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Particle Identification at the PANDA Experiment

A. Sanchez Lorente
on Behalf of the PANDA collaboration

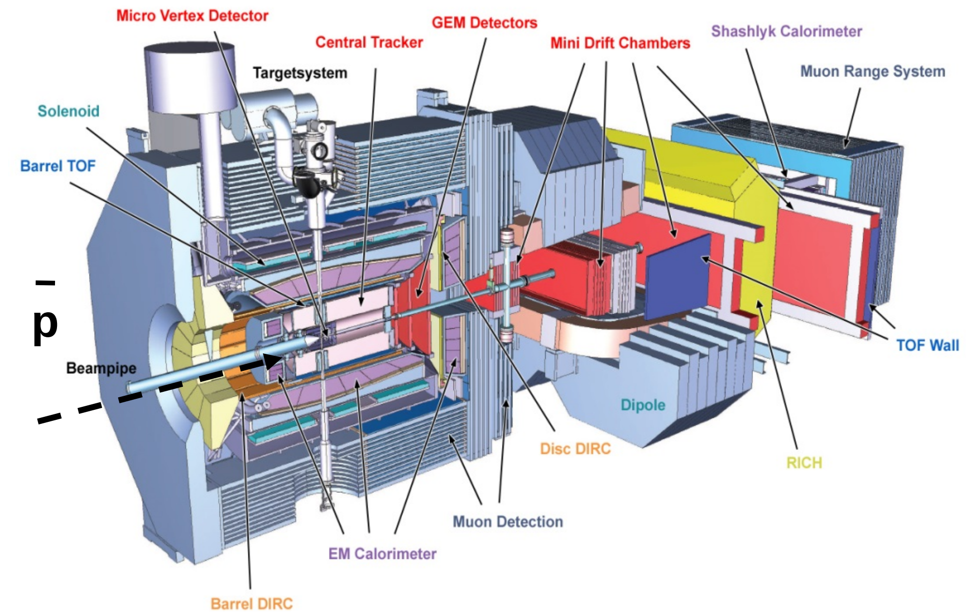
La Biodola, Tau-charm Worksop,
26. May -31. May, Isola d'Elba

- PID Detector system at PANDA
- Calorimetry
- Charged PID
- The time of flight (TOF) system
- Summary

PID Detector system

PANDA PID Requirements:

- Particle identification essential for PANDA
- Momentum range 200 MeV/c – 10 GeV/c
- Different process for PID needed



PID Processes:

