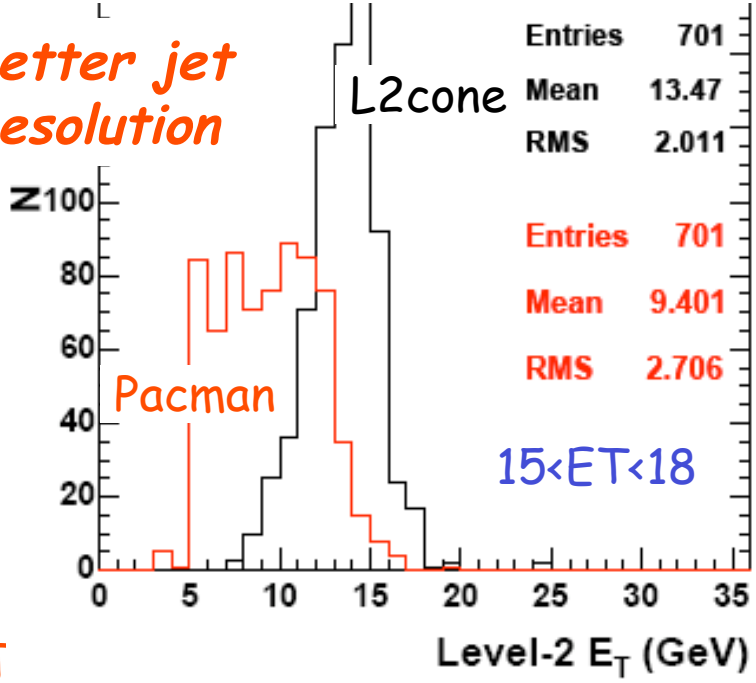
Same Pulsars
Same mezzanines



Better Resolution & Efficiency Turn on for MET



Better jet Resolution

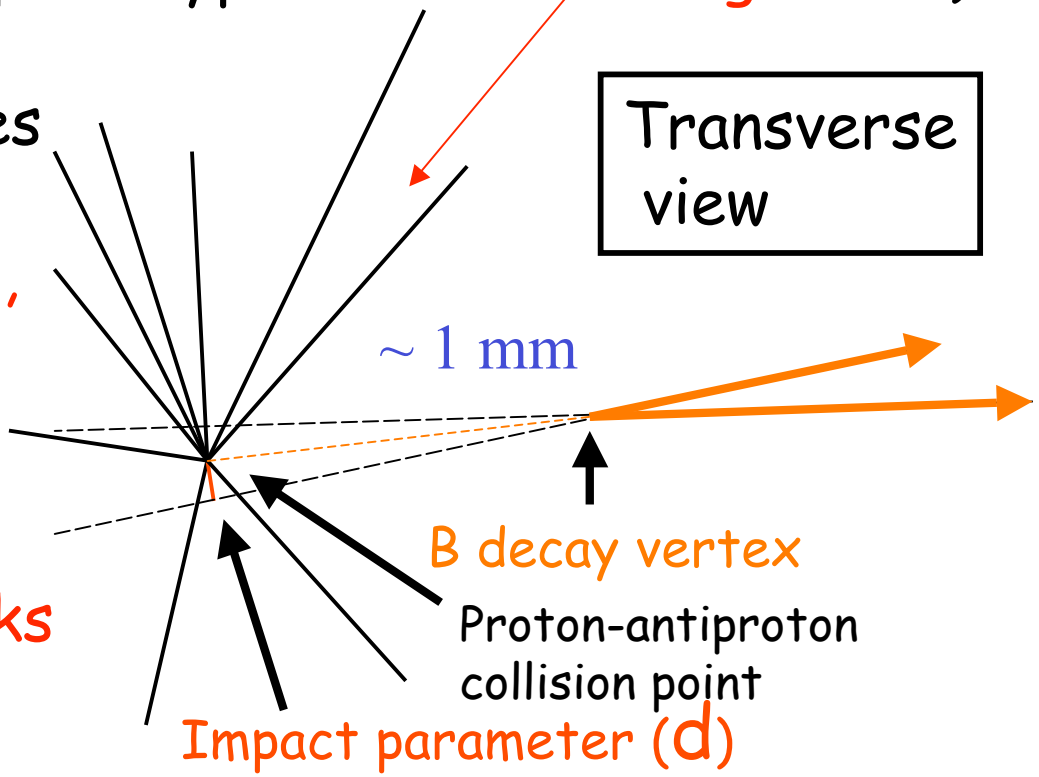


CPU & STARS

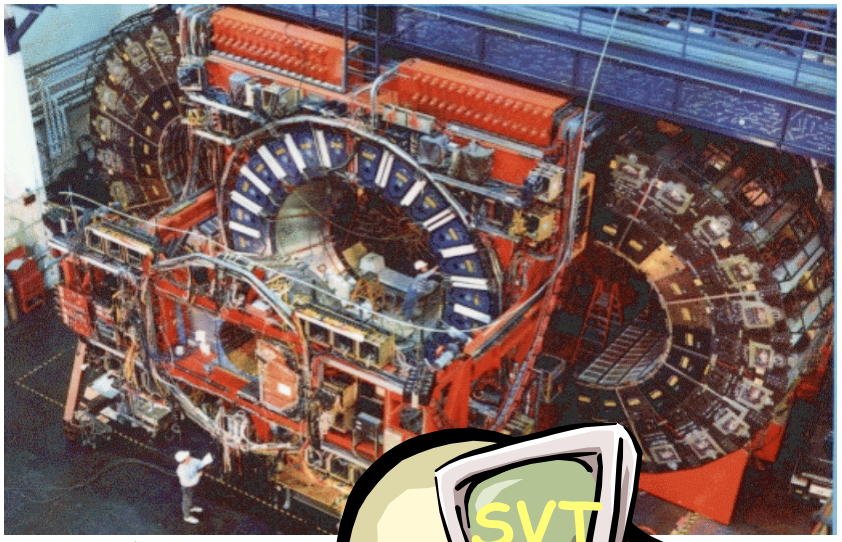
LHC HLT strategy: we "JUST" buy CPUs and write software…
CPUs are flexible but *missing time* can freeze the flexibility!

