

# Panda Pavia 2008/09



<b>Ricercatori:</b>		<b>%2009</b>
Bendiscoli	PO	60
Rotondi	PO	60
Radici	1RIC	20
Boca	RU	30
Braghieri	RIC	50
Fontana	RIC	40
Montagna	RU	70
Salvini	RIC	20
Genova	ass.ric.	20
Lavezzi		0
Costanza	DOTT	100
Panzarasa docente		(50)
<b>Tot 2009</b>		<b>4.7 FTE (5.2)</b>

## Assegnazioni 2008:

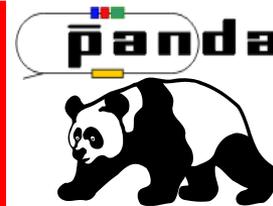
Miss.interne 6 k€      Miss.estere 17.5 k€  
Consumo 3 k€          Inventariabile 3 k€



## Situazione e aggiornamenti su:

- FAIR
- PANDA Collaborazione
- PANDA Italia
- PANDA Pavia:
  - **SW**
    - simulazioni STT
    - track fitting STT/MVD
    - pattern recognition STT
  - **HW**
    - test STT
    - studi HPGe in campo magn.

# Tracking TDR - 2009→10



## Tracciatore: opzione STT

- Primi studi e prototipo:  
Frascati (+Pavia)
- Nuova geometria  
(e realizzazione?):  
Julich
- Supporto meccanico:  
Frascati
- Simulazioni e test  $dE/dx$ :  
Pavia
- Ancora competizione  
con TPC...
- Technical Design Report  
per tutto il sistema di  
tracciamento

## PANDA Tracking Group Tracking Technical Design Report Table of Contents

Chapter 1: Overview of the project and the requirements

Chapter 2: The Micro Vertex Detector

Chapter 3: The Straw Tube Tracker

3.1 General overview (Editor(s): P. Gianotti)

3.2 Straw tube design

3.2.1 Straw materials (Editor(s): P. Wintz)

3.2.2 Pressurized straws (Editor(s): P. Wintz)

3.2.3 Gas mixture (Editor(s): P. Wintz)

3.3 The layout of the whole detector (Editor(s): P. Gianotti)

3.4 Mechanics and detector installation (Editor(s): P. Gianotti)

3.5 Gas system (Editor(s): P. Wintz)

3.6 Readout electronics (Editor(s): P. Salabura)

3.7 Calibration and Monitoring (Editor(s): A. Rotondi/P.  
Wintz)

3.8 Simulations (Editor(s): A. Rotondi)

3.9 Prototype tests (Editor(s): P. Wintz)

3.10 Organization (Editor(s): P. Gianotti/J. Ritman)

Chapter 4: The Time Projection Chamber

Chapter 5: The CT-Forward GEM Detectors

Chapter 6: The Forward Tracker





# Software: contributo Pavia

## STT: codice di simulazione e ricostruzione

- Simulazione singolo straw tube  
(Rotondi)
- Pattern Recognition  
(Boca)
- GEANE track follower e Kalman filter  
(Rotondi, Fontana, Genova, Lavezzi, Costanza)

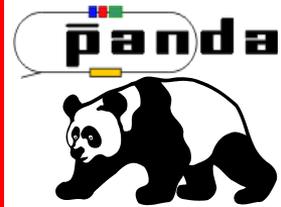
STT locale completato (2008) e superato in quanto inserito nel codice globale

## STT+MVD: codice globale (GENFIT), test su STT

A Kalman filter has been developed in collaboration with the GSI and Munich groups: **genfit**, GENeric FITter, GEANE based.

- Studi di efficienza, risoluzione, valutazione parametri  
(Costanza, Lavezzi)

# STT+MVD: Kalman filter



PANDA Report PV/01-09

## Study of the Kalman filter performances with STT+MVD

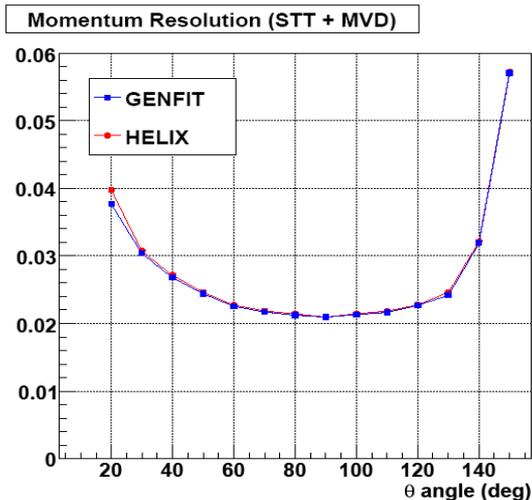
S. Costanza and L. Lavezzi

A brief description of the code and the mathematics used in order to perform the fit procedure is described. A list of the results obtained so far from the application of this fitting procedure to the Straw Tube Tracker (STT) + Micro Vertex Detector (MVD) simulated points follows.

### Contents

- 1 The Helix Fit
- 2 The Kalman Filter
- 3 The simulation environment
- 4 Results
  - 4.1 Kalman procedure testing
  - 4.2 Systematic tests on momentum resolution
    - 4.2.1 Dependence on the straw tubes length
    - 4.2.2 Dependence on the skew angle
    - 4.2.3 Dependence on the drift tube resolution curves

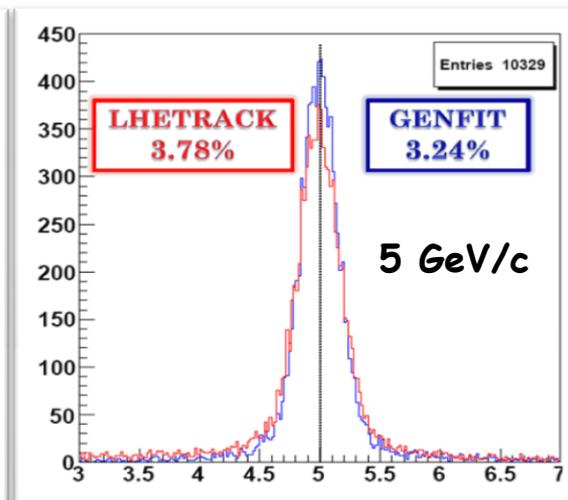
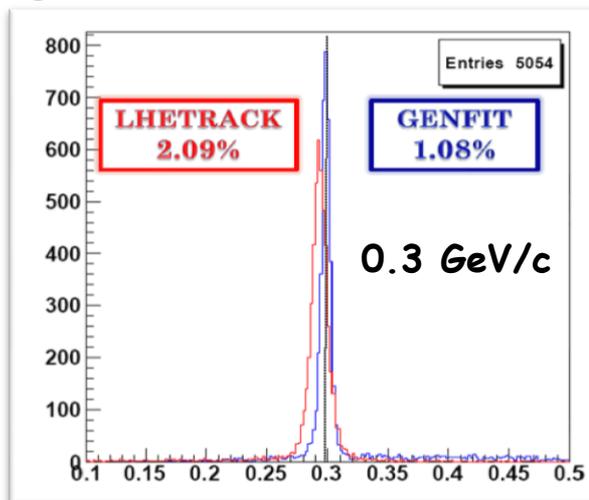
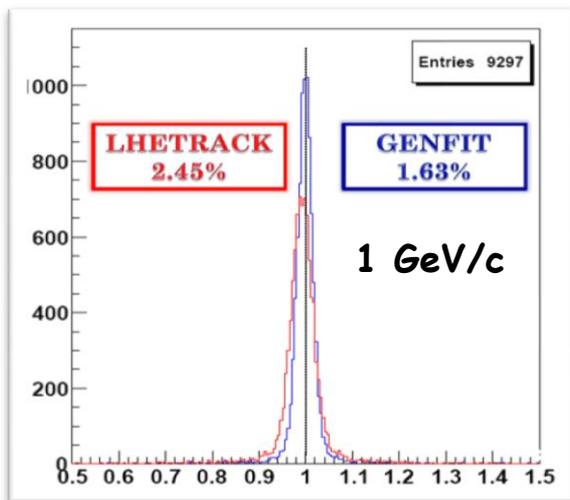
# STT+MVD: Kalman filter



Tests performed in december 2008 showed no improvement with respect to by Kalman filter application to STT + MVD with respect to helix fit  
By changing:

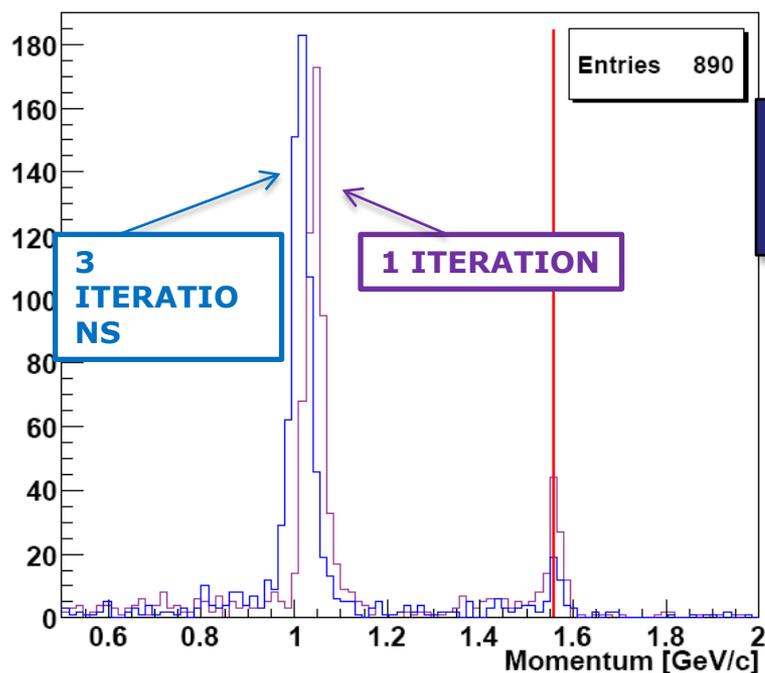
- starting pos/mom errors;
- MVD and STT measured point coord. covariances
- Kalman filter planes orientation

we get these results:



