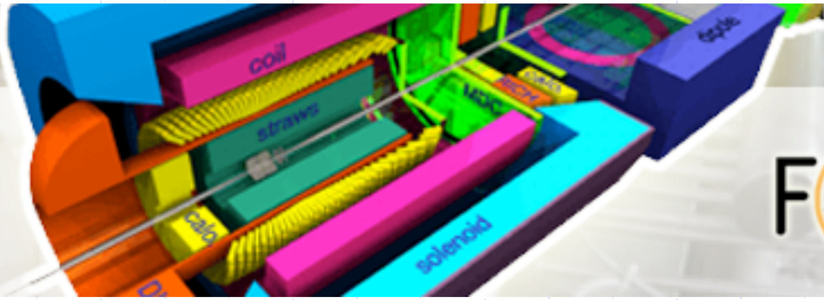
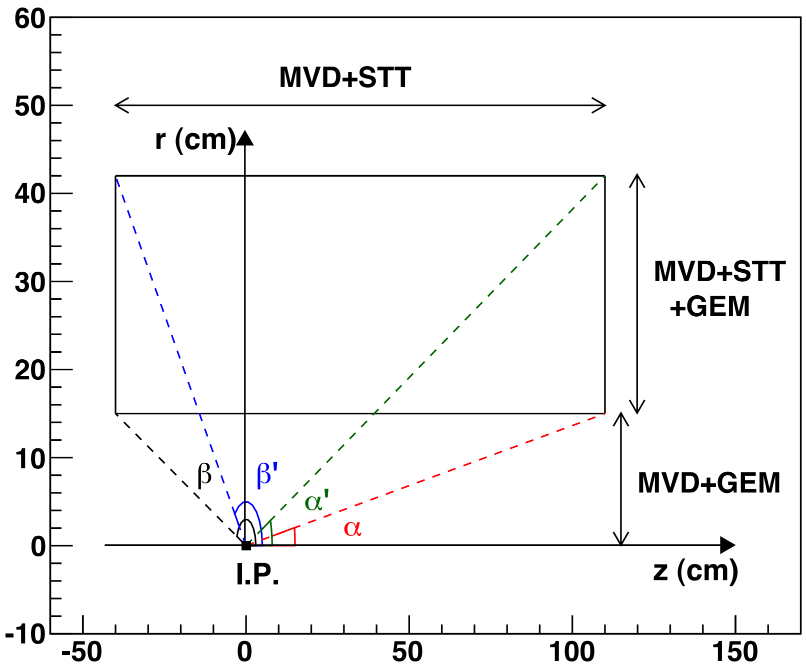


Requirements for the P̄ANDA Tracking system

- Tasks and constraints;
- Figures of merit;
- Benchmark channels.

Paola Gianotti

Requirements for the PANDA tracking



$\alpha = 7.8^o$, $\alpha' = 20.9^o$

$\beta = 133.6^o$, $\beta' = 159.5^o$

- High precision charged particles track measurement.
- High precision momentum measurement from 100 MeV up to 15 GeV.
- Secondary vertex capabilities for hadrons with c- and s-quark content.
- Help in identifying particle species.

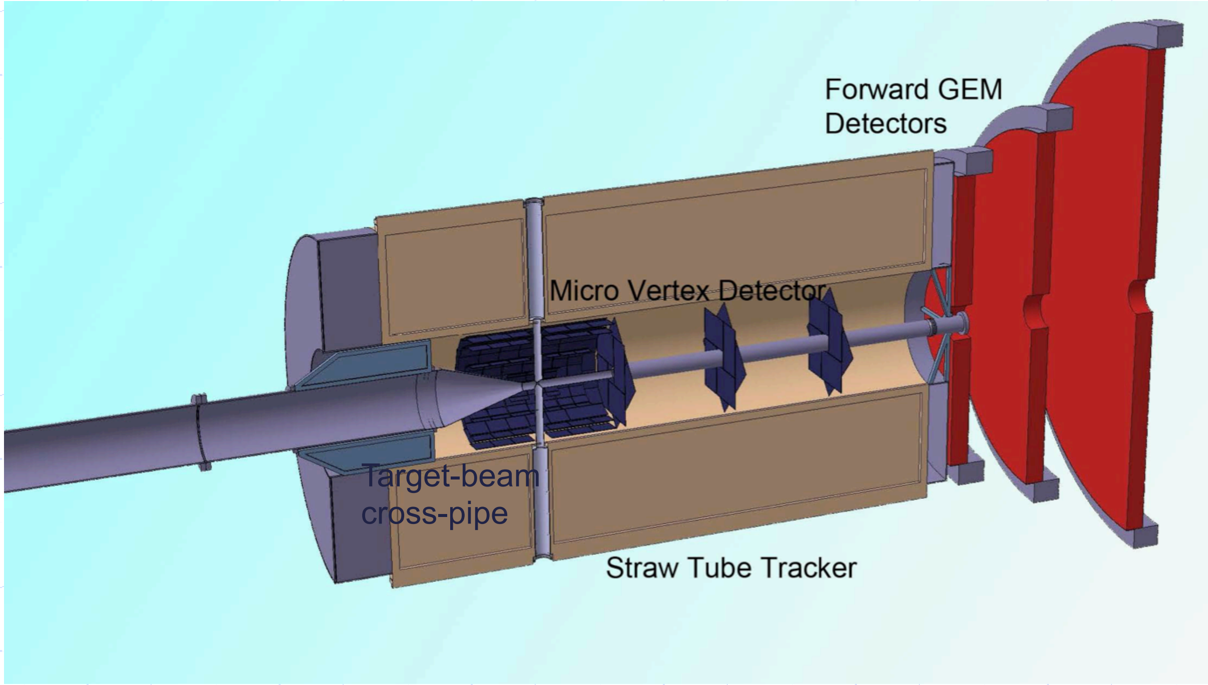
Constraints for the PANDA tracking

- High rate capability: interaction rate up to 2 $\cdot 10^7$ annih/s
- Contain the material budget in order to minimize multiple Coulomb scattering and secondary emission;
- Due to the presence of the target-beam cross-pipe the volume is divided in 2 halves.
- Very tight space for services due to high density of detectors

PANDA Tracking system

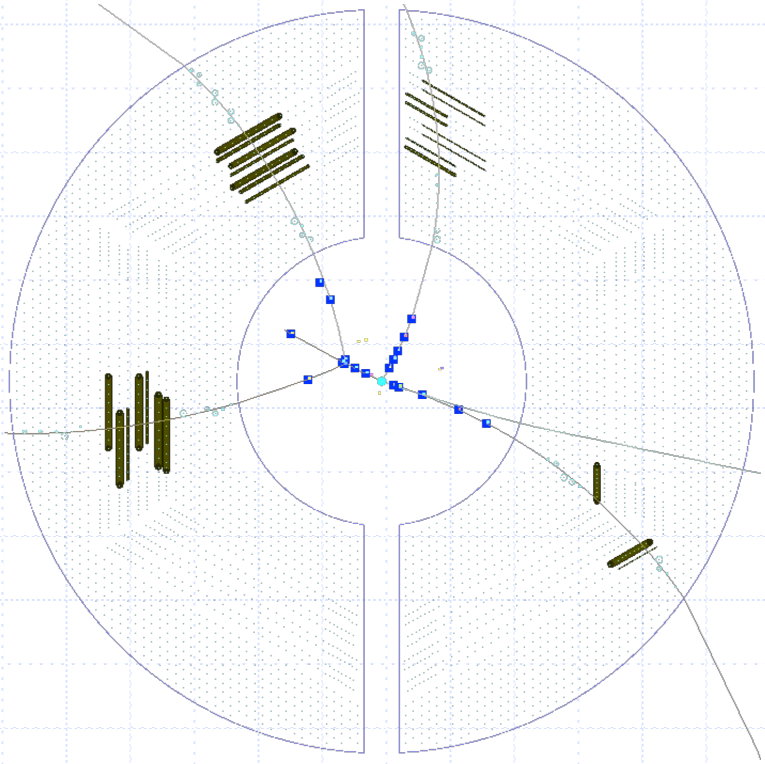
The tracking of charge particles will be done with a set of different detectors located in the Target and Forward Spectrometers.