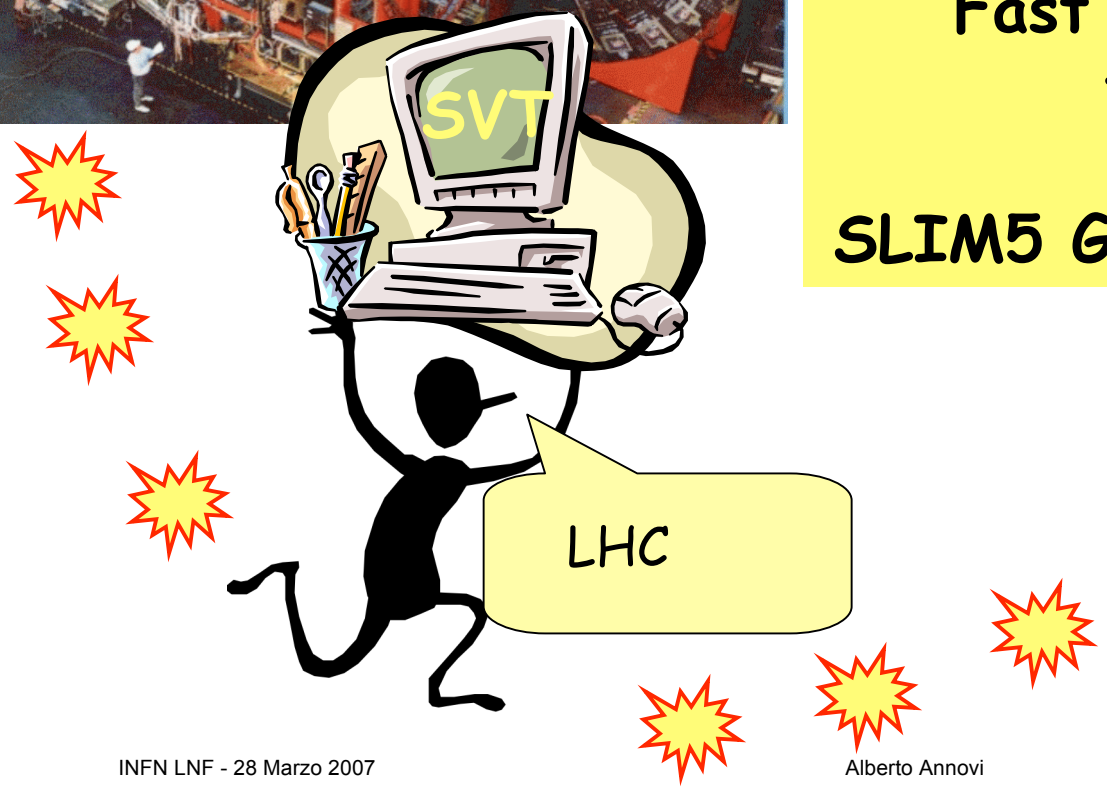
SVT approach: (1st STARS prototype born for a tough JOB)
split the algorithm
among different technologies
VLSIs (AM chip),
FPGAs (Pulsars+mezzanines),
CPUs
Use the appropriate tool
i.e. no time waste!

We will also buy STARS blocks
(Pulsars & AM chips)
& write firmware + software



What next ?





Next challenge is silicon tracking at both Level 1 & Level 2

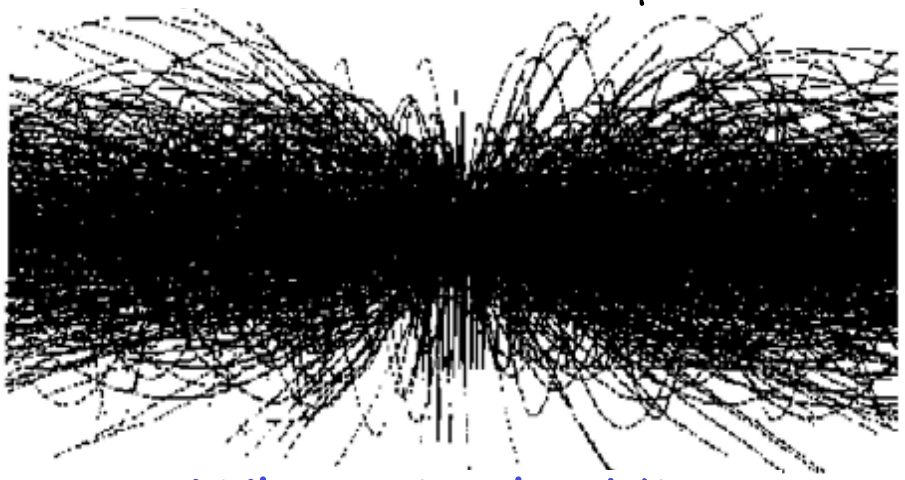
Fast Track (FTK) Gr V for L2 @ LHC

SLIM5 Gr V for L1 @ SuperB?

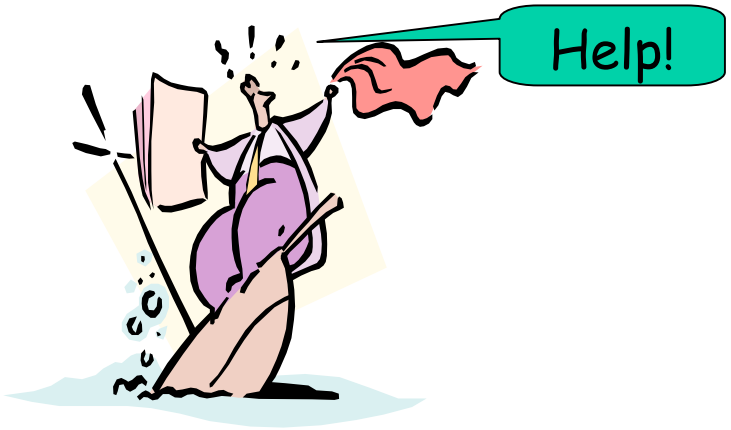
Ideas from
P. Giannetti
M. Dell'Orso
L. Ristori G. Punzi
A. Annovi