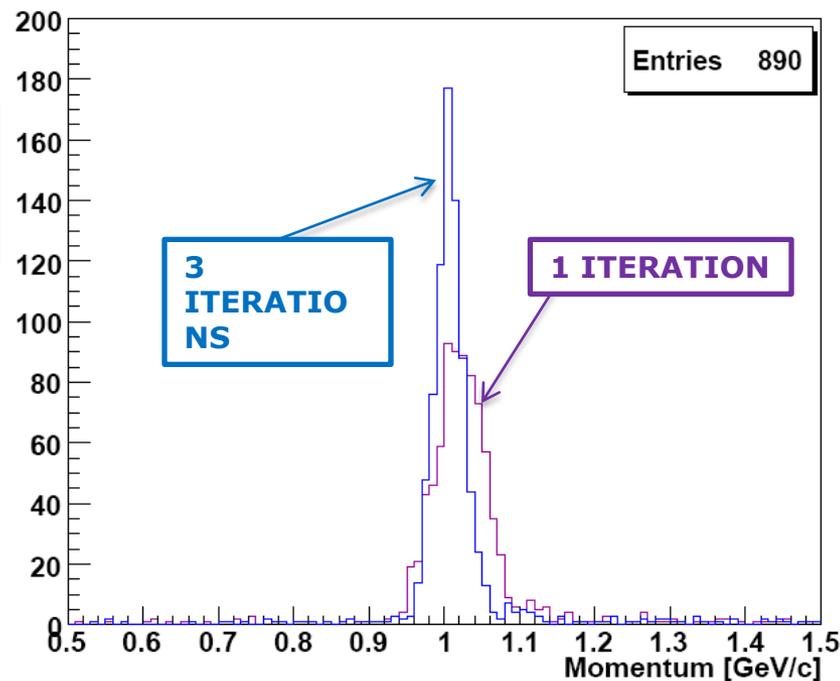
# STT+MVD: Kalman filter

Even starting from a REALLY WRONG starting momentum, the Kalman procedure (after 1 and more after 3 iterations) finds the right one!



Kalman input 1:

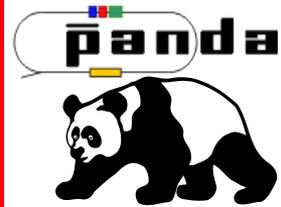
$(-0.9, -0.9, -0.9)$  GeV/c



Kalman input 2:

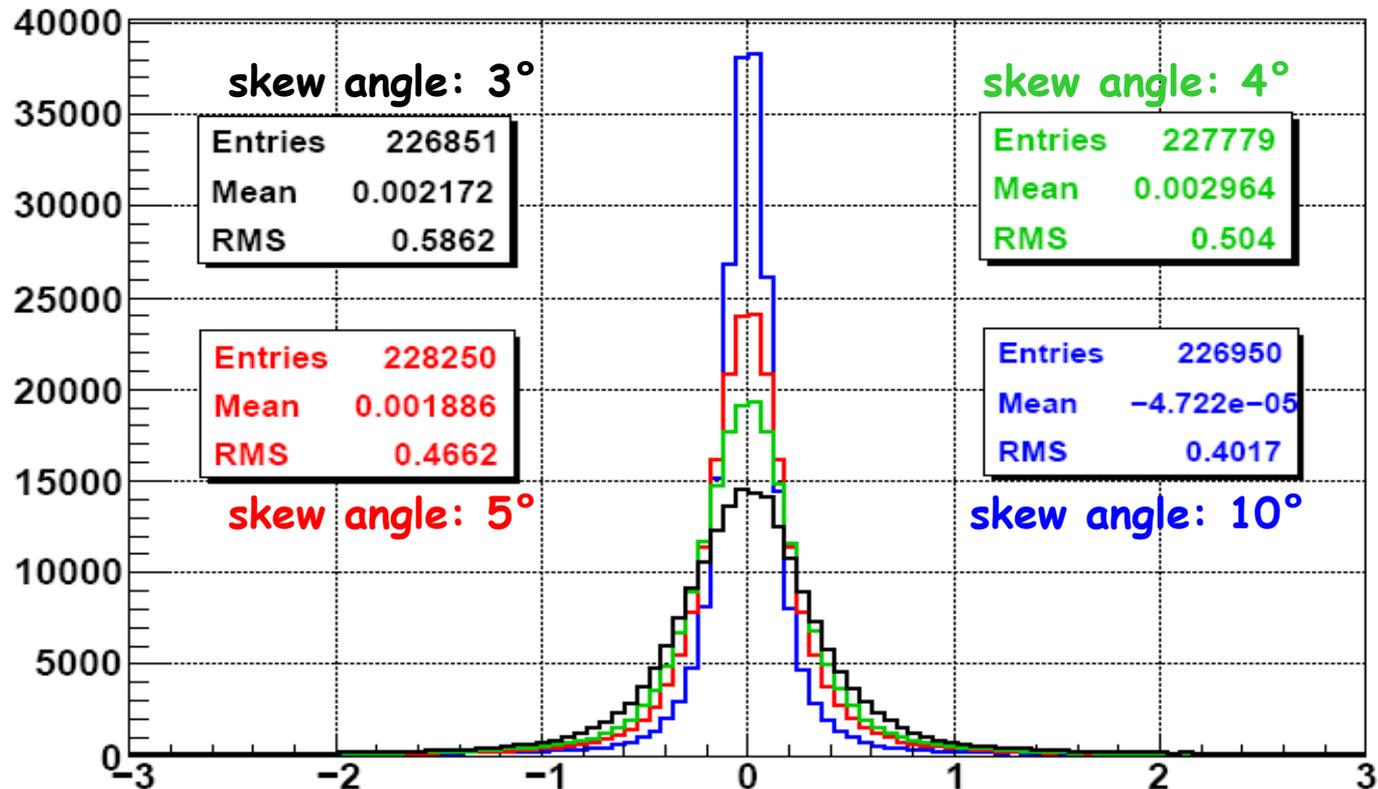
MCmom +  $(0.4, 0.4, 0.4)$  GeV/c

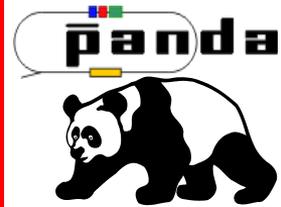
# STT test: skew angle



10000  $\mu^-$ ,  $\pi^-$  @ 1 GeV/c,  
generati uniformemente in  $\phi$  ( $\phi = [0^\circ, 360^\circ]$ ) e  $\cos\theta$  ( $\theta = [20^\circ, 140^\circ]$ )  
Geometry layout: skew angle =  $3^\circ$ ,  $4^\circ$ ,  $5^\circ$ ,  $10^\circ$

Residui della  
coordinata z





# STT test: lunghezza dei tubi

10000  $\mu^-$  @ 1 GeV/c

$$\theta = \{20^\circ, 25^\circ, 30^\circ, 35^\circ, 40^\circ\} \pm 2.5^\circ$$
$$= \{50^\circ, 80^\circ, 110^\circ, 140^\circ\} \pm 5^\circ$$

Risoluzione in momento ( $\sigma(p)/p$ )