Combining the information of different detectors we will fulfill all the requirements.



Detector's parameters definition

Design choices were driven by the physics performance of the detector options resulting by simulation and prototype performance results.



STT+MVD event display

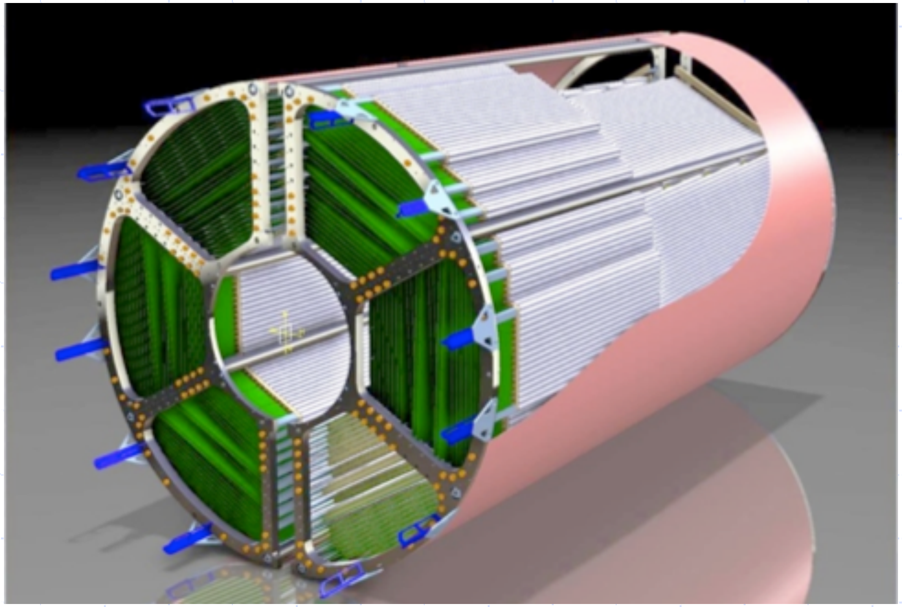
A set of figures of merit have been defined for each subsystem which allows to characterize the performance issues of the detector options.

Specific requirements for the CT

- **Acceptance**
  Almost 4π
- **Minimal Material budget**
  $X/X_0 \sim 1.5\%$
- **Resolving complex events**
  Multiple tracks, secondary vert.
- **High rate capability**
  $1 \cdot 10^4$ ev cm^{-2} s^{-1}
- **Spatial resolution**
  $\sigma_{r\varphi} \sim 150\mu m$
  $\sigma_z \sim$ few mm
- **Radiation hardness**
  0.1 – 1 C cm^{-1} y^{-1}
- **Momentum resolution**
  $\delta dp/p \sim 2\%$
- **Fit tight physical space**
  custom design of electronics and services

The Straw Tube Central Tracker

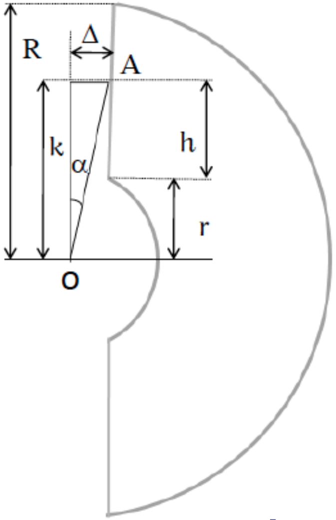
The Central Tracker is a two-halves cylindrical device enclosing the MVD. Straw tubes have been chosen as active elements.



$$\Delta = 2\ \text{cm}$$

$$R = 42\ \text{cm}$$

$$r = 15\ \text{cm}$$

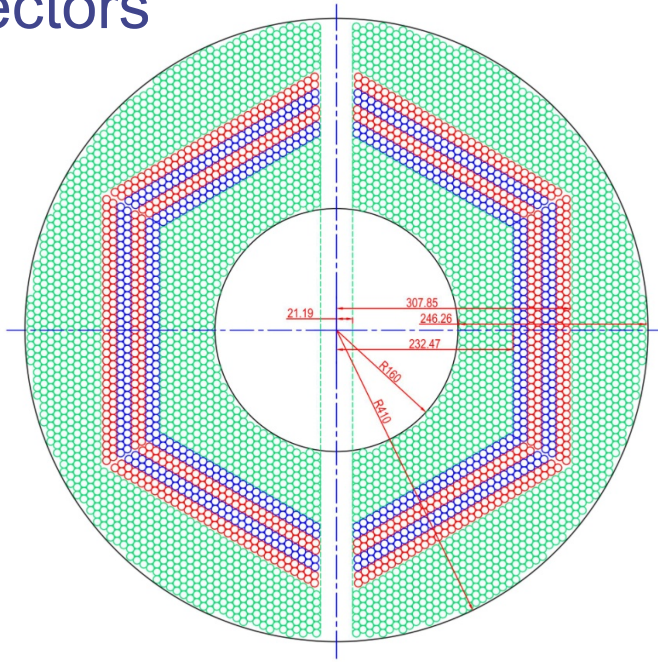


Acceptance loss due to the target pipe, from a rough geometrical calculation: $\frac{2\alpha}{\pi} \approx 4.5\%$

STT Layout

- 4636 Straw tubes in 2 semi-barrels around beam/target cross-pipe
- 23-27 planar layers in 6 hexagonal sectors

15-19 axial layers (green) // to beam axis for *x,y* determination; 4 stereo double-layers for z reconstruction with ±2.89° skew angle (blue / red)



Benchmark Channels

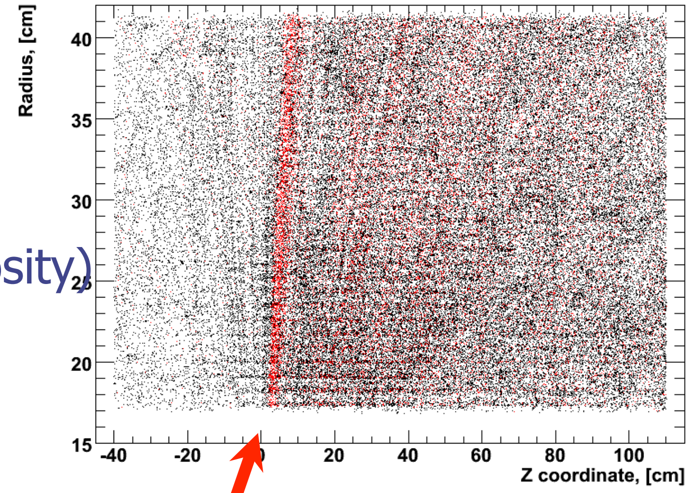
In order to assess the performance of the Central Tracker a list of benchmark channels has been simulated to cover the full range of physics tasks for this detector.

Channel	Final state
$\bar{p}p \to (n)\pi^+\pi^-$	$(n)\pi^+\pi^-$
$\bar{p}p \to \Psi(3770) \to D^+D^-$	$2K4\pi$
$\bar{p}p \to \Lambda\bar{\Lambda}$	$p\pi^-\bar{p}\pi^+$
$\bar{p}p \to \eta_c \to \phi\phi$	$4K$
$\bar{p}p \to \bar{p}p$	$\bar{p}p$

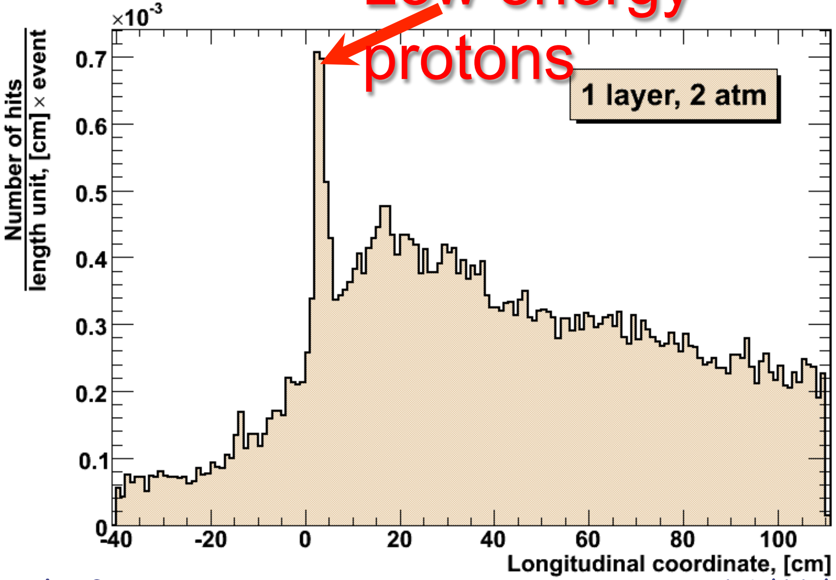
Single track events have also been simulated to test STT performance.