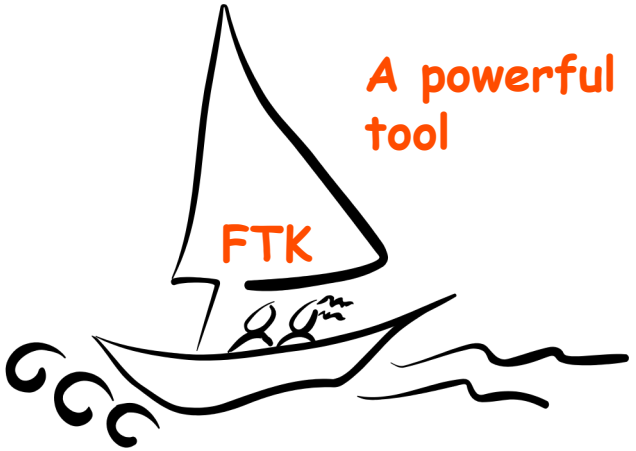
Online tracking: a tough problem

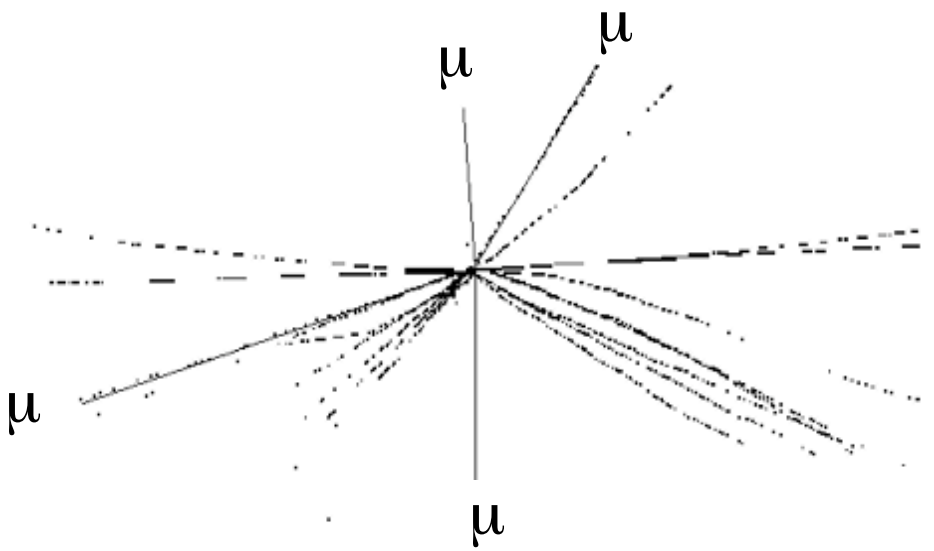
CMS: 30 minimum bias events + H->ZZ->4μ



Where is the Higgs?



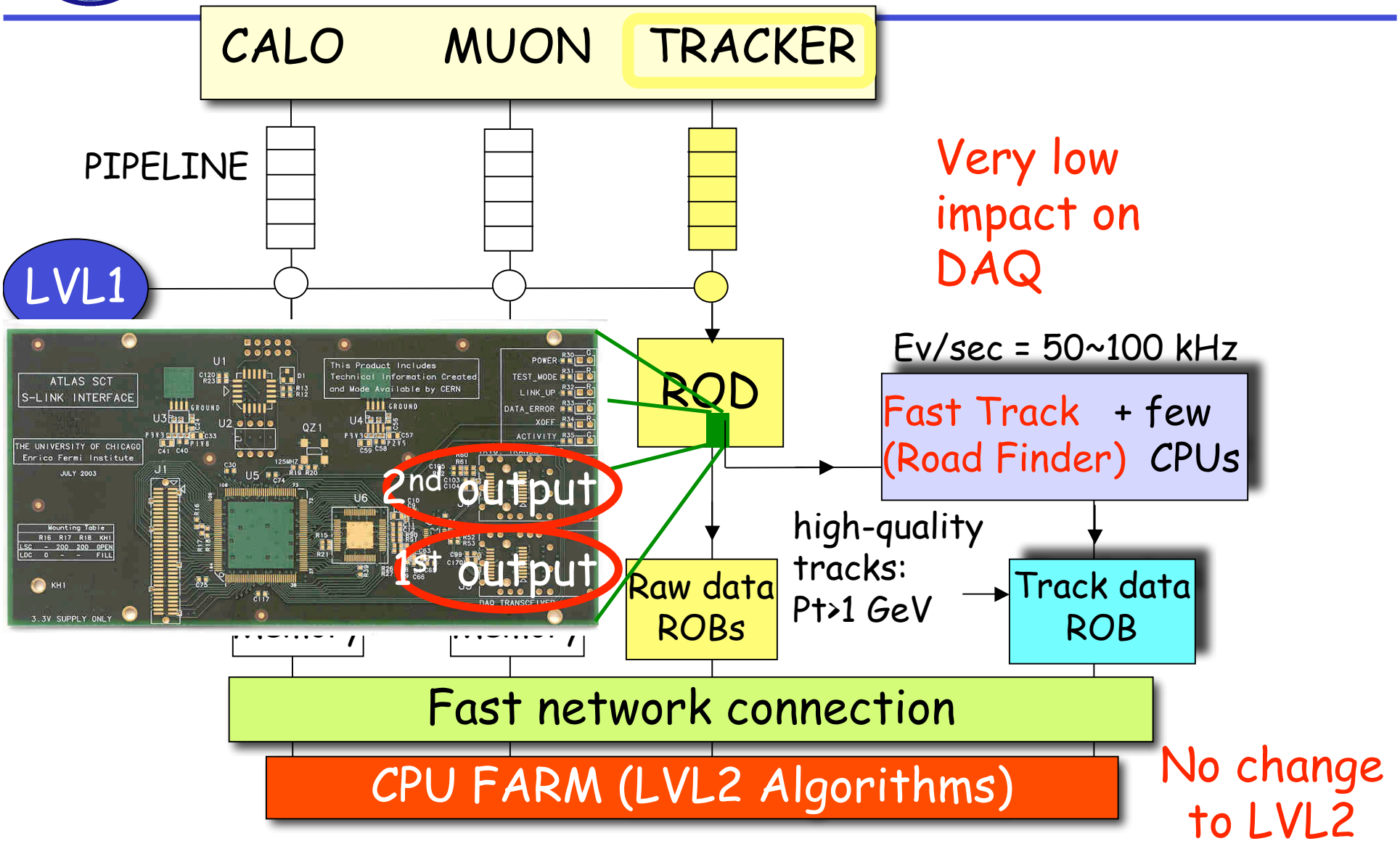




Tracks with P_t>2 (or Pt>1) GeV for b/τ-tagging @ level 2;
P_t>5 GeV for leptons @ level 1

Where could we insert FTK?