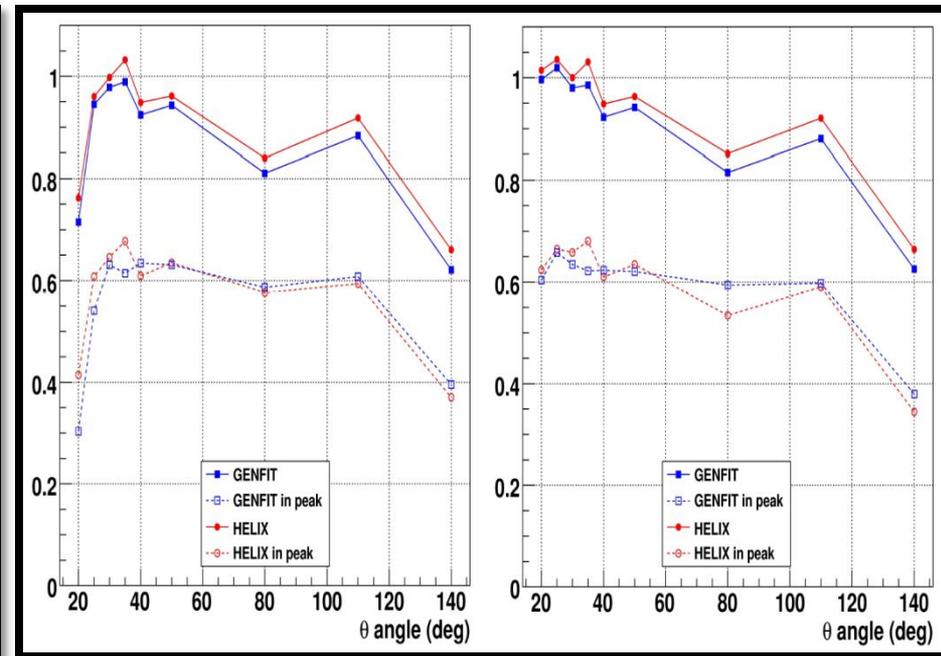
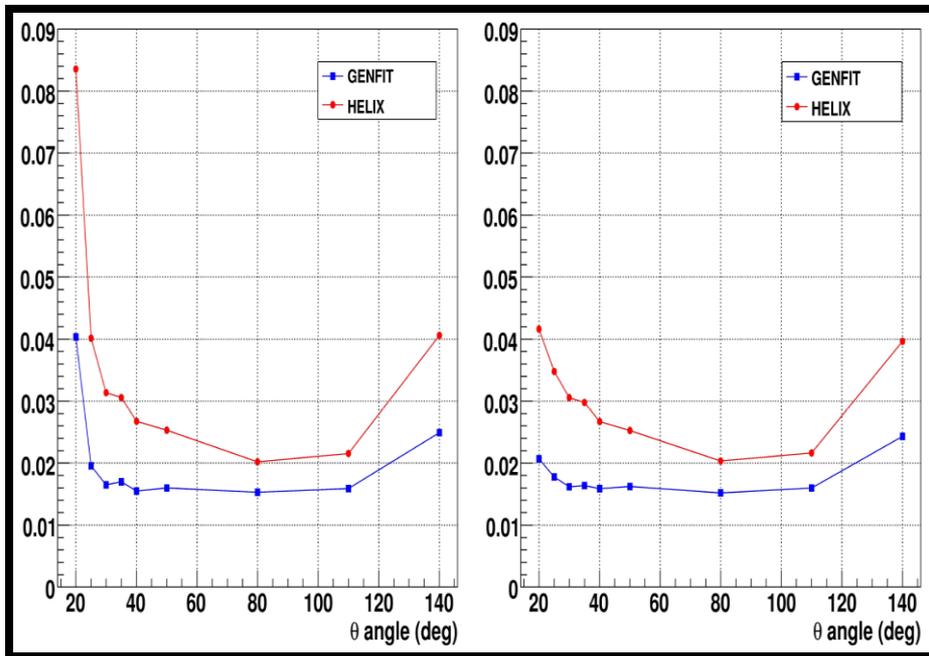
Efficienza

120 cm

150 cm

120 cm

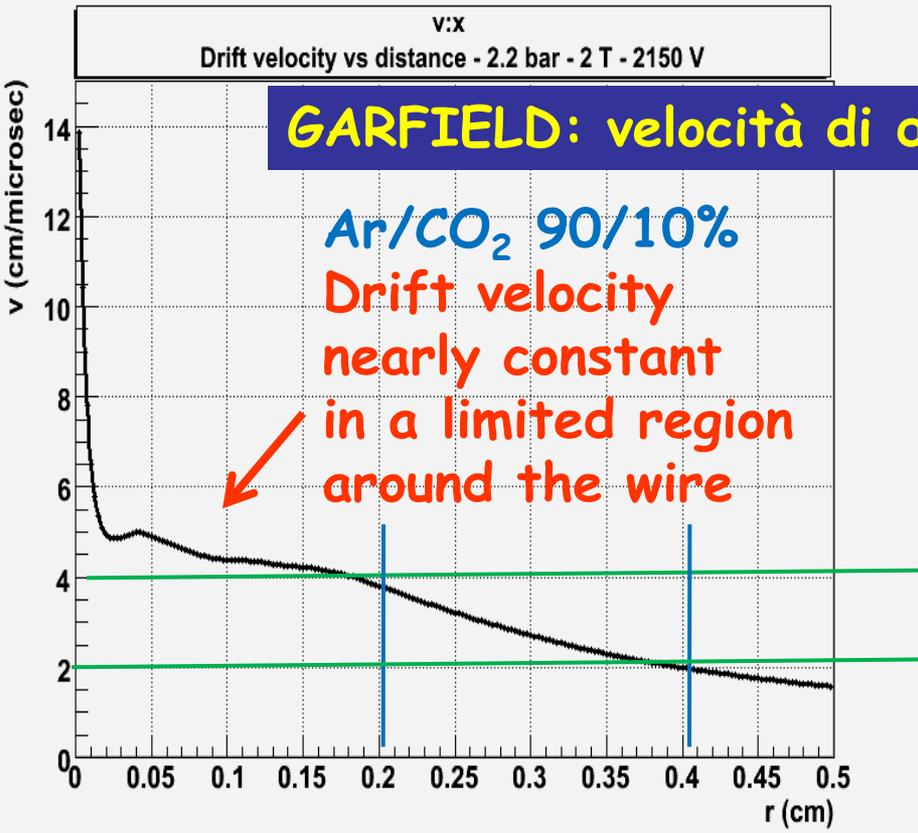
150 cm



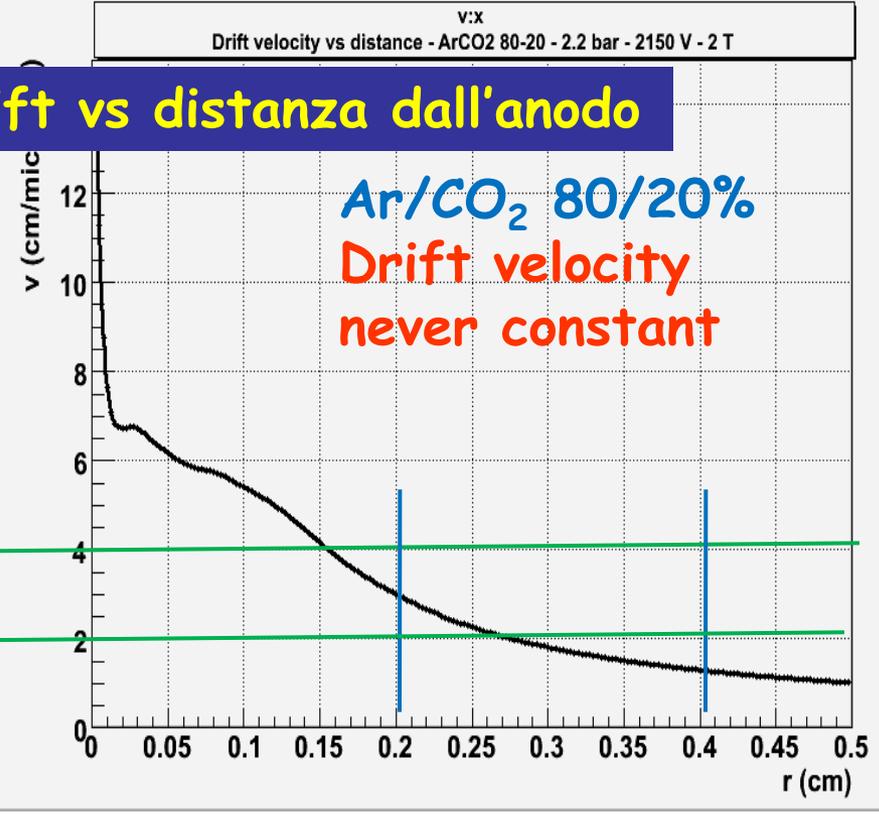
# STT test: miscela di gas

## GARFIELD: velocità di drift vs distanza dall'anodo

Ar/CO<sub>2</sub> 90/10%  
 Drift velocity  
 nearly constant  
 in a limited region  
 around the wire



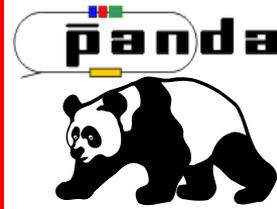
Ar/CO<sub>2</sub> 80/20%  
 Drift velocity  
 never constant



Both cases:

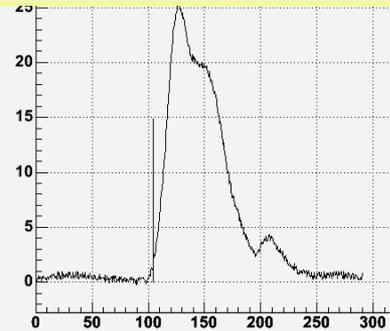
$p = 2.2 \text{ bar}$      $\Delta V = 2150 \text{ V}$      $B = 2 \text{ T}$   
 tube diameter = 1 cm    anode diameter = 20  $\mu\text{m}$