Particle Rates in the CT

- $p\bar{p}$ elastic scattering provide high rate at 90^{o}
- All numbers for innermost STT layer
- Event rate of 2×10^{7} evts/ sec (max. PANDA luminosity)
- Particle rates
  - ~ 5-8 kHz/ cm in forward region
  - ~ 14 kHz/ cm at z = 2±1 cm
  - ~ 800 kHz/ straw
- Energy losses dE per cm
  - Min: ~ 5 keV/cm from mips
  - Mean: ~ 10 keV/cm
  - Max: ~ 45 keV/cm (at θ ~ 90°)
- Charge loads ($A=5\times10^{4}$):
  - ~ 0.2 C/cm/year
  - ~ 1.0 C/cm/year at Δz ~ 2±1cm



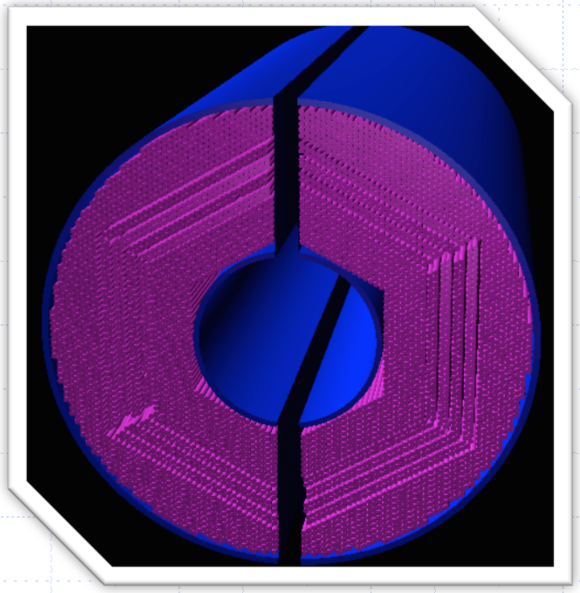
Low energy protons

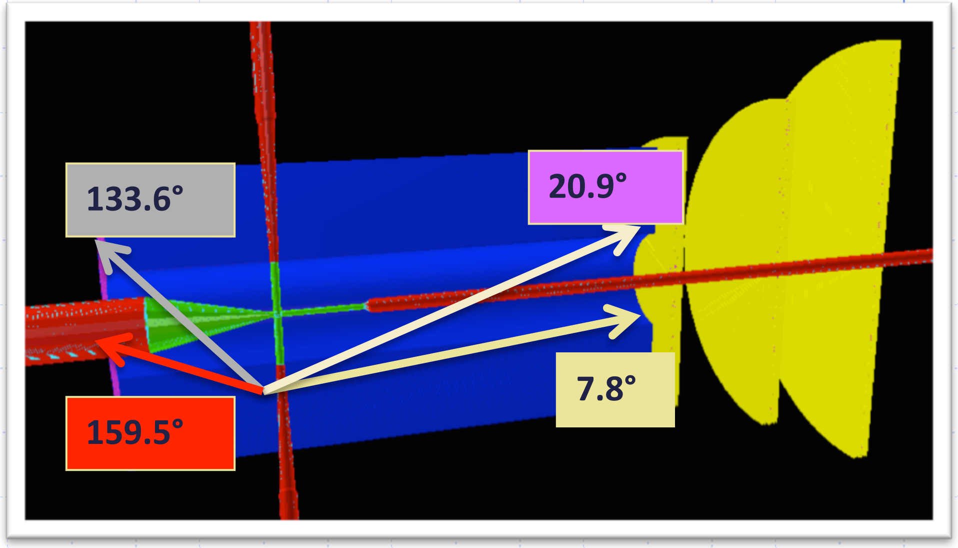


MonteCarlo Design Study

10^5 μ-single track events, generated at the I.P.

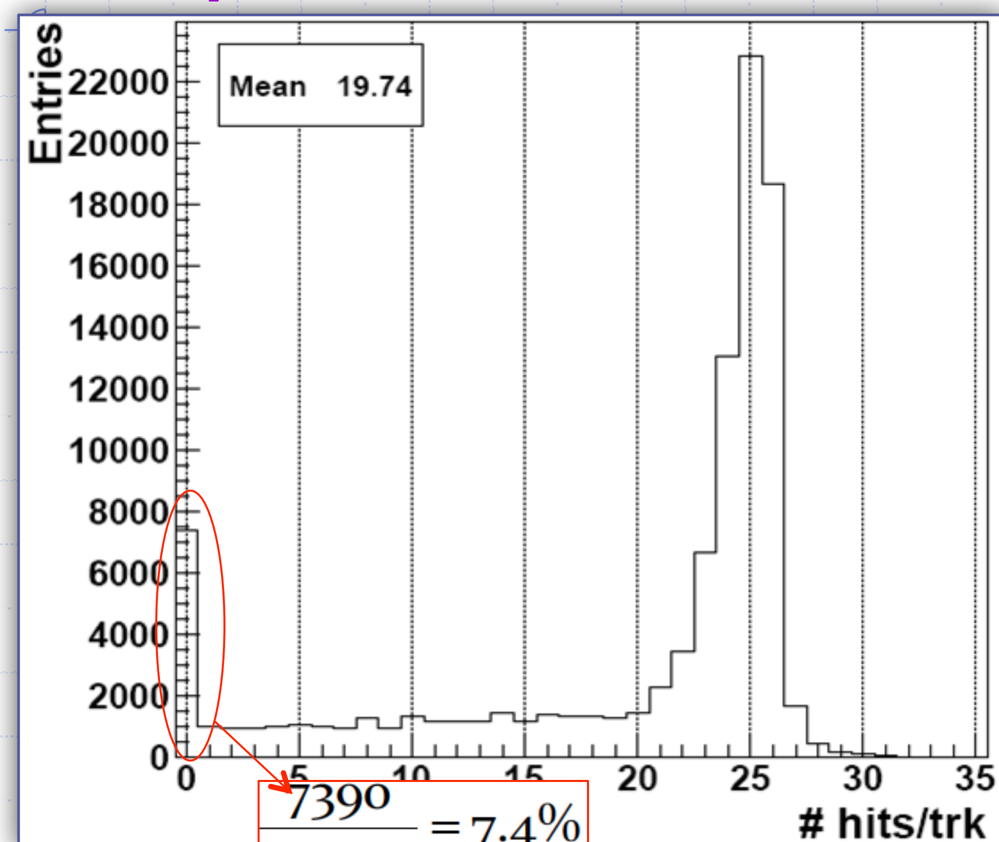
uniformly in $\varphi(0°, 360°)$ and $\cos\theta$, $\theta \in (7.8°, 159.5°)$