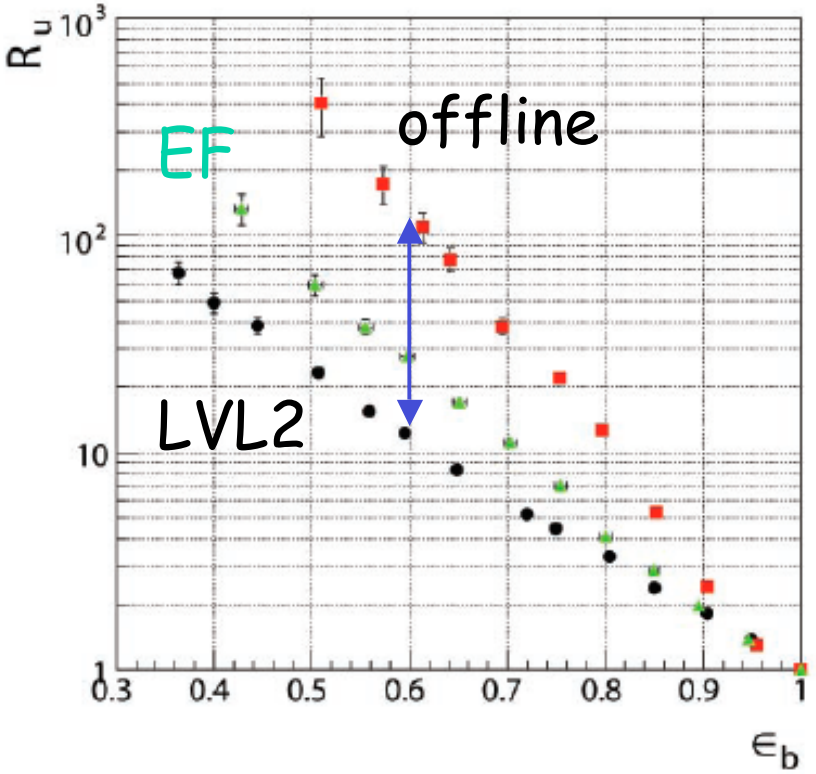
SVT



B-tagging @ ATLAS (w/o & w/ FTK)

SVT

ATLAS T&P march 2007



with Fast-TracK offline
b-tag performances @LVL2

LVL2 vs offline
10 times less rejection

EF vs offline difference being investigated

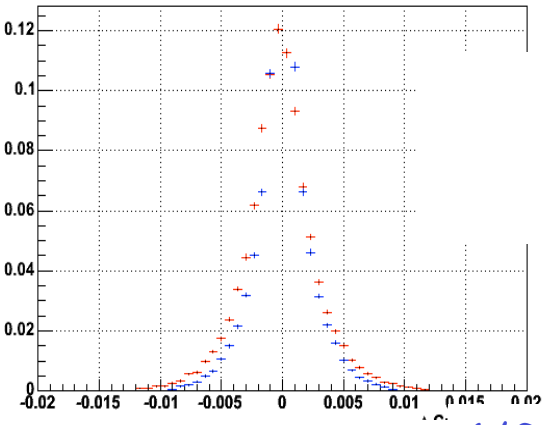
With FTK use offline-quality tracks for all triggers, e.g.

sophisticated τ triggers

FTKsim versus iPatRec - Resolution

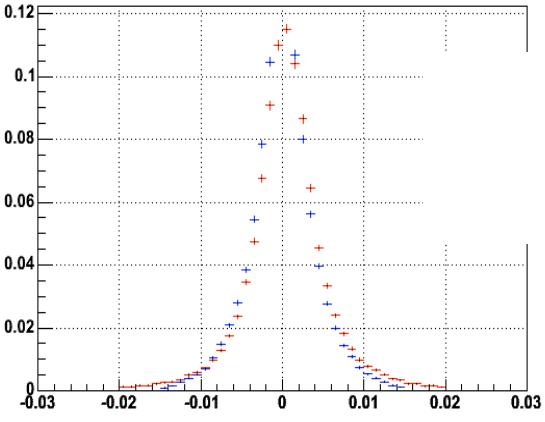
SVT

Curvature



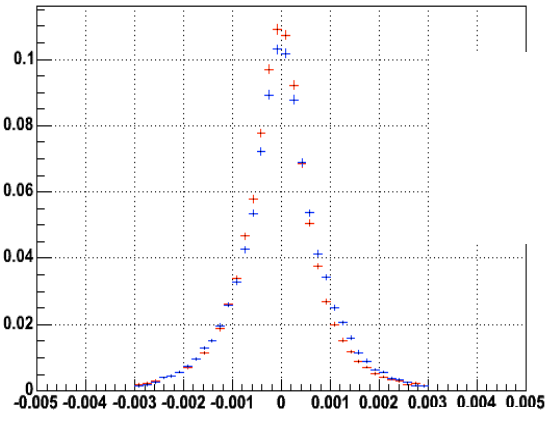
1/GeV

Impact Parameter



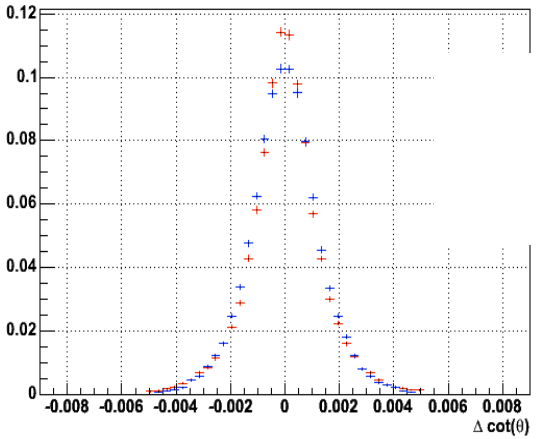
cm

Φ



rad

Cot(θ)