- Cherenkov radiation: above 1 GeV

  Radiators: quartz, aerogel, C4F10

- Energy loss: below 1 GeV

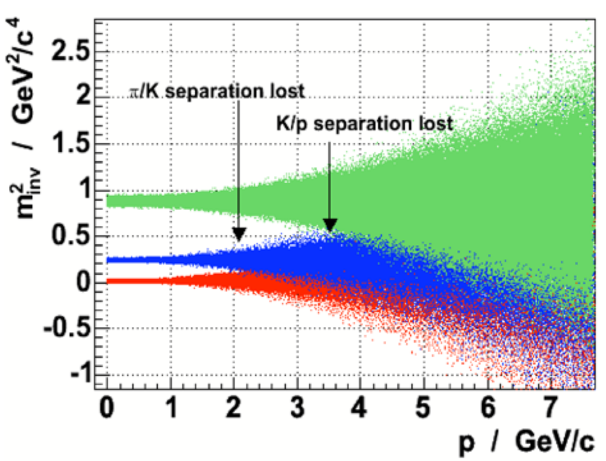
  Best accuracy with central tracker

- Time of flight

  Challenge: no start detector -> relative timing

- Electromagnetic showers: EMC for e and γ

Forward ToF



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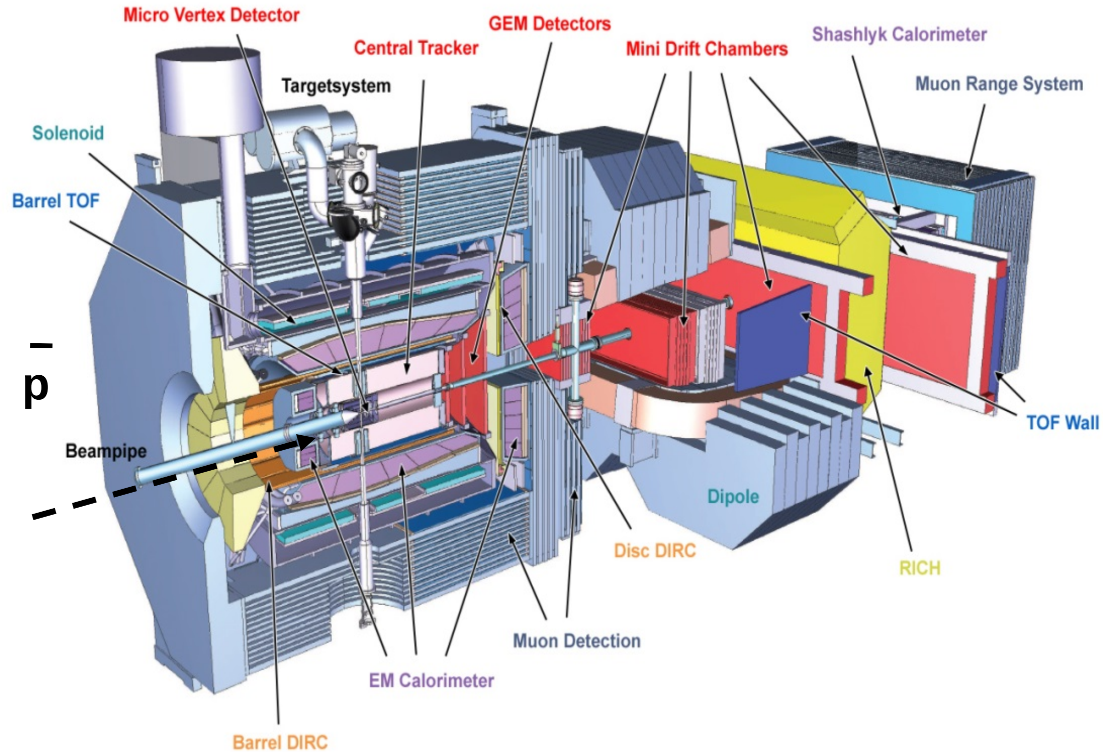
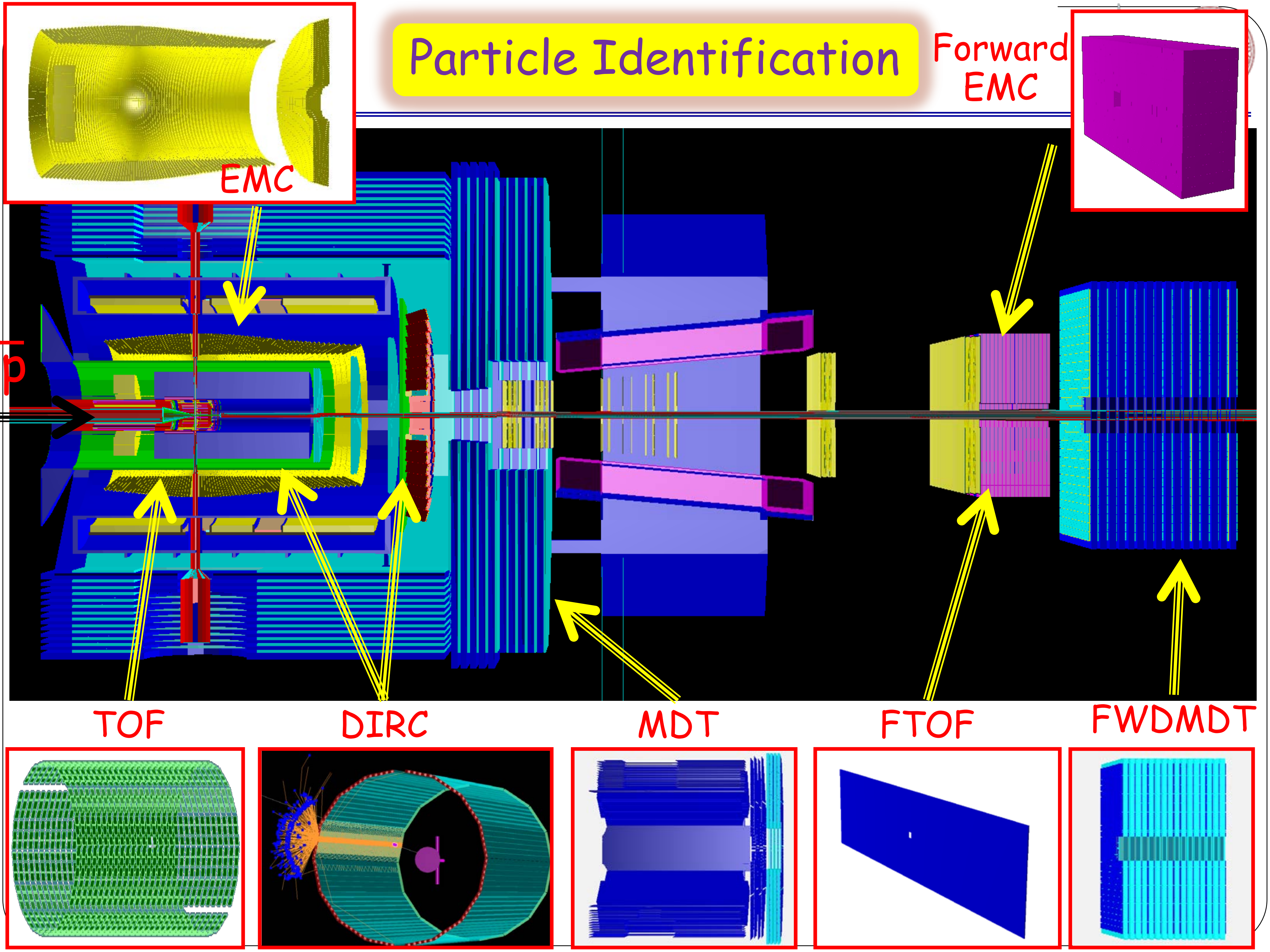
Charged Particle Identification