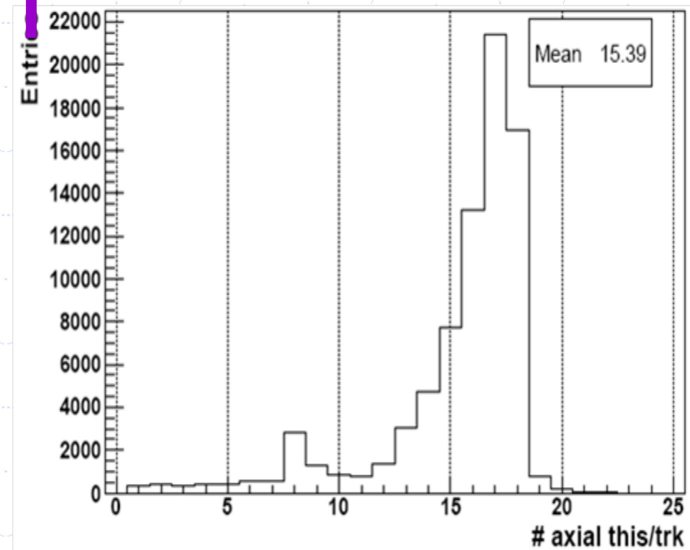


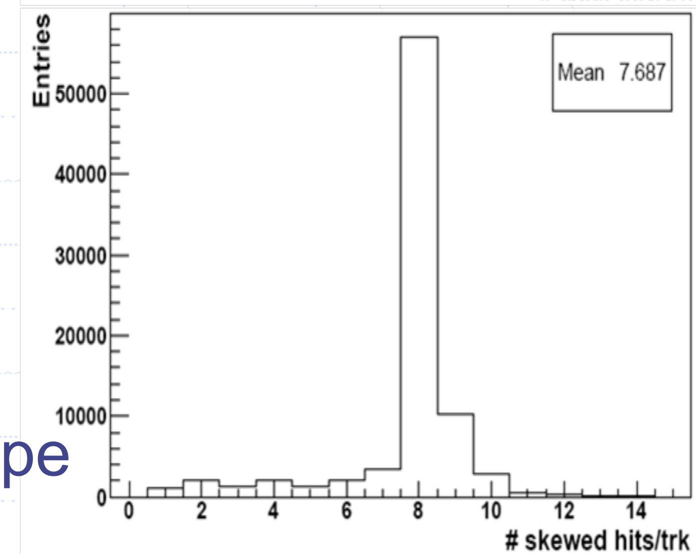
Muon's momentum fixed: 1.5 GeV/c

Hit/track distribution



$$\frac{7390}{100000} = 7.4\%$$



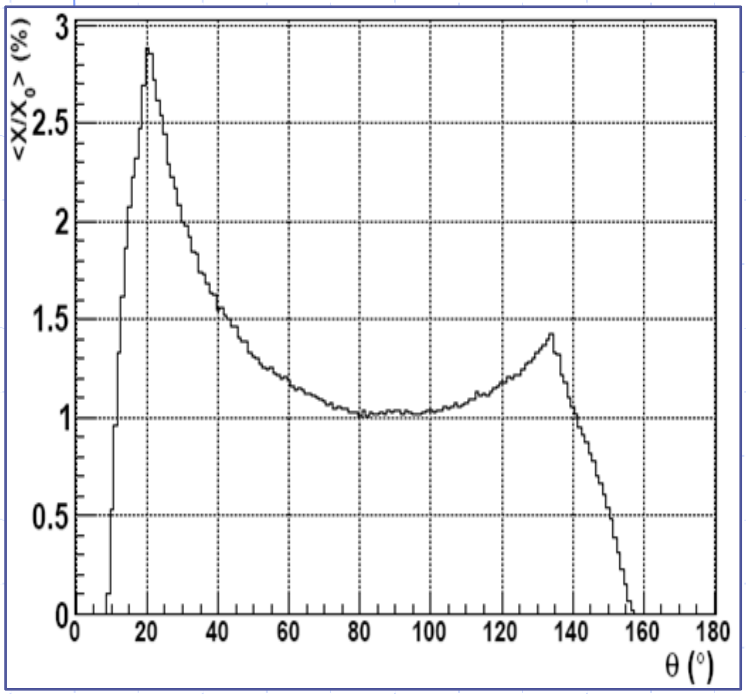


Loss of acceptance due to the beam pipe

Radiation Length

For each tube: $\langle X/X_o \rangle = 0.04\%$

$$(mean\ \#hits/trk)\cdot\langle X/X_0\rangle/\sin\vartheta$$



Element	Material	$X[mm]$	$X_0\ [cm]$	X/X_0
Film Tube	Mylar, 27 μm	0.085	28.7	3.0×10^{-4}
Coating	Al, $2\times0.03\,\mu$m	2×10^{-4}	8.9	2.2×10^{-6}
Gas	$Ar/CO_2(10\%)$	7.85	6131	1.3×10^{-4}
Wire	W/Re, 20 μm	3×10^{-5}	0.35	8.6×10^{-6}
			$\sum_{straw}$	4.4×10^{-4}

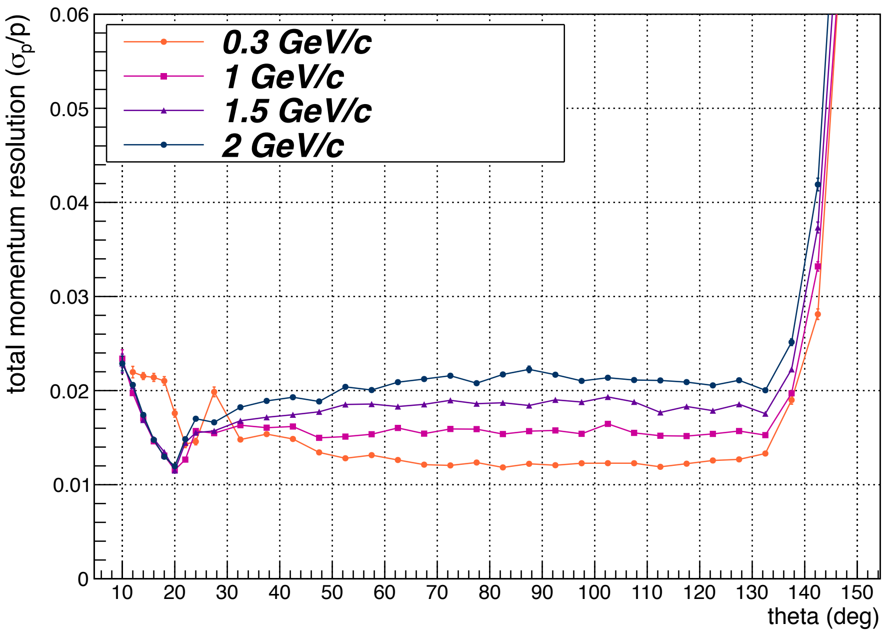
The numbers for the gas are evaluated at 20° C and 2 atm.
Two protection walls *(0.084% X/X_0)* will be placed in and out.

Mean value < 1.5%

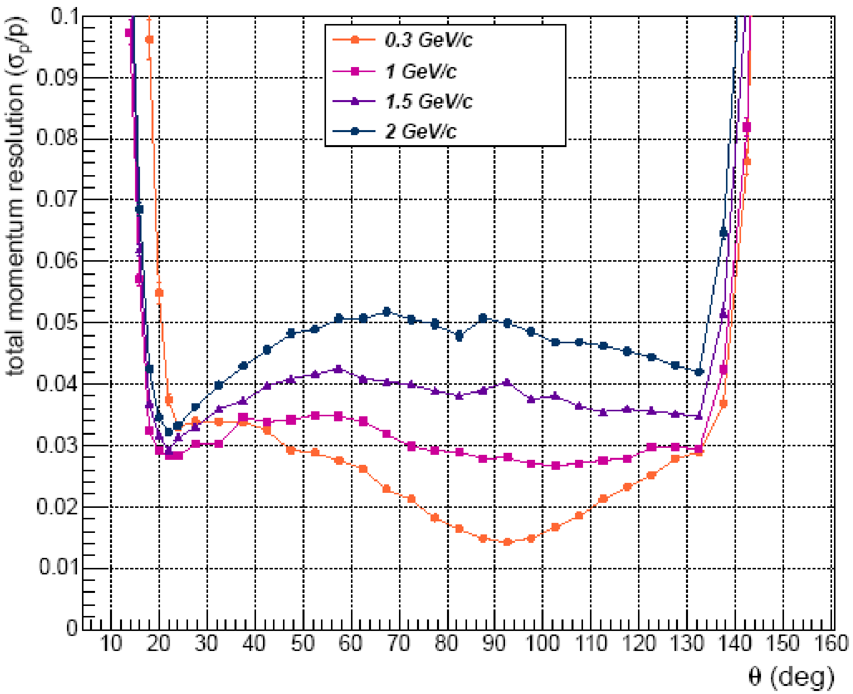
Momentum resolution

Muon of different momenta have been simulated.