On going Real Time Tracking & b/τ/Bs tagging performance study

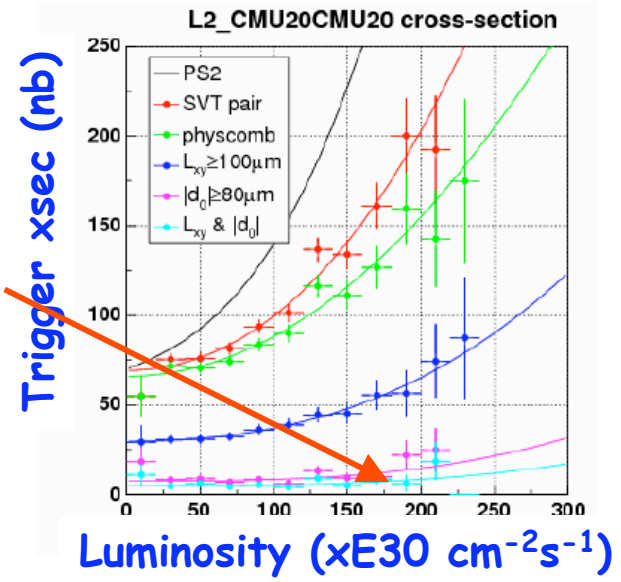
M. Dell'Orso, F. Crescioli, G. Punzi, G. Volpi, P. Giannetti et al. (Pisa-Chicago)

Selected triggers with tracks/jets

SVT

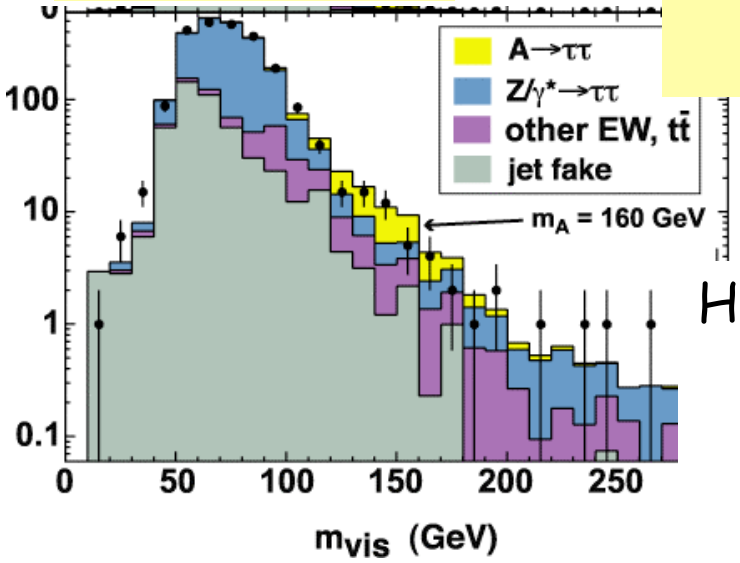
- Di Muon trigger (J/Psi, Bs-> μ μ)
  - L1 two muons Pt>1.5
  - L2 Pt>2 && Dynamical Prescale
    - will use SVT in the future
- Z -> bb trigger (bjet calibration, top mass)
  - L1 jet5, trk5.5, trk2.5
  - L2 two trk ip>160 μm, ~ same z vertex
    two jet5

Rate Bs-> μ μ with SVT

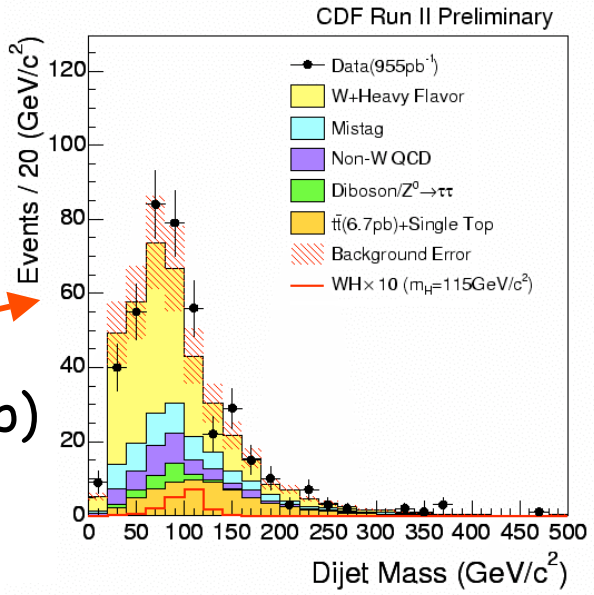


(MSSM Higgs)

- Hadronic di tau
  - L1 2jet5, 2trk6
  - L2 2jet10, 2trk10



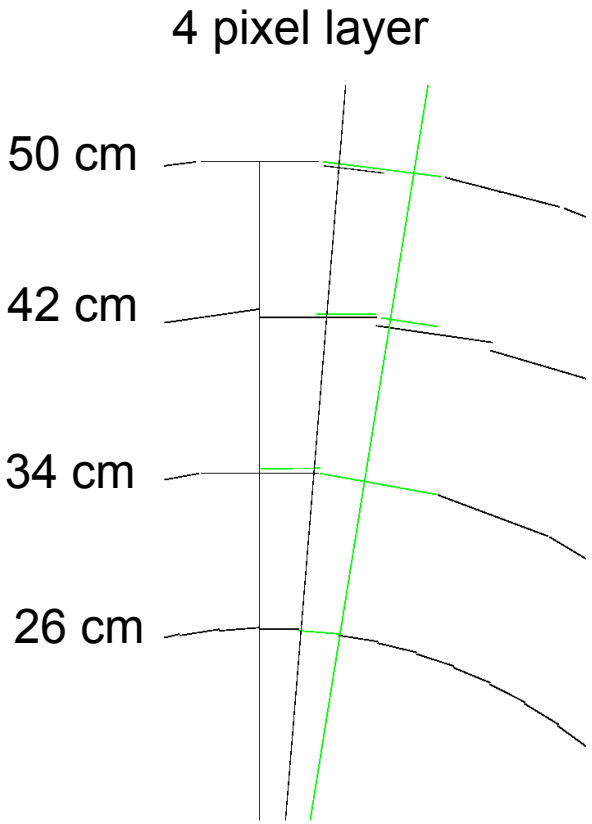
High Pt electron
(W, Z, W+H, top)
- L1 EM8, trk8
- L2 EM16, trk8