- Barrel DIRC
- Barrel TOF : SciTil
- EndCap DIRC
- Forward RICH
- Forward TOF
- Muon detectors



Particle Identification



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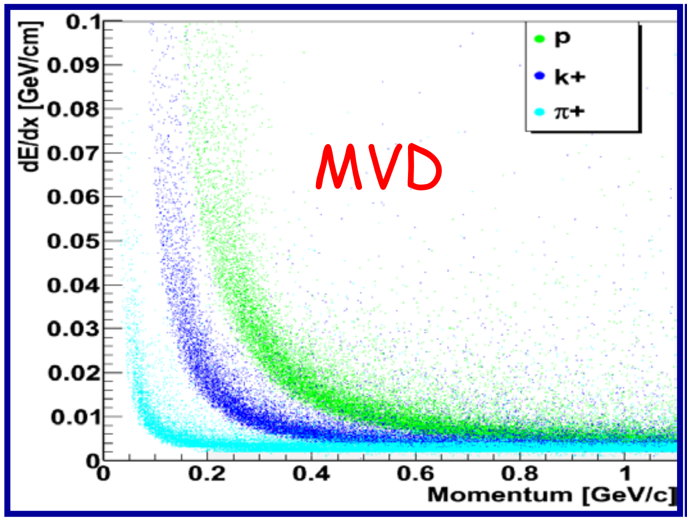
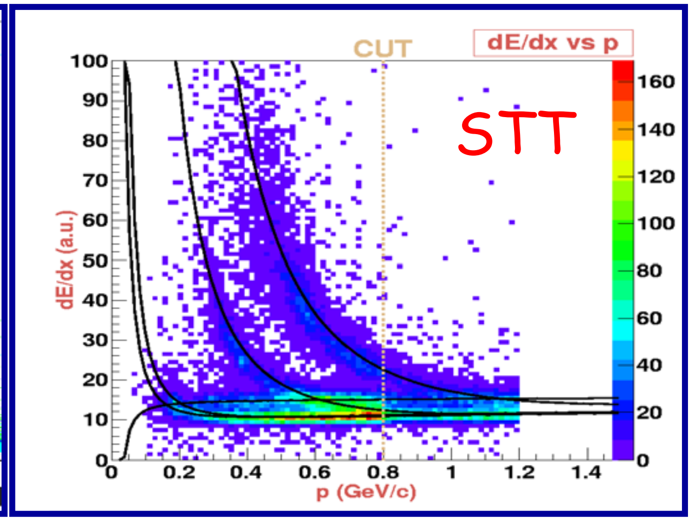
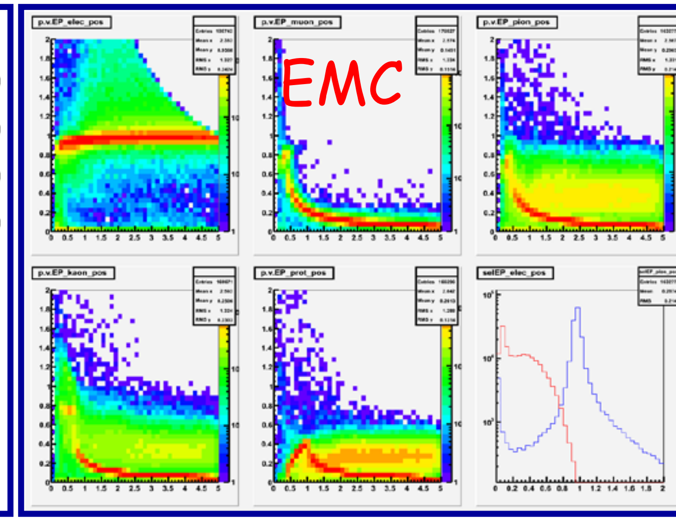
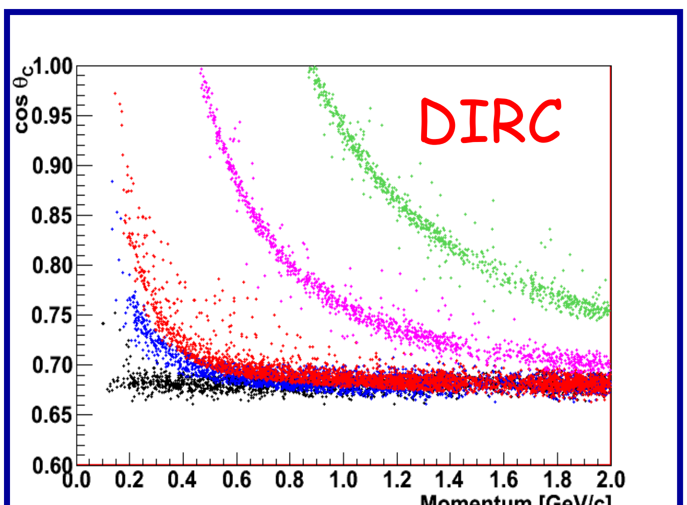
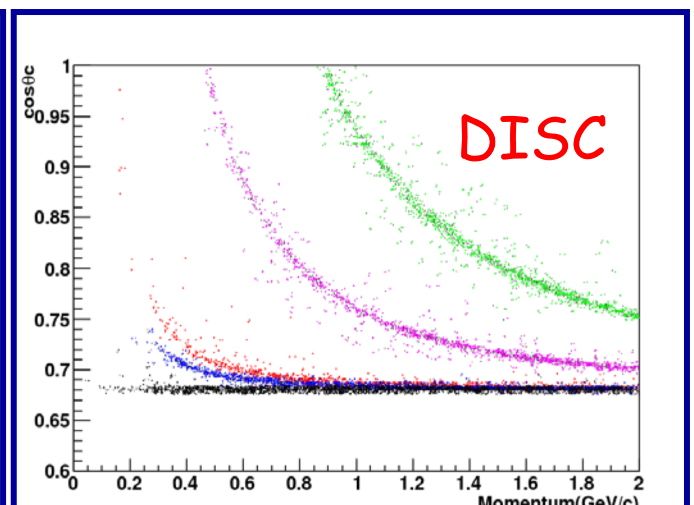
Implemented PDFs for many detectors (Bayes)