MVD+STT+GEM



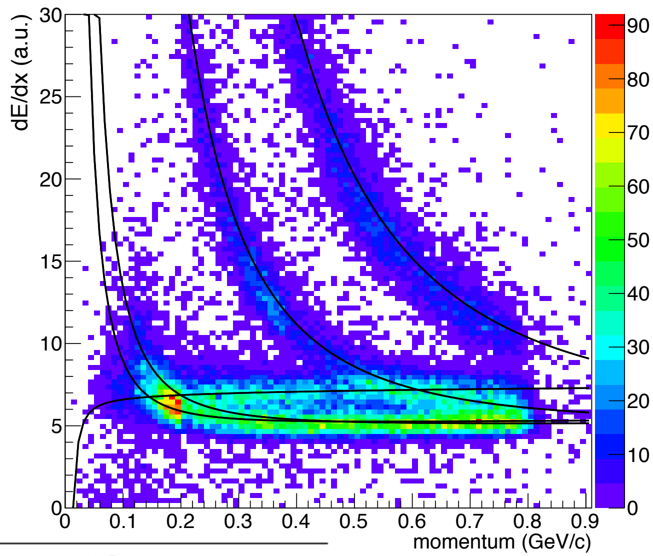
STT alone



dE/dx capability of STT

The use of straw as tracking device is well known. The possibility to perform dE/dx was explored.

Having a mean # of ST of 20/track.



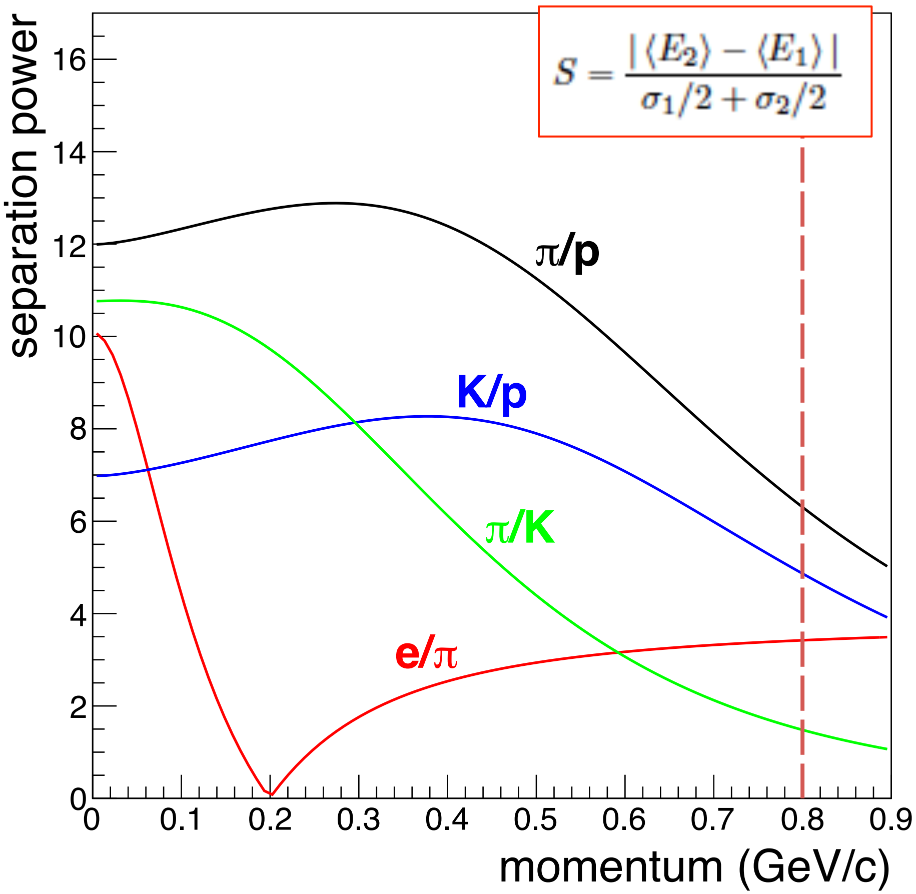
The dE/dx (truncated mean) vs momentum distributes on different bands depending on the mass of the particle.

Test: electrons, pions, kaons and protons

		frequencies of p.i.d. (%)				
		e	μ	π	K	p
true part.	e	78.9	5.2	5.6	10.1	0.2
	π	9.0	47.2	40.7	2.9	0.2
	K	22.3	8.0	1.6	65.1	3.0
	p	0.1	[0.01]	0.1	1.0	98.8

efficiency (%)	**true particle**	**purity (%)**
78.9	**e**	71.5
87.9	**Π**	81.1
65.1	**K**	82.3
98.8	**p**	96.7

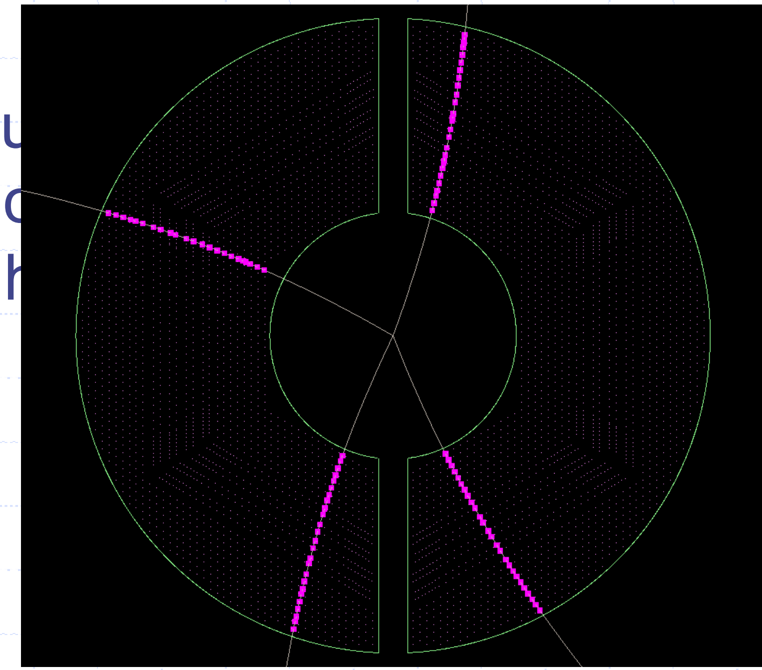
Separation power



Simulation results show that with an energy resolution ~ 10% we can contribute to PID in the low momentum range (<0.8 GeV/c)

Physics Channels Analysis

To evaluate vertex, mass resolu
and efficiency of the overall trac
system the following channels h
been simulated:



$\bar{p}p \rightarrow (n)\pi^+\pi^-$ [n=2,4]

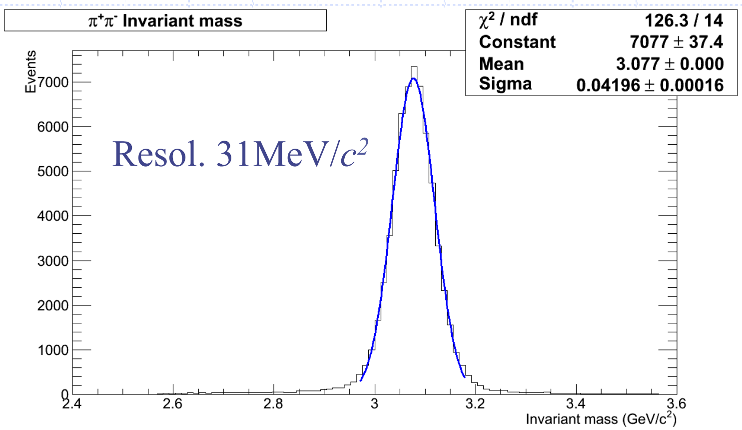
$\bar{p}p \rightarrow \eta_C \rightarrow \varphi\varphi \rightarrow K^+K^-K^+K^-$