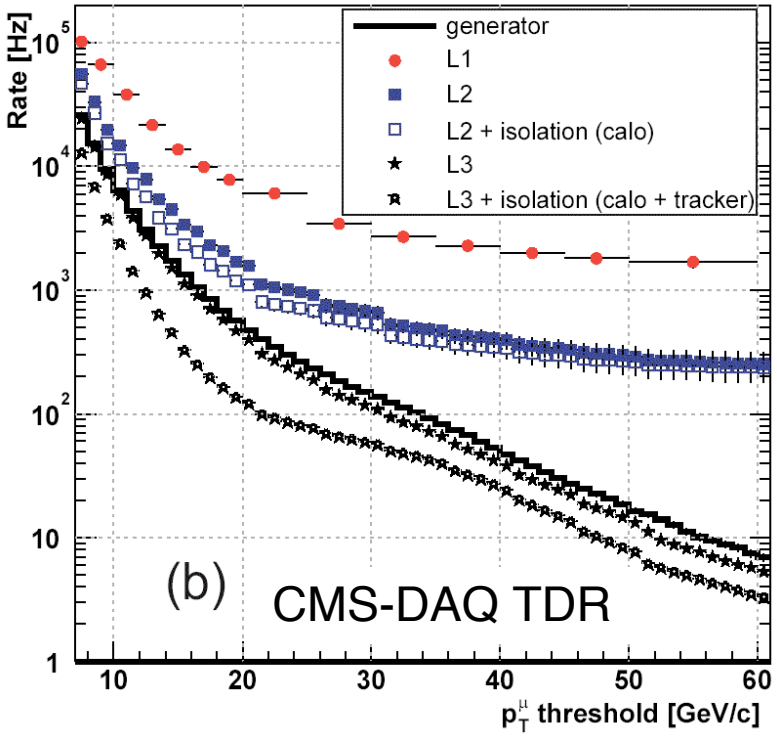
F. Palla Proposal (LECC06 workshop)

SLHC:

- ~100 Minimum Bias events/bx (12.5 ns) [4xLHC]
- occupancy degrades performance of trigger algorithms
- Implies raising E_T thresholds or use tracks
- ~2000 tracks/bx in $|\eta|<1.5$
  - But only a few ‰ have $p_T>5$ GeV/c



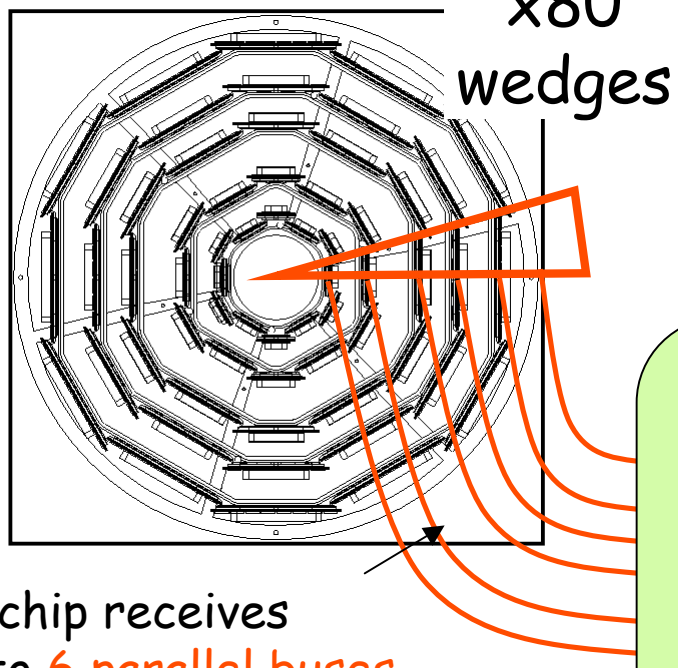
CMS Muon Rate at $L = 10^{34}$ cm^{-2} s^{-1}



Note limited rejection power (slope) without tracker information

- This plan match with AMchip features!!!

Same blocks --> different applications



Main problem: AM input Bandwidth, even if powerful: >10 Gbits/sec
→ divide the detector in thin ϕ sectors.
Each AM searches in a small $\Delta\phi$

1 AM for each enough-small $\Delta\phi$
space-time Patterns
Hits: position+time stamp
All patterns inside a single chip
N chips for N overlapping events
identified by the time stamp

AMchip receives
up to 6 parallel buses
for 6 layers at frequency:
AMchip now: 50 MHz (Level 2)
Next generation: 100 MHz
or more

Goal: use SAME CHIP
for Level 2 & 1

Similar use (L1 tracking) for

CMS (F.Palla proposal)