# Simulazione singolo straw tube: curva di risoluzione spaziale

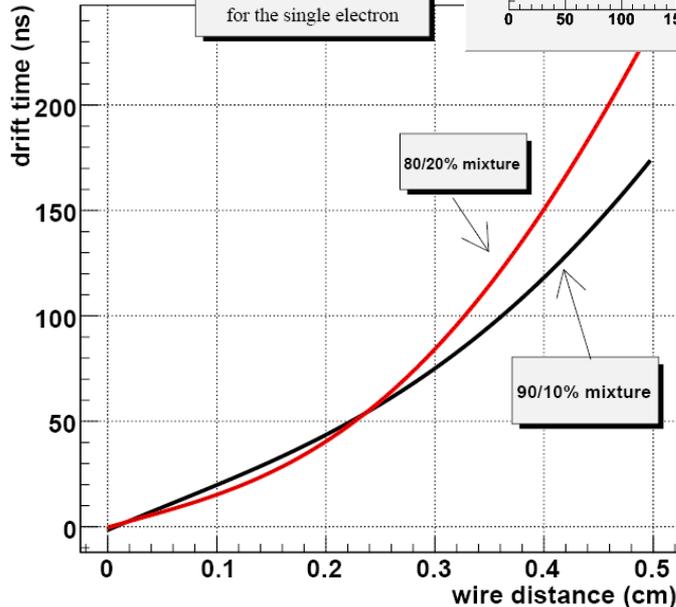


Drift faster in  
Ar/CO<sub>2</sub> 90/10%  
mixture

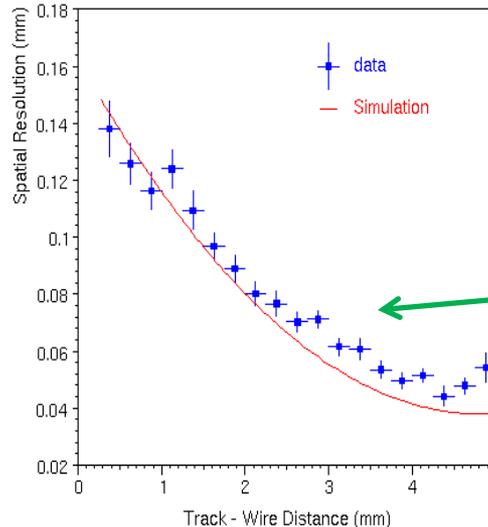
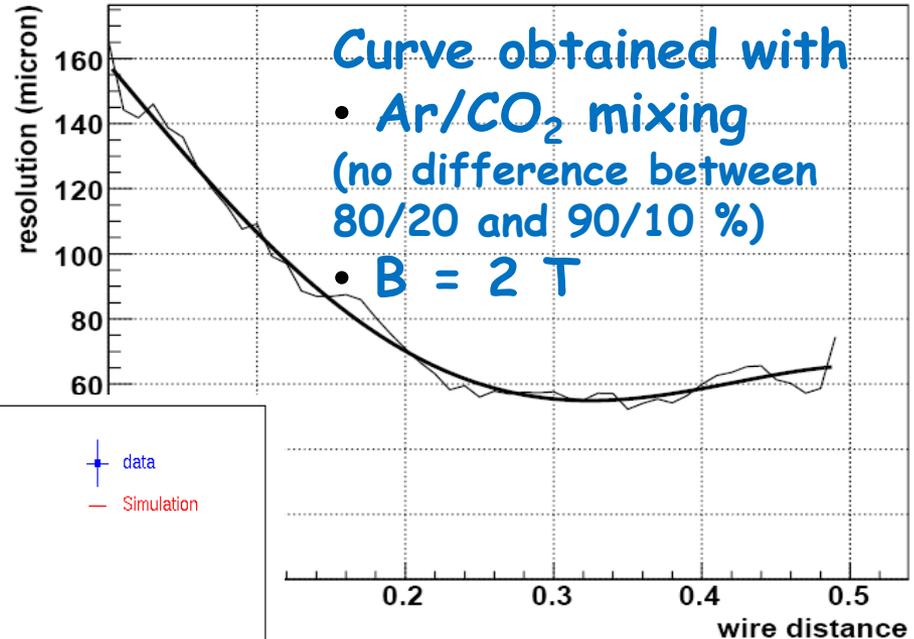
Signal in time (ns)



x-t curves from GARFIELD  
for the single electron

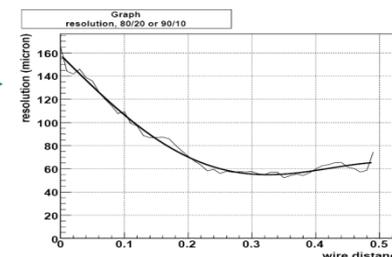


Graph  
resolution, 80/20 or 90/10

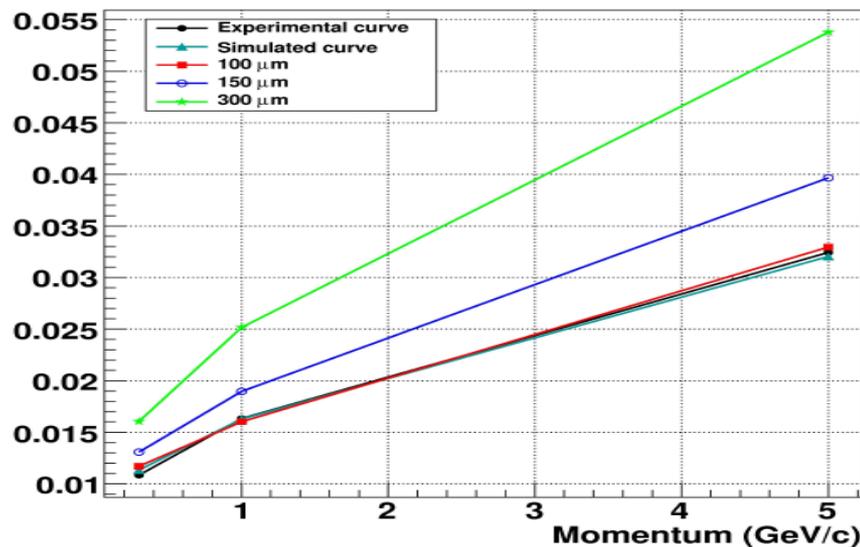


# STT+MVD test: dipendenza dalla curva di risoluzione spaziale

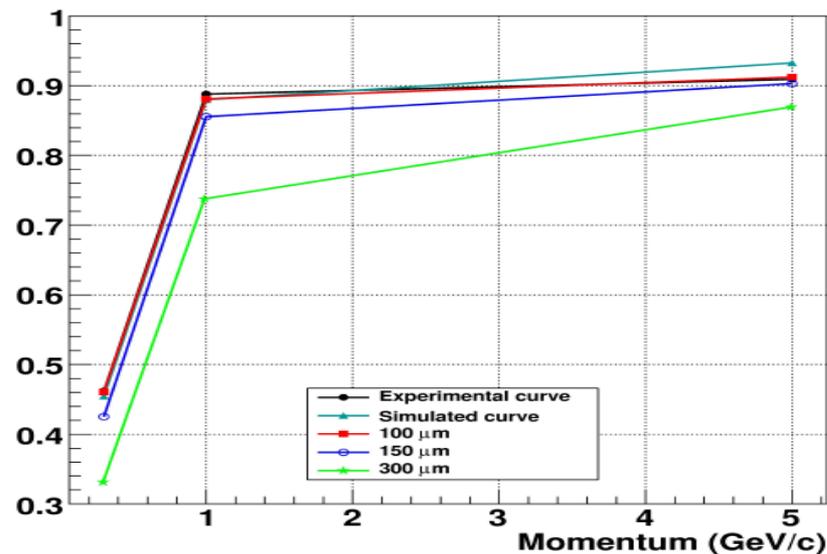
- Curva sperimentale di Juelich, senza campo magnetico
- Curva simulata con GARFIELD, con campo magnetico
- Curva a risoluzione costante a 100  $\mu\text{m}$
- Curva a risoluzione costante a 150  $\mu\text{m}$
- Curva a risoluzione costante a 300  $\mu\text{m}$



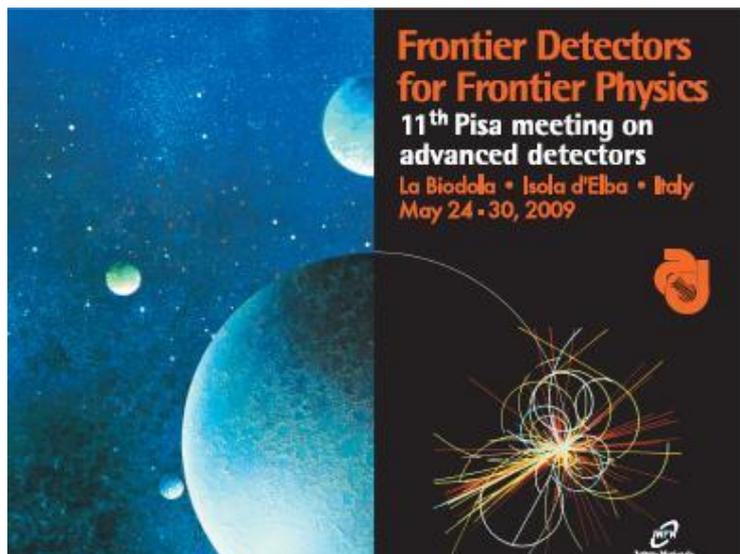
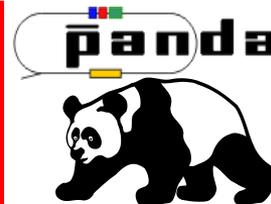
## Risoluzione in momento



## Efficienza



# STT in sintesi



**Frontier Detectors for Frontier Physics**  
**11<sup>th</sup> Pisa meeting on advanced detectors**  
 La Biodola • Isola d'Elba • Italy  
 May 24 - 30, 2009