$\bar{p}p \rightarrow \Psi(3770) \rightarrow D^+D^- \rightarrow K^+\pi^+\pi^-K^-\pi^+\pi^-$

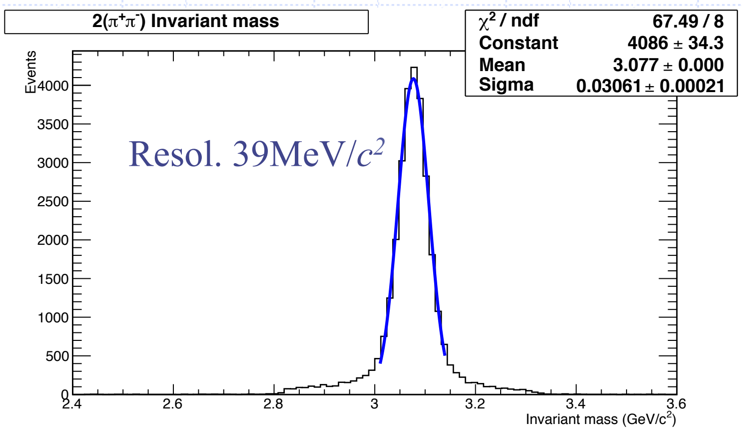
All channels have been simulated adding DPM bkg

Multi-pion final states

$\bar{p}p \rightarrow (n)\ \pi^+\pi^-$ [n=2,4] are the basic channels to test the STT performance. CMS energy 2.954GeV. Simulations has been performed including also DPM background events.



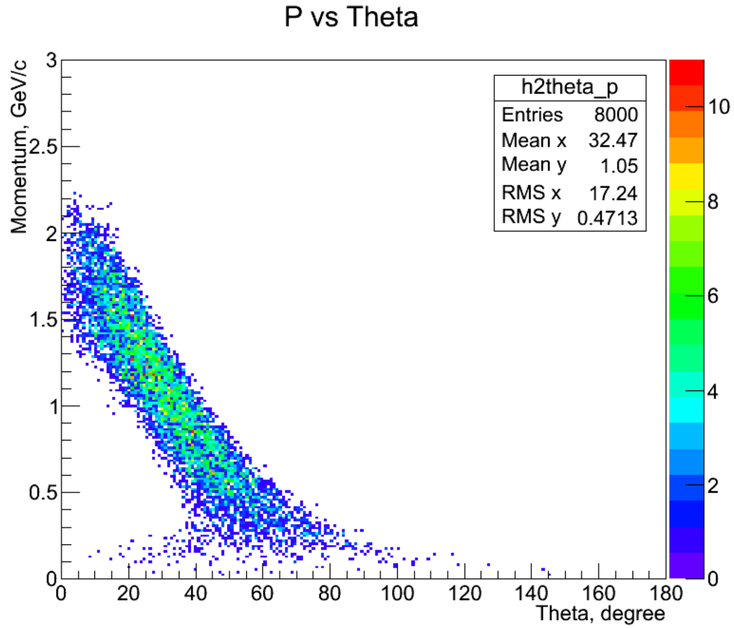
Rec. Eff.(31.7±0.2)%

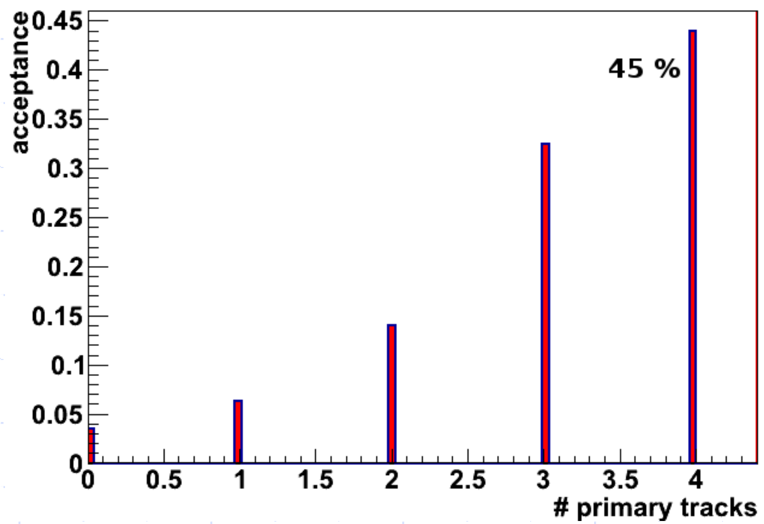


Rec. Eff.(17.2±0.2)%

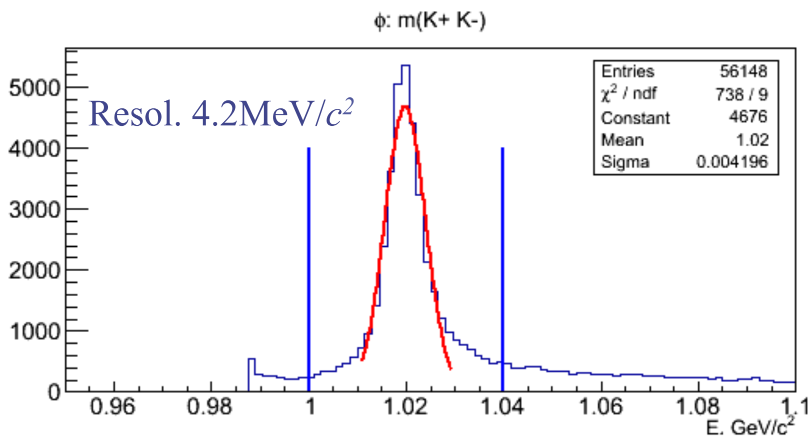
$\bar{p}p \rightarrow \eta_c \rightarrow \phi\,\phi$

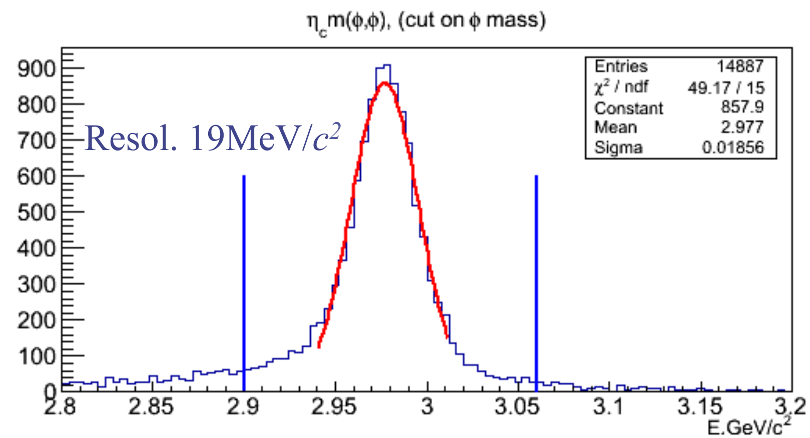
For the study of η_c to test the central tracker performance, the decay mode with kaons has been chosen.





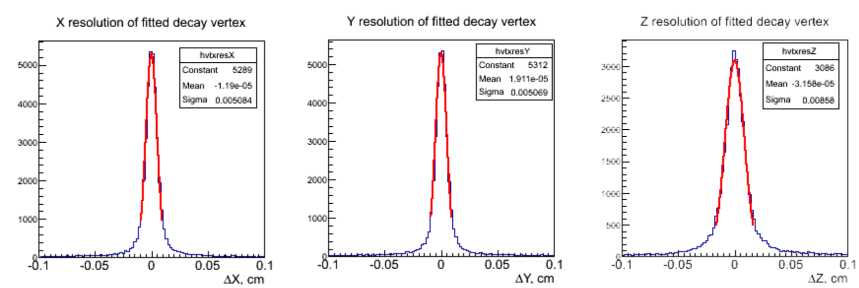
$\bar{p}p \rightarrow \eta_c \rightarrow \phi\,\phi$





Mass resolution for Φ and η_c for events with DPM bkg. mixing.