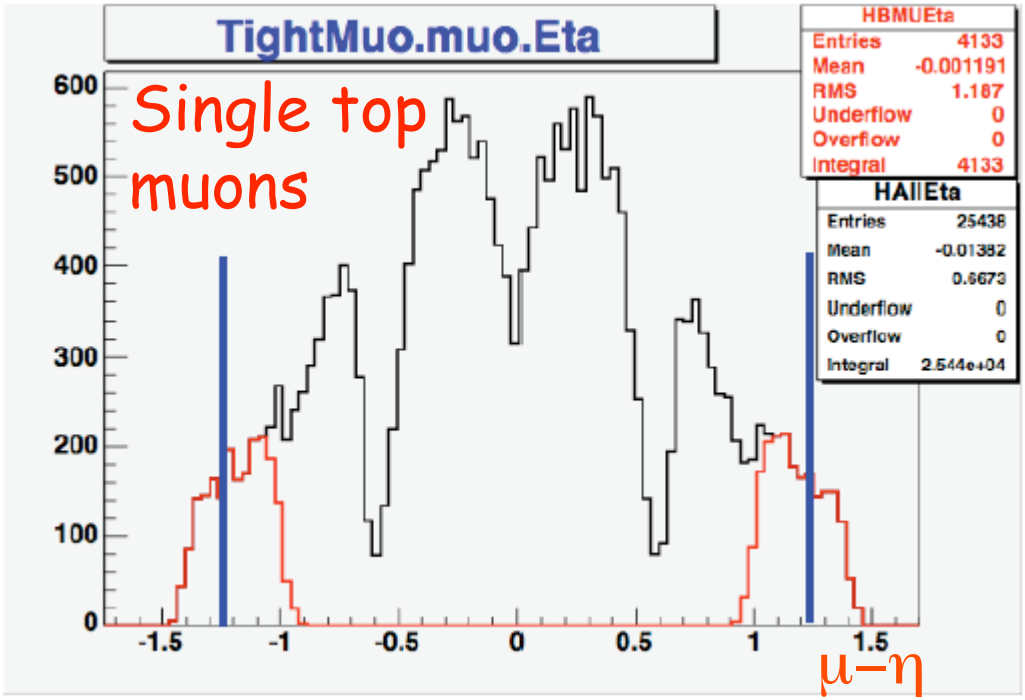
SLIM5 SuperB? (F. Forti, M. Giorgi et al.)

The trigger harmonizes the experiment

→ exclusive selections

SVT

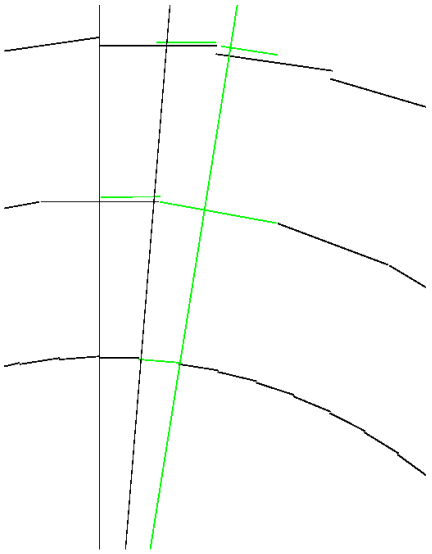
The power of a detector can cover the weakness of another



1. Weak μ coverage? → use only tracking & calorimeter to release muon identification

2. Trigger power: no need for trigger dedicated detectors. The trigger MUST not constrain the detector design!

An alternative CMS L1 track trigger
Double layers
more material
to simplify the
the trigger.
Is this a good
idea?



Same blocks --> different applications

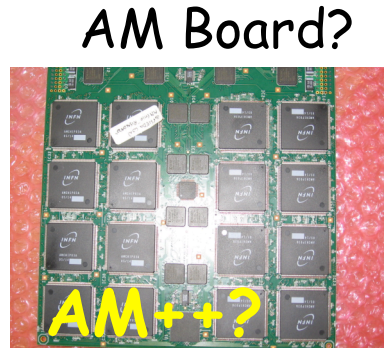
SVT

SVT for Calo?

MEG proven SVT Track Fitter algorithm could do offline gamma reconstruction with 800 phototubes.

Can we use "STARS" for offline-quality calorimeter reconstruction?

Same structure
Similar Hardware
To be studied...
@ LVL1 ?!?