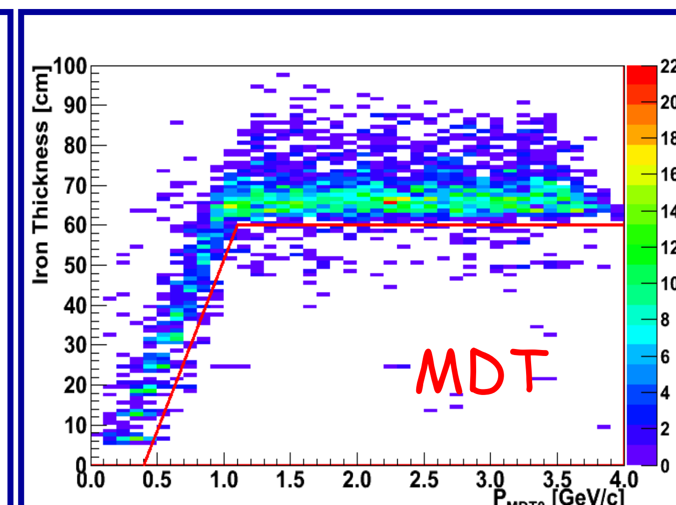












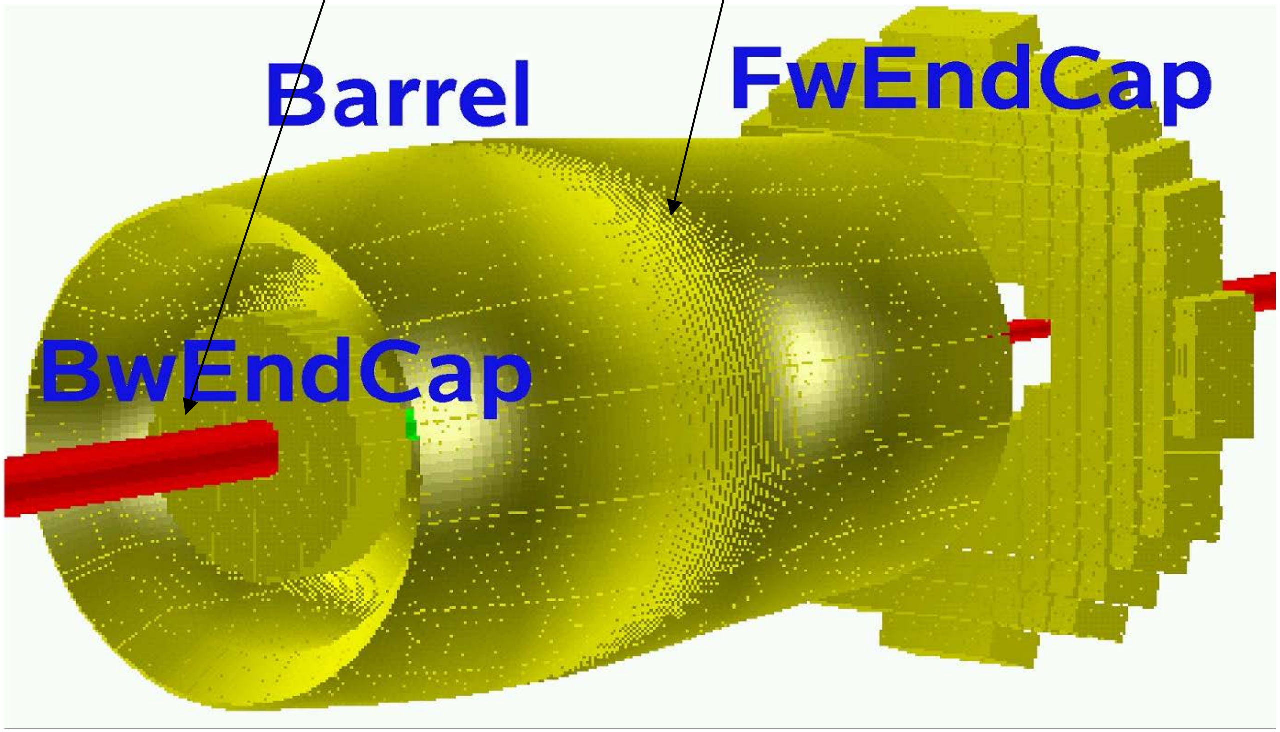
A.Cecchi, L.Lavezzi, R.Kunne, Y.Lang, L.Zotti