The final efficiency for this channel is 11.6%.

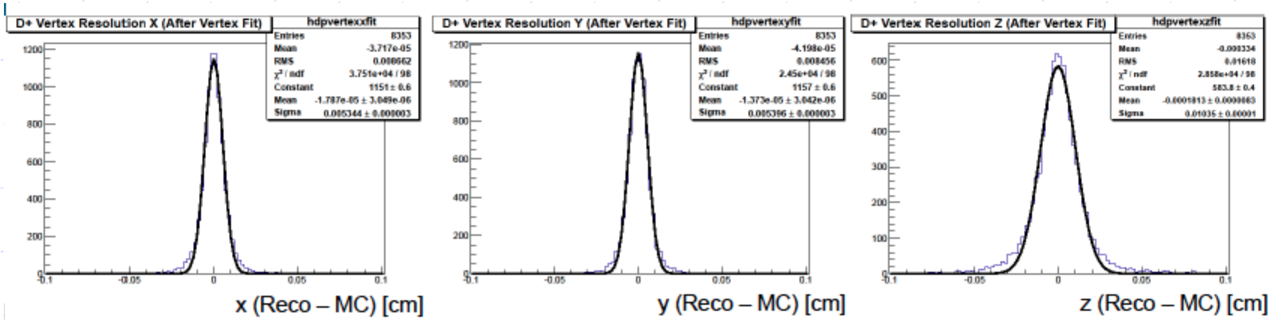


Vertex Resol. 51*μm (x,y); 86μm (z)*

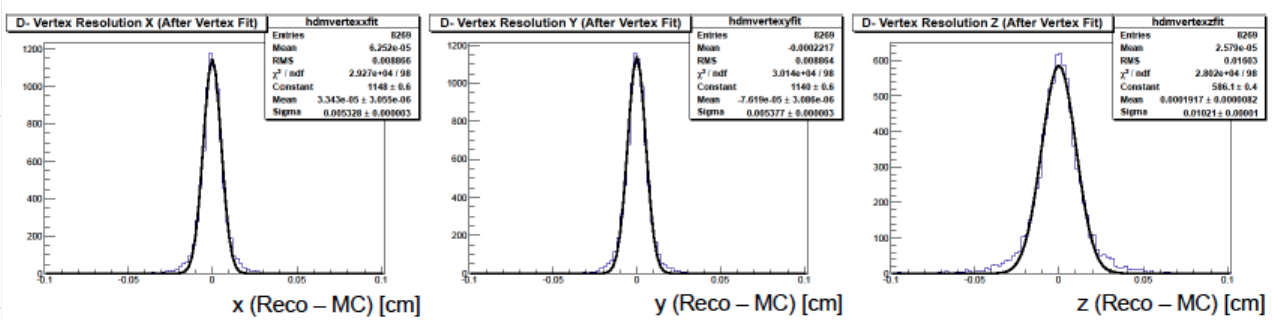
Open charm

The following channel has been simulated for a beam momentum of 6.5788 GeV/c

$$\bar{p}p \rightarrow \Psi(3770) \rightarrow D^+D^- \rightarrow K^-\pi^+\pi^+\, K^+\pi^-\pi^-$$



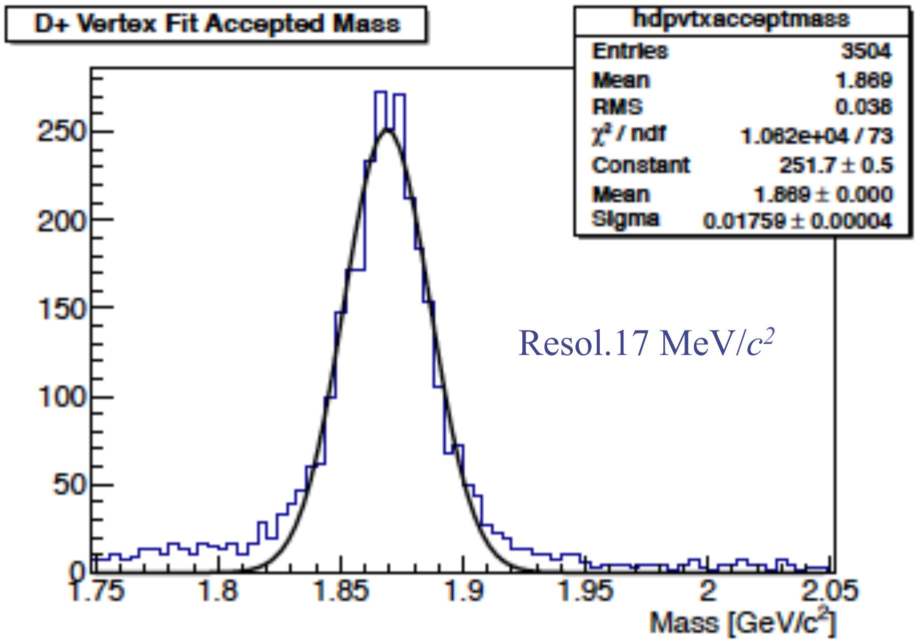
σ_x = (53.44±0.03) μm σ_y = (53.96±0.03) μm σ_z = (103.5±0.1) μm