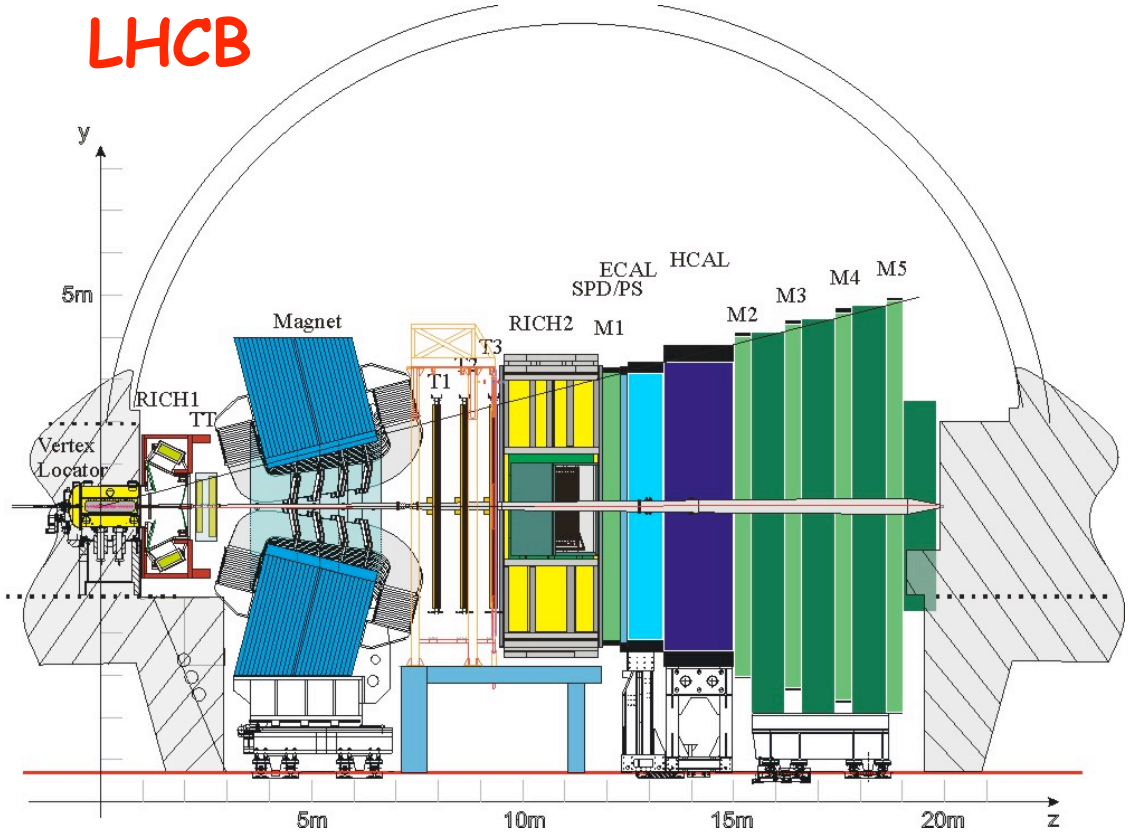
Same blocks --> different applications

SVT

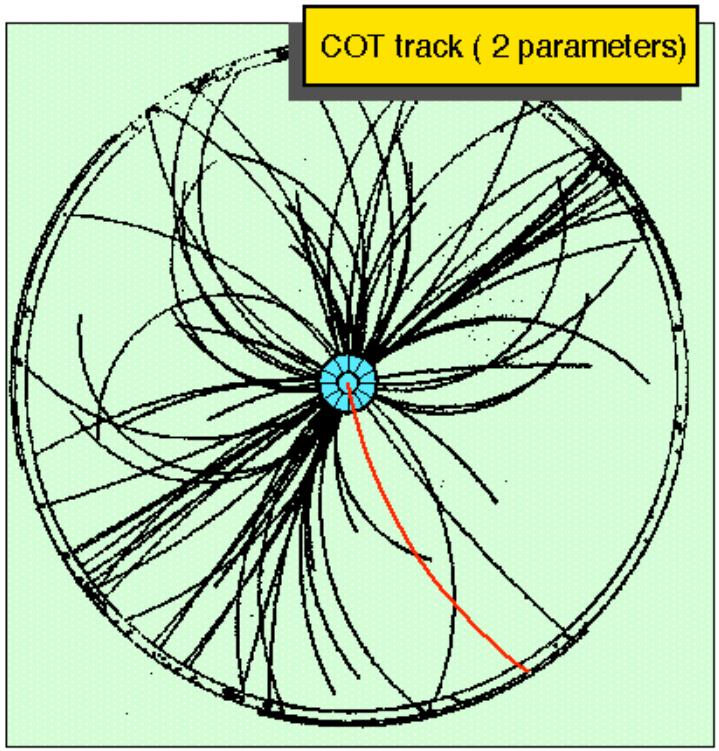
AM: massive parallelism in data correlation searches coincidence/anticoincidence of up to 12 measurements!

For example: Muon:
T1&T2&T3&not(Ecal)&not(Hcal)&M1&M2&M3&M4&M5

LHCB



CDF



Cosa vogliamo fare con i fondi Ideas??

Creare un gruppo di esperti (ampio campo di conoscenze per algoritmi, trigger, fisica, diverse tecnologie e loro interconnessioni: FPGA, standard cell, CPUs, links) che possa in parte realizzare (CDF-FTK) in parte favorire la crescita delle idee esposte con:

1. massa critica sufficiente
2. finestra temporale sufficientemente ampia

Cosa vogliamo fare con i fondi Ideas??

1. Complete CDF: Hardware/Trigger studies/Analysis
2. FTK @ ATLAS (ongoing upgrade proposal Pisa/Chicago +….): Physics case/Hardware/Analysis (to be approved)
3. New AM chip for level1 – level2

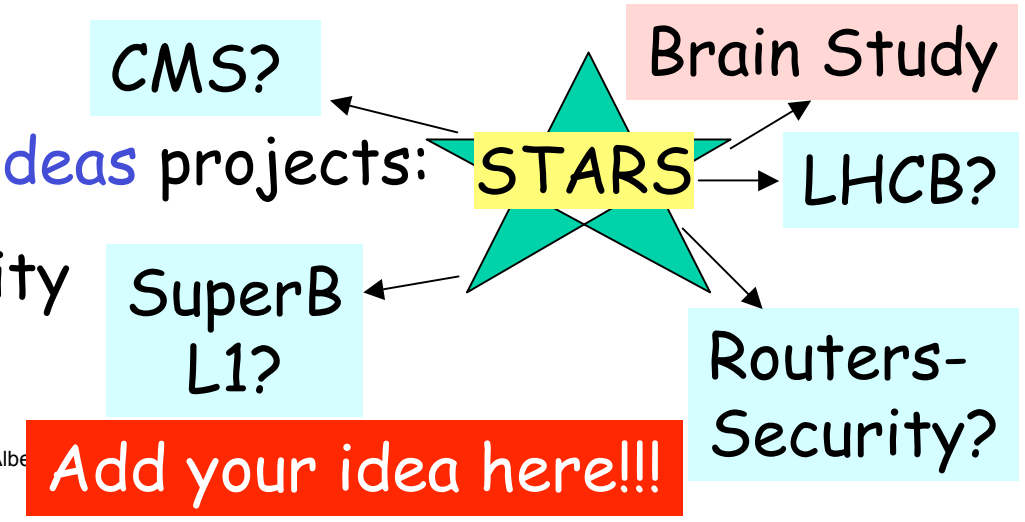
Favor other project development for upgrades & other

CMS – SuperB ….. sharing:

1. Hardware (in particular new AM chip)
2. software tools (simulation/diagnostic-control-config.)
3. Trigger ideas

STARS could generate new Ideas projects:

Brain study – Routers – security (Cooperation)



CHI SIAMO e Richieste VII FP

1. FRASCATI: A. Annovi (art. 36-PI, SVT upgrade ex-project leader), S. Torre (Ass. Ric., SVT operations manager)
2. PISA: P. Giannetti (Dir. Ric.), M. Dell'Orso (Prof. Ass.), L. Sartori (M. Curie OIF, AM chip designer, L2 cal. upgrade technical coordinator)
3. FERRARA: storica collab. Ape-CDF per AM standard cell. F.Schifano (RU), R. Tripiccione (Prof. Ord.) – Invitato a partecipare il gruppo Babar – speriamo che accetti

IDEAS tot 400 keuro/year (5 years):

1. **Man Power for** 5 year: Frascati PI + 2 art. 23 – Pisa 1+1/2 art. 23 – Ferrara 1+1/2 art. 23 = 56 + 44 * 5 = 275 + 55 (20% over.) = **330 keuro**
2. **70 keuro/year** AM chip subcontractors. Prototype using MPW with very challenging technology (~350 keuro tot)
3. Missioni/conferenze/… = 0 euro