Electromagnetic Calorimeters

- **Backward Endcap**
  - 800 Crystals
  - Worse resolution due to service lines of trackers
  - Needed for hermeticity

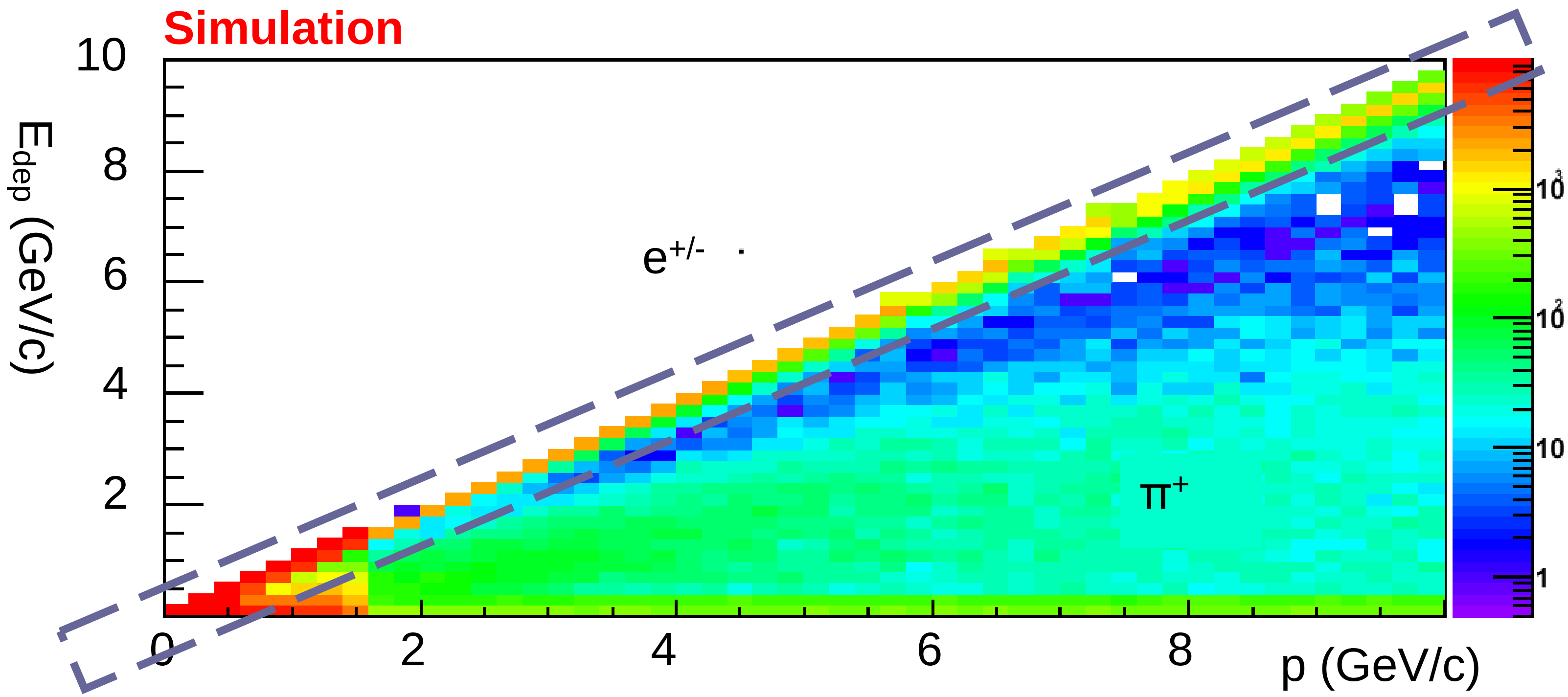
- **Barrel Calorimeter**
  - 11000 PWO Crystals
  - LA APD readout
  - $\sigma(E)/E \sim 1.5\%/\sqrt{E}$ + const.

- **Forward Endcap**
  - 4000 PWO crystals
  - High occupancy in center
  - Readout LA APD or vacuum triodes