**S. Costanza,**  
**The Straw Tube Tracker**  
**of the PANDA experiment,**  
 Poster a  
**11° Pisa Meeting on advanced detectors**  
**Elba-LaBiodola, maggio 2009**

### The Straw Tube Tracker of the PANDA experiment

L. Basso<sup>1</sup>, A. Baghetti<sup>1</sup>, G. Boca<sup>1</sup>, S. Costanza<sup>1</sup>, P. Gronzoni<sup>1</sup>, P. Gianotti<sup>1</sup>, L. Lavezzi<sup>1</sup>, V. Luchetti<sup>1</sup>, P. Montagna<sup>1</sup>, D. Orsini<sup>1</sup>, D. Pieraggi<sup>1</sup>, J. Rinnert<sup>1</sup>, M. Rostner<sup>1</sup>, A. Rotondi<sup>1</sup>, A. Russer<sup>1</sup>, P. Wüster<sup>1</sup>  
<sup>1</sup> INFN Laboratori Nazionali di Frascati, Via E. Fermi 40 - 00044 Frascati, (Italy)  
<sup>2</sup> Dept. Nucl. Theor. Phys., Pavia University, Via Bassi 6 - 27100 Pavia (Italy)  
<sup>3</sup> INFN Pavia, Via Bassi, 6 - 27100 Pavia (Italy)  
<sup>4</sup> BIP Forschungszentrum Jülich, D-51742 Jülich (Germany)

**THE PANDA EXPERIMENT**  
 PANDA is one of the major projects of the FAIR facility at Darmstadt, which is an extension of the existing Heavy Ion Research Lab (GSI), expected to start its operation in 2018.  
 The universal PANDA detector will be built in order to study fundamental questions of hadron and nuclear physics in interactions of antiprotons with fixed target protons and nuclei, using the High Energy Storage Ring.

**THE STRAW TUBE TRACKER OF PANDA**  
 The Straw Tube Tracker (STT) is one of the possible options for tracking the charged particles inside the target spectrometer. Its goal is to provide precise measurements of the track coordinates and to reach a momentum resolution on the percent level.

**STT DESIGN**  
 The proposed arrangement will have:  
 - 4 double layers parallel to the detector axis,  
 - 4 skewed double-layers with an angle of  $\pm 3^\circ$  with respect to the beam axis,  
 - further 4 straight double-layers,  
 - incomplete double-layers in the outer region, for a total number of 420 straw tubes.

**STT MECHANICS**  
 In order to support the straw tube double-layers, an support structure has been designed. In order to reduce the weight of the support structure, the tubes are close-packed and the wires are stretched by 50 g @ 4p - 1 bar at this gas overpressure the double-layers become self-supporting.

**SINGLE STRAW SIMULATION**  
 A detailed simulation of the charge generation and collection in a single straw tube includes ionization statistics, electron diffusion, gas gain and noise and discriminator threshold.  
 - The position and number of electron clusters is sampled from the exponential distribution.  
 - The number of electrons belonging to a cluster is taken from both experimental and theoretical papers.  
 - Their position is dispersed according to the GARFIELD diffusion curves.  
 - The arrival time of each electron on the wire is derived from a Poisa distribution having as mean value the gain given by GARFIELD.

**SIMULATIONS**  
 All the simulations have been performed inside the PandaROOT framework, by running the complete chain simulation: digitization-reconstruction and by using the packages devoted to the global tracking.  
**Simulation**  
 The simulations are run using more than one subdetector with the addition of the passive elements.  
**Digitization**  
 - Ideal: geometrical distance of closest approach to the wire - Geant energy loss  
 - Real full: full simulation (ionization clusters, diffusion process, drift time, gain, signal formation)  
 - Real fast: sampling from simulated or experimental resolution to track-sect distance  
**Reconstruction**  
 The fitting algorithm has been developed using the helix model and serves as a prefit of the track. It's performed in two planes separately:  
 -y plane, perpendicular to the magnetic field direction, with a circle fit;  
 -x-z track length plane, with a straight line fit.

**AGING TESTS**  
 The straw setup consisted of a double-layer of 32 tubes, installed behind the COSY-TOF apparatus and exposed to the residual proton beam with a momentum of 3 GeV/c. Each tube was made of 30 µm thick mylar film tubes with 30 mm diameter and had a length of 505 cm. The gas supply was divided into 4 individual circuits with one circuit for every 8 straws, in order to test different gas mixtures (Ar based, with different fractions of CO<sub>2</sub>). The gas pressure was 150 mbar for all mixtures.

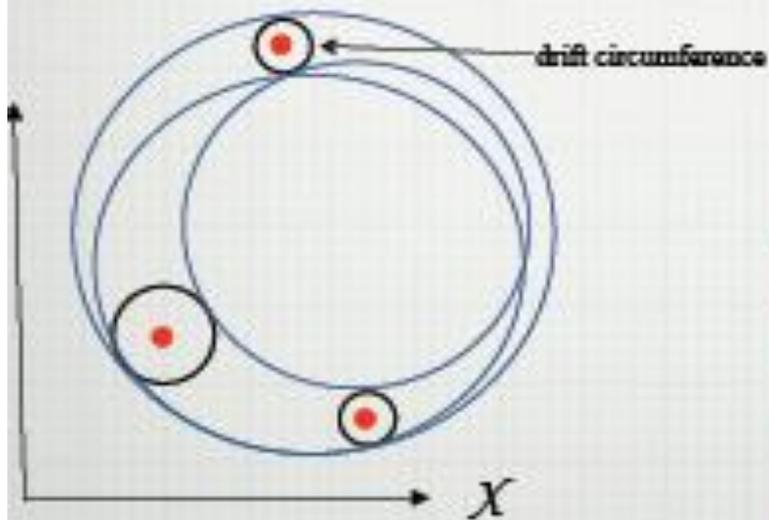
**EXPERIMENTAL RESULTS**  
 Signal of 3 wires in proton beam, signal rates of a few µA sec<sup>-1</sup>  
 Single straw signals (cosmic) and corresponding discriminator output  
 The total charge is obtained by summing the signal over the number of e<sup>-</sup>.  
 - When considering the arrival time of each electron and assigning a gaussian-shaped electrical response to each charge multiplication, the shape of the electrical signal can be reproduced too. The time is given by the threshold on the impulse.  
 - The cumulative of the simulated time histogram gives the response curve  $r(t)$  of the tube.  

$$\int_0^t dt' \int_0^{t-t'} dt'' \int_0^{t-t-t''} dt''' \dots \int_0^{t-t-t-t''-t'''} dt^{(n)} \dots$$
  
 This allows to obtain the resolution curve  
 Experimental: without magnetic field  
 Simulated: with magnetic field  
 Kalman fit  
 The Kalman filter is applied to improve the momentum resolution. The procedure can be iterated several times until it converges.  
 Experimental resolution curve without magnetic field  
 Momentum distributions for 10000 fit reconstructed with MVD & STT  
 Simulated resolution curve with magnetic field