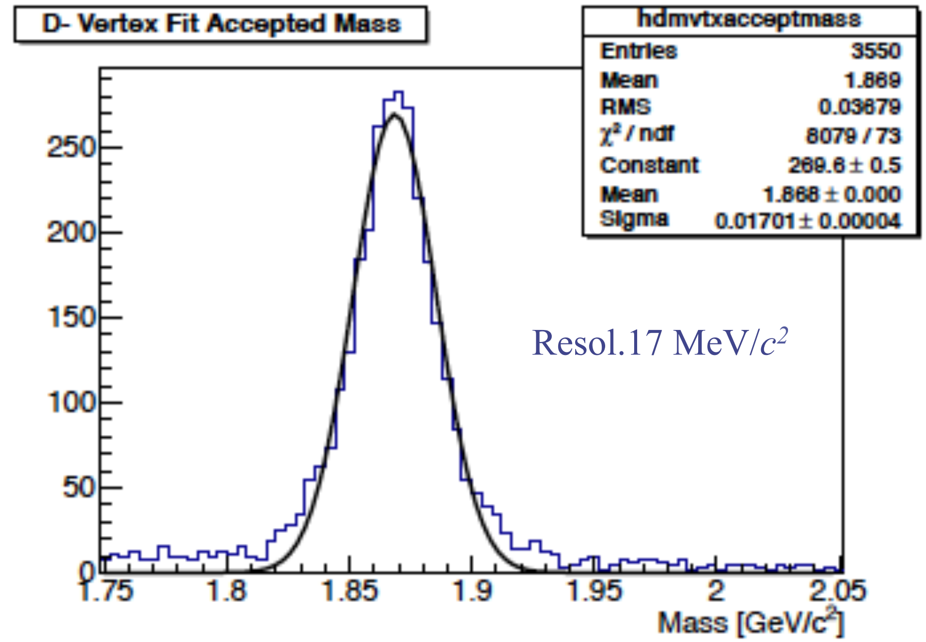


σ_x = (53.28±0.03) μm σ_y = (53.77±0.03) μm σ_z = (102.1±0.1) μm

D-meson vertex resolution

D meson mass resolution

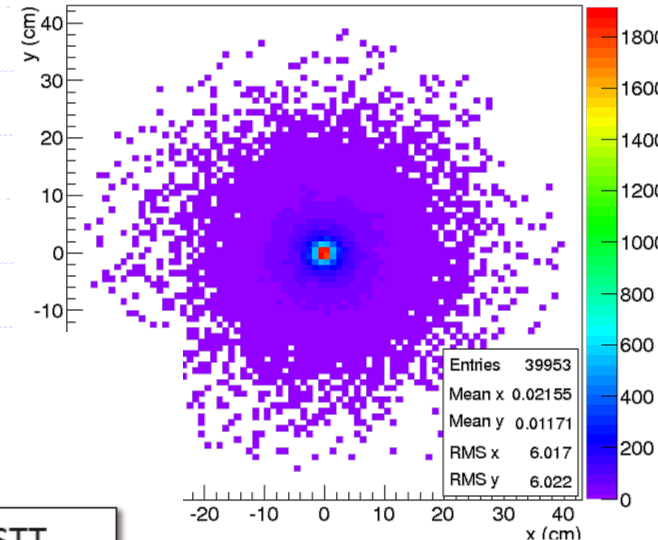


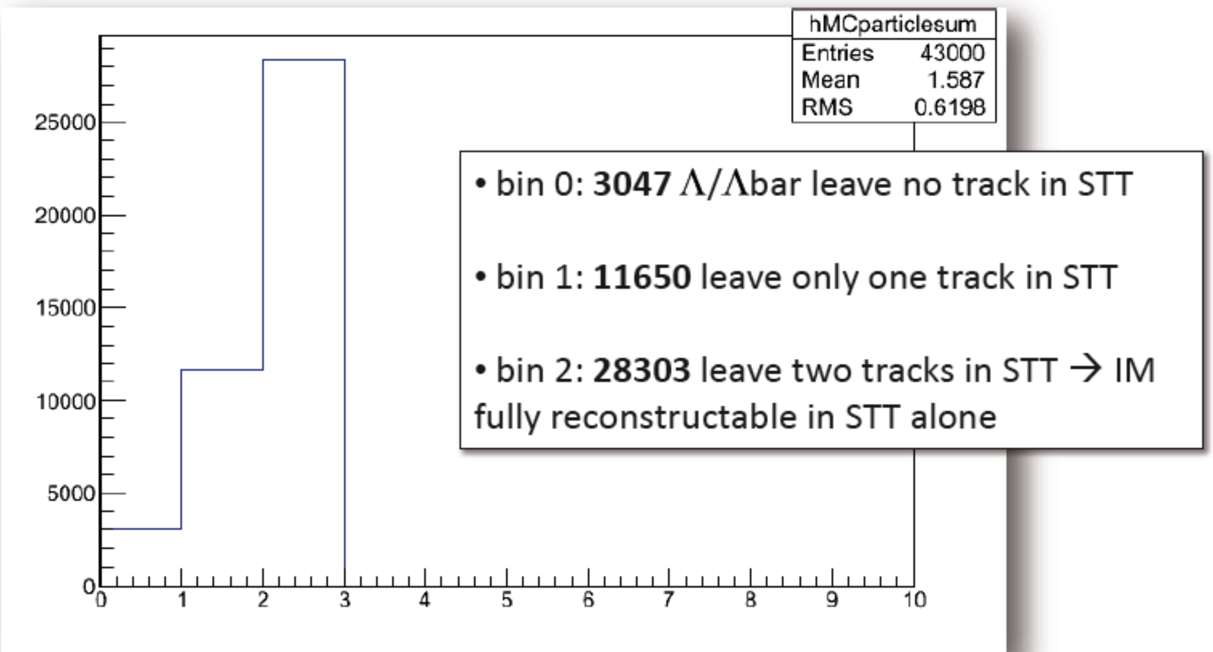


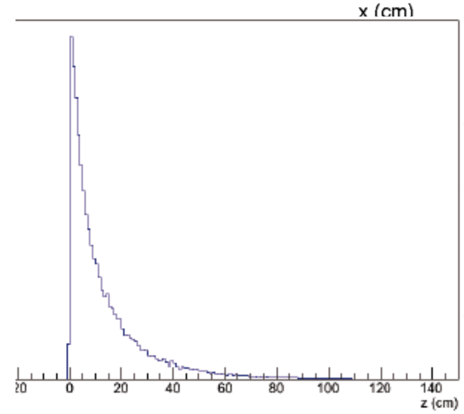
The overall efficiency for this channel is 5.9%, and is the convolution of the acceptance and of the reconstruction efficiency. This reduces to 3.3% when the bkg is added.

$\Lambda\bar{\Lambda}$ Events

The events have been generated with a ph.sp. distribution ➔ No forward peaked angular distribution. Λ decay $p+\pi^-$

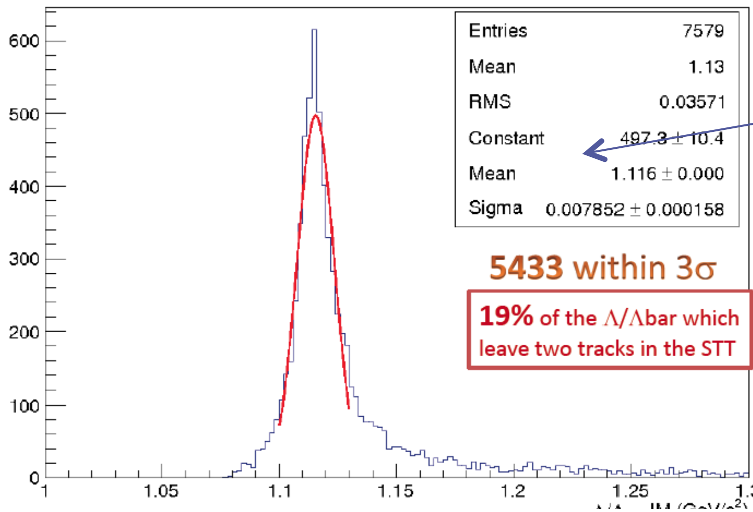


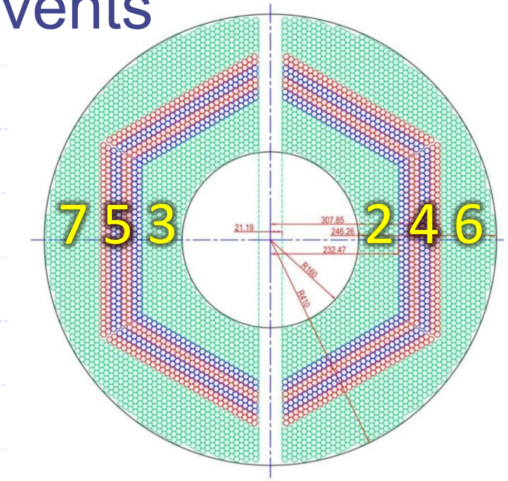




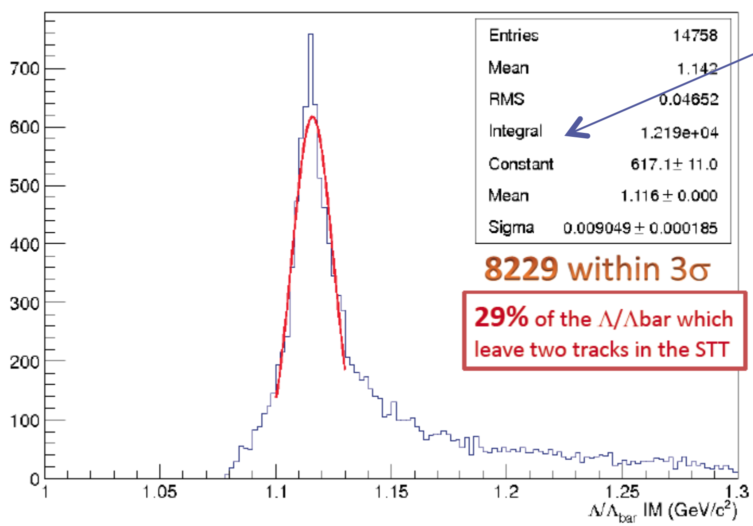
Λ reconstruction

3 sectors events





all events



just the simplest vertex finder was used no kinematic fit. Its application will improve results and lower the tail.

Other parameters

Other parameters that have to be considered are:

- Feasibility in the needed time: available infrastructures, manpower, etc…;
- Production and maintenance;
- Integration with other detectors;
- Costs and financing issues for construction and maintenance.

These more general aspects are not entering the TDR, they are subjects of discussion within the PANDA Technical and Financial Boards.