# STT - Pattern Recognition



## Pattern Recognition for STT Based on Hough transformation of Helix trajectory G. Boca, giugno 2009



### Parametrization of the Helix trajectory

$$x - x_0 = R \cos(Kz + \varphi_0)$$

$$y - y_0 = R \sin(Kz + \varphi_0)$$

$$\varphi = Kz + \varphi_0$$

### 5 parameters :

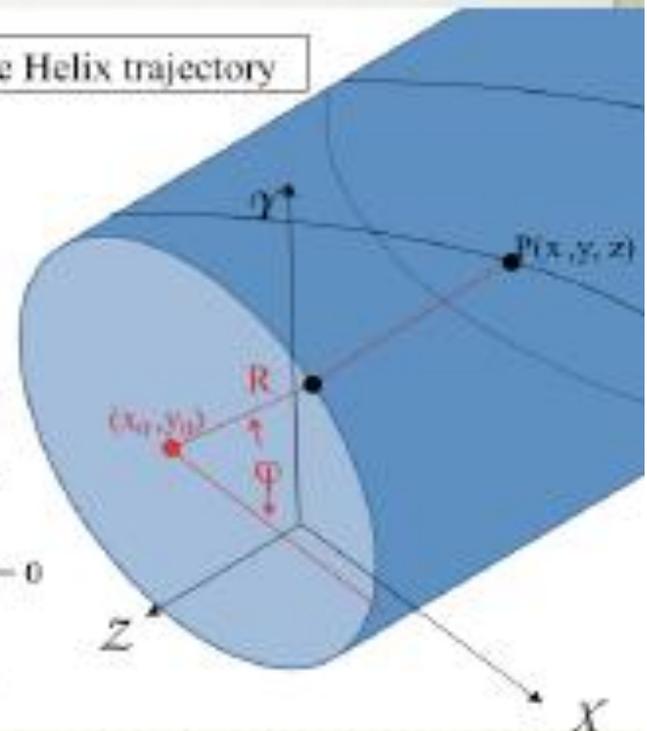
$x_0$  = abscissa of center of cylinder

$y_0$  = ordinate of center of cylinder

$\varphi_0$  = azimuthal angle at  $z = 0$

$R$  = radius of cylinder

$K$  = rate of increase of  $\varphi$



Gianluigi Boca

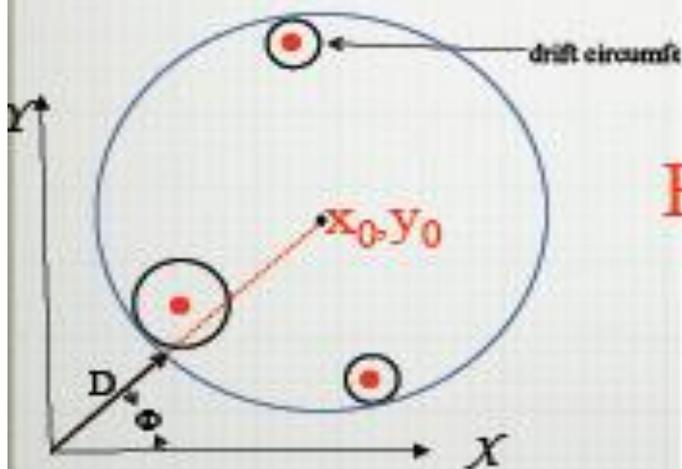
# STT - Pattern Recognition



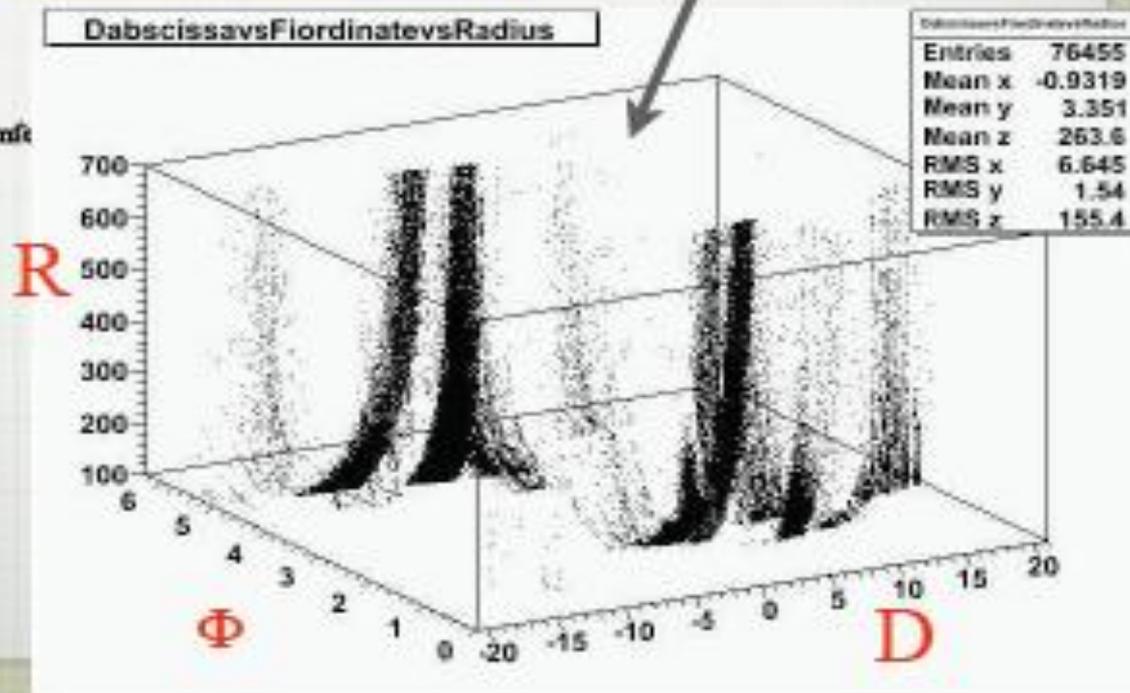
• Good news: speed of code OK (0.1-0.2 secs/event)

• Bad news: efficiency moderate (44-90%); problems to overcome for hit finding for skew straws

peak finding !!!



Gianluigi Boca



# STT R&D: Test su prototipo

Risposta STT in regime proporzionale  
Test con cosmici

Coincidenza tra due slabs di scintillatori  
plastici (45 x 7 x 0.5 cm) a distanza 10 cm

Rate basso: 1000 cosmici/ora  
2% su singolo straw tube

**Prototipo STT (by LNF):**

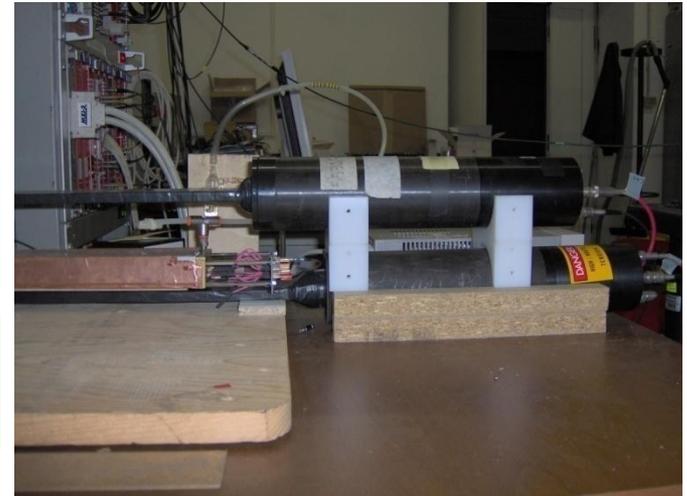
12 tubi da 70 cm,  $\varnothing$  6 mm  
di kapton XC e alluminio (tot. 100  $\mu$ m)  
(prod. LAMINA, metodo LHCB)

3 strati incollati

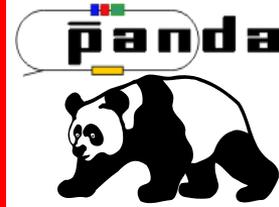
Anodo: tungsteno-rhenio dorato,  $\varnothing$  20  $\mu$ m)

Gas: 93% Ar, 7% CO<sub>2</sub>

d.d.p. 1300 Volt



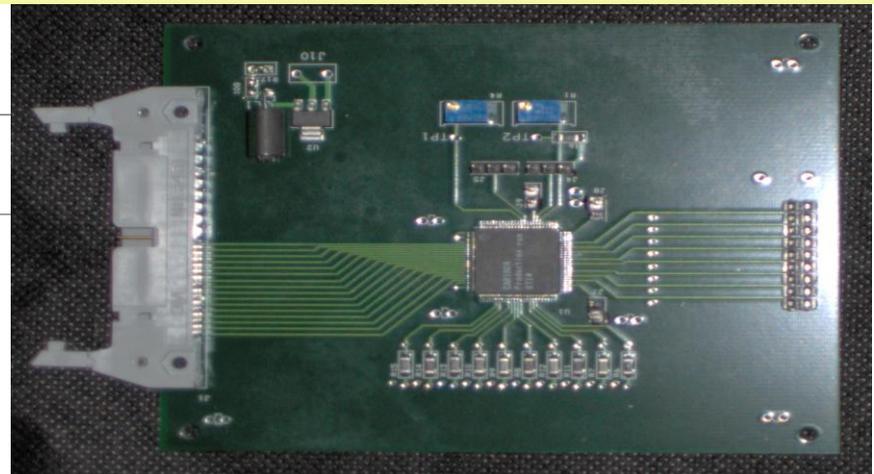
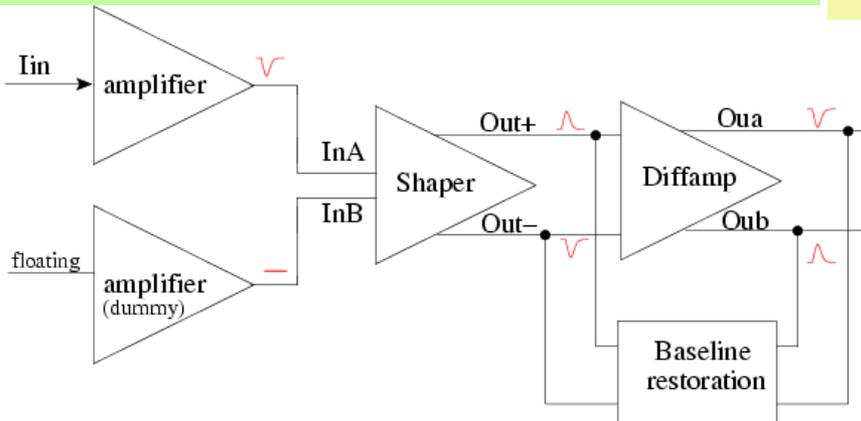
# STT R&D: Sviluppo elettronica



- **Utilizzo di chips CMOS multicanale:**  
**Charge Preampl+filter+shaper**
- **Prime esperienze con "antiquato" chip GASSIPLEX 16**
- **Progettazione e realizzazione di una scheda basata su chip CARIOCA10 (++) Supporto & ++ Performances):**  
**scheda di test ServEI PV**

Attività di laboratorio: test di misura dell'ampiezza della carica rilasciata negli straw tubes, per l'identificazione di particelle cariche mediante  $dE/dx$ .

E' stata messa a punto e testata una scheda di Front End (FE) basata sul chip Gassiplex a tecnologia CMOS. Le prime misure hanno dato esito positivo, tuttavia si è ritenuto di cambiare tipo di chip in quanto il gassiplex non verrà supportato e prodotto a lungo ed inoltre è richiesta una seconda scheda FE per la misura del Drift Time (TDC). Dunque si è deciso di utilizzare un chip differente denominato CARIOCA che permette di misurare sia il drift time (mediante un TDC) sia l'ampiezza di carica mediante la tecnica del Time-Over-Threshold (TOT).



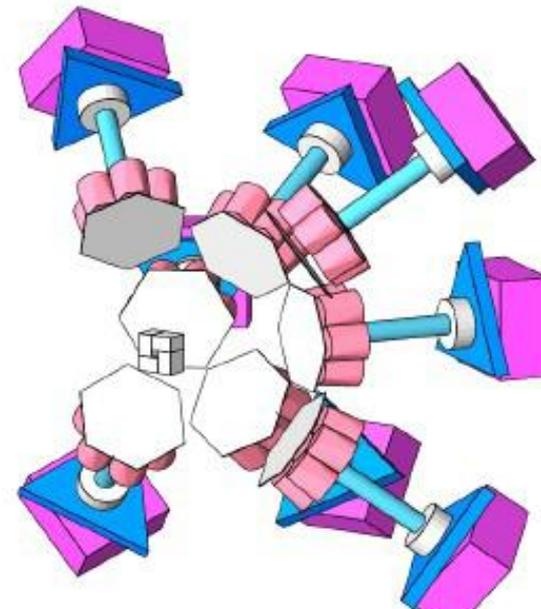
# HPGe: obiettivo



## Studio delle performances di un cristallo di Germanio ad alta purezza (HPGe) in campi magnetici elevati

Obiettivo: caratterizzazione di un cristallo di Germanio HPGe in campo magnetico di elevata intensità (fino a 2.5 T) con campo diretto lungo l'asse del cristallo.

Studio preliminare alla costruzione del rivelatore per spettroscopia gamma di ipernuclei di Panda.



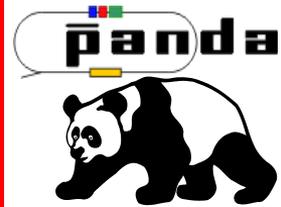
**PRIN 2005: Pavia, Torino, Bologna, Catania**

**Misure effettuate ai LNS, nov.2007**

**Risultati presentati da A.Fontana a ANIMMA 2009, Marsiglia, mag.09**

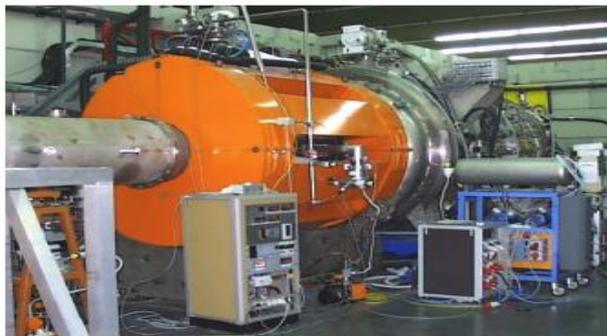
*Advancements in Nuclear Instrumentation, Measurement Methods and their Applications*

# HPGe: experimental setup



## Experimental setup @ INFN LNS Laboratory

**Germanium detector:** GX10P4-S-PLUS coaxial crystal manufactured by ORTEC.  
High-purity, **n-type**, non-segmented, germanium cylindrical crystal (external diameter: 42 mm, length: 57 mm).  
Nominal **energy resolution:** 1.8 keV at 1332.50 keV (for the  $\gamma$ -ray of the  $^{60}\text{Co}$ )  
Nominal **efficiency:** > 10% is guaranteed.  
**Cooling** of the crystal: ORTEC electric cooler CFG-X-Cool-II-230, placed outside the magnet.



**Magnetic field:** superconducting SOLE magnet located at the Laboratori Nazionali del Sud (LNS) of the National Institute of Nuclear Physics (INFN).

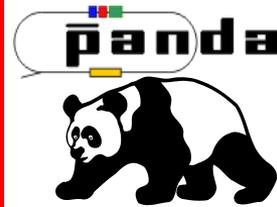
**Maximum value of the magnetic field:** 2.5 T

**Uniformity:** within 0.95% up to 15 cm from the coil axis.

Total free volume allows to place the HPGe detector with its symmetry axis along the field direction and to tilt the crystal up to a **maximum angle of 40°** with respect to the magnet axis.

HPGe detectors in high magnetic fields – Conference ANIMMA 2009 – presented by Andrea Fontana, INFN Pavia

# HPGe: effetti del campo magnetico sugli spettri gamma



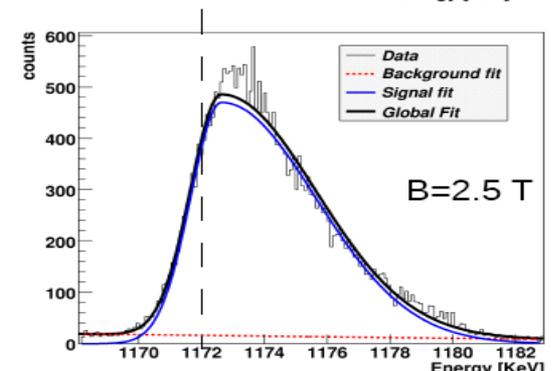
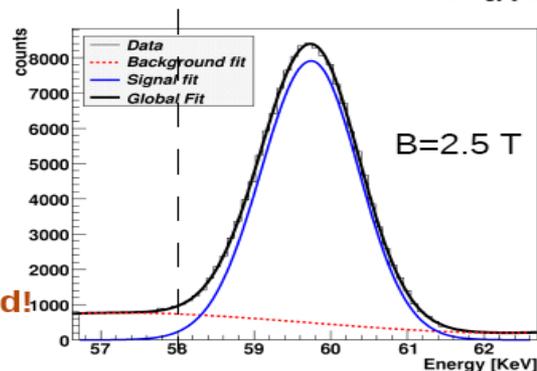
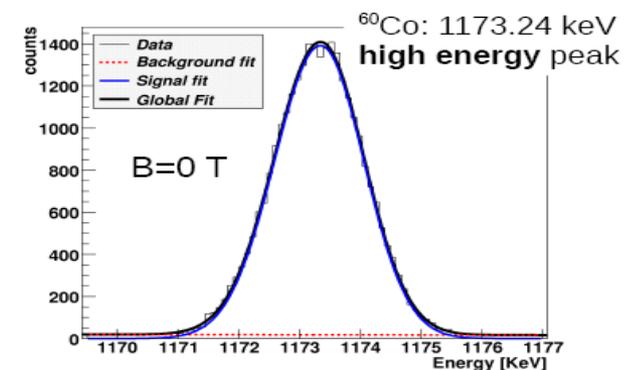
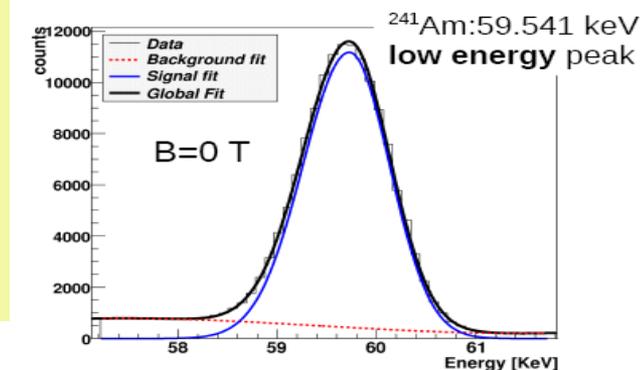
## Observed effects of magnetic field on $\gamma$ spectra

Tre effetti attesi su picchi dello spettro:

- spostamento a sinistra del centroide
- aumento della FWHM
- perdita di efficienza

The effect varies as a function of the  $\gamma$  energy and of the B field intensity.

Note background!



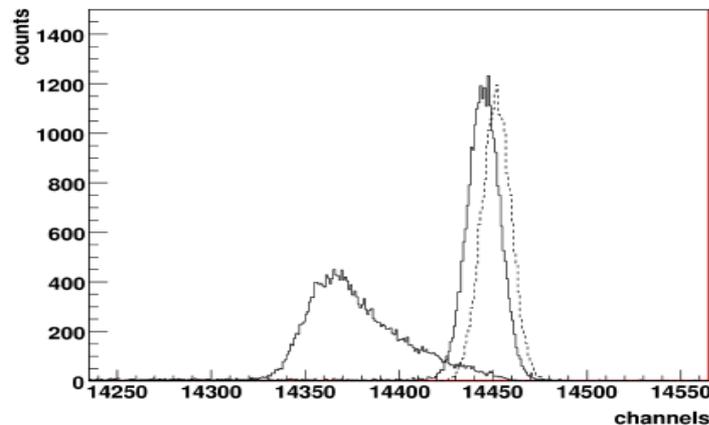
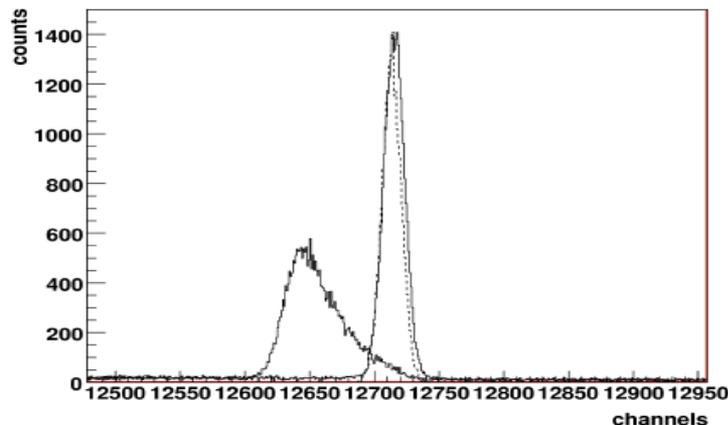
HPGe detectors in high magnetic fields – Conference ANIMMA 2009 – presented by Andrea Fontana, INFN Pavia

# HPGe: metodo di correzione

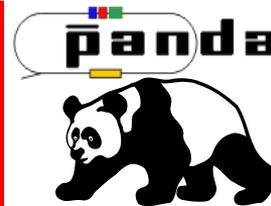
## Spectra recovery procedure

By using the interpolating functions for  $\sigma_1$ ,  $\sigma_2$  and for the centroid shift and the experimental values for the efficiency loss, it is possible to **correct the peak shape** measured in magnetic field by extrapolating the parameters to the zero field value.

- 1) the peak **centroid shift** is calculated and added to the measured centroid position;
- 2) the **ratios**  $R_1 = \sigma_1(B=0)/\sigma_1(B \neq 0)$  and  $R_2 = \sigma_2(B=0)/\sigma_2(B \neq 0)$  are calculated;
- 3) the experimental  $\sigma_1$  and  $\sigma_2$  obtained with  $B \neq 0$  are multiplied by  $R_1$  and  $R_2$  to obtain the **corrected  $\sigma$ 's**;
- 4) the efficiency loss is evaluated from the data and is used to **rescale** the number of entries of the measured spectrum.



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# HPGe: risultati e conclusioni

## Results and conclusions

- We have studied the performances of a **HPGe detector**, with commercial assembly, placed in the **highest magnetic field** ever tried for this type of detectors (**2.5 T**).
- The results show that the detector **works well** globally with **performances slowly worsening** with increasing energy of the  $\gamma$ -rays and field intensity.
- The peaks have been fitted with a **bi-gaussian function** whose parameters have been deduced as a **function of the energy and the field intensity**.
- We obtained an **almost full recovery of the detector resolution** and efficiency and we **demonstrated the possibility of using the HPGe's in very high magnetic fields**.

Our paper has been published (online) last week on **Nuclear Instruments and Methods A** with doi:10.1016/j.nima.2009.04.035 and is available at:

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Study of the performance of HPGe detectors operating in very high magnetic fields

M. Agnello<sup>a,b</sup>, E. Botta<sup>b,c</sup>, T. Bressani<sup>b,c</sup>, M. Bruschi<sup>d</sup>, S. Bufalino<sup>b,c</sup>, M. De Napoli<sup>e</sup>, A. Feliciello<sup>b</sup>, A. Fontana<sup>f,g</sup>, B. Giacobbe<sup>d</sup>, L. Lavezzi<sup>h,i</sup>, G. Raciti<sup>e</sup>, E. Rapisarda<sup>e</sup>, A. Rotondi<sup>h</sup>, C. Sbarra<sup>d,i</sup>, C. Sfienti<sup>e</sup>, A. Zoccoli<sup>d,i</sup>

<sup>a</sup> Dipartimento di Fisica, Politecnico di Torino, Italy  
<sup>b</sup> INFN Sezione di Torino, Italy  
<sup>c</sup> Dipartimento di Fisica Sperimentale, Università di Torino, Italy  
<sup>d</sup> INFN Sezione di Bologna, Italy  
<sup>e</sup> Dipartimento di Fisica, Università di Catania and INFN Sezione di Catania, Italy  
<sup>f</sup> INFN Sezione di Pavia, Italy  
<sup>g</sup> Dipartimento di Chimica Generale, Università di Pavia, Italy  
<sup>h</sup> Dipartimento di Fisica Nucleare e Teorica, Università di Pavia, Italy  
<sup>i</sup> Dipartimento di Fisica, Università di Bologna, Italy

# Contributo teorico

M.Radici

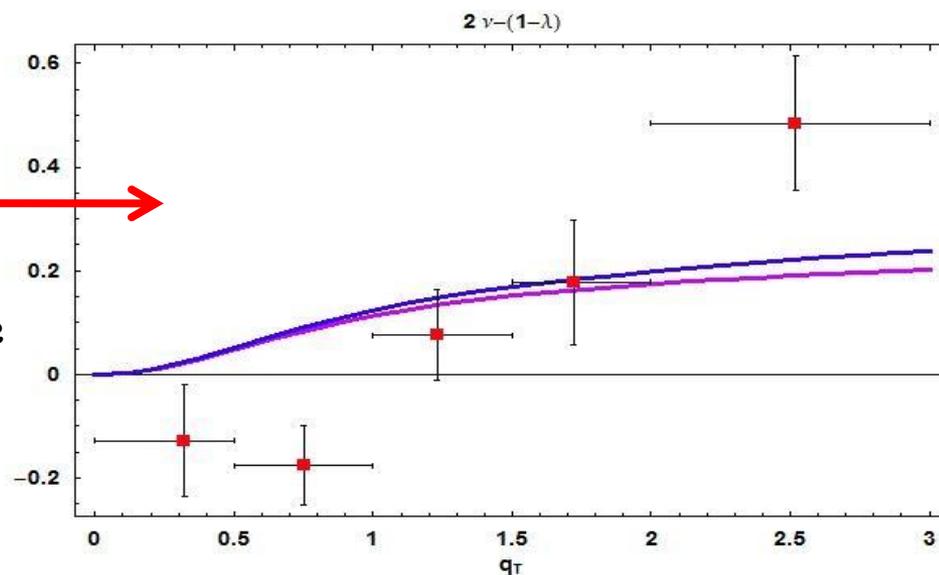
Studio della struttura partonica di spin del nucleone attraverso simmetrie azimutali che coinvolgono distribuzioni partoniche "esotiche"  
 → come costruire lo spin  $\frac{1}{2}$  dallo spin totale dei partoni costituenti  
 Studi di fattibilità con nuovo modello MC

Processo

Drell-Yan non polarizzato

Dati NA10,  $\pi^- p \rightarrow \mu^+ \mu^- X$   
 con fasci di pioni di 190 GeV

L'asimmetria azimutale dei dati potrebbe essere dovuta al moto trasverso dei partoni negli adroni, cioè al loro moto orbitale (che in QCD perturbativa si trascura sistematicamente).

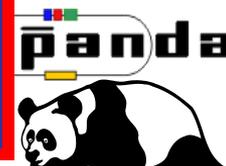


In PANDA reazione analoga:  $p\bar{p} \rightarrow \mu^+ \mu^- X$

(annichilazione dominante in entrambi i casi u-bar-u)

Miglior copertura angolare: grande riduzione delle barre di errore

# Panda PV 2010: impegni e richieste



Situazione simile al 2009:

**Ricercatori: %2010 %09**

<b>Bendiscioli</b>	PO sr	<b>100</b>	60
<b>Rotondi</b>	PO	<b>60</b>	60
<b>Radici</b>	1RIC	<b>20</b>	20
<b>Boca</b>	RU	<b>50</b>	30
<b>Braghieri</b>	RIC	<b>50</b>	50
<b>Fontana</b>	RIC	<b>30</b>	40
<b>Montagna</b>	RU	<b>70</b>	70
<b>Salvini</b>	RIC	<b>20</b>	20
<b>Genova</b>	ass.ric.	<b>20</b>	20
<b>Lavezzi</b>		<b>0</b>	0
<b>Costanza</b>	DOTT	<b>100</b>	100
<b>Cattaneo C.</b>	docente	<b>(20)</b>	(0)
<b>Panzarasa</b>	docente	<b>(50)</b>	(50)

**Tot 2010 5.2 FTE (5.9)**  
(2009 4.7 FTE)

+ 100% ass.ric.biennale  
Hadron FP7 - nov.09?

## PREVENTIVO DI SPESA 2010

**Missioni interne: 9 K€**

- 2 meeting Collab.italiana x 4 ric. x 2gg (2 k€)
- 4 meeting resp.locali e coordinatori (Montagna, Braghieri x 2gg Roma, 4 k€)
- contatti LNF per sviluppo STT (2 ric. x 5gg, 1.5 k€)
- contatti gruppi italiani SW (2 ric. x 5gg, 1.5 k€)

**Missioni estere: 37 K€**

- 4 meeting Collab. x 3 ric. x 5gg (18 k€)
- Mobilità rappr.Speakers Board e coord. SW-Tracking (Rotondi, 4x3gg, 5k€)
- 2 SW workshop x 2 ric. x 5gg (6 k€)
- Contatti con Julich per sviluppo STT (2x3gg, 3 k€)
- 2 meeting tracking x 2 ric. x 3gg (5 k€)

**Consumo: 5 K€**

- gas: argon, etano, freon, mix Ar-CO2 (3 k€)
- realizzazione stampati test carioaca10 2° versione per time-over-threshold (1 k€)
- varie, piccola meccanica, comp.elettronica (1 k€)

**Materiale inventariabile: 10 K€**

- 4 HD 750 GB per upgrade server (1 k€)
- discriminatore VME constant fraction (3 k€)
- PC per catena test DAQ (2 k€)
- modulo sampling ADC Wiener test DAQ (4 k€)

**TOTALE 2010 61 k€**

**2009**  
Rich. Ass

12 6

39 17.5

6 3

9 3

TOT '09

65 29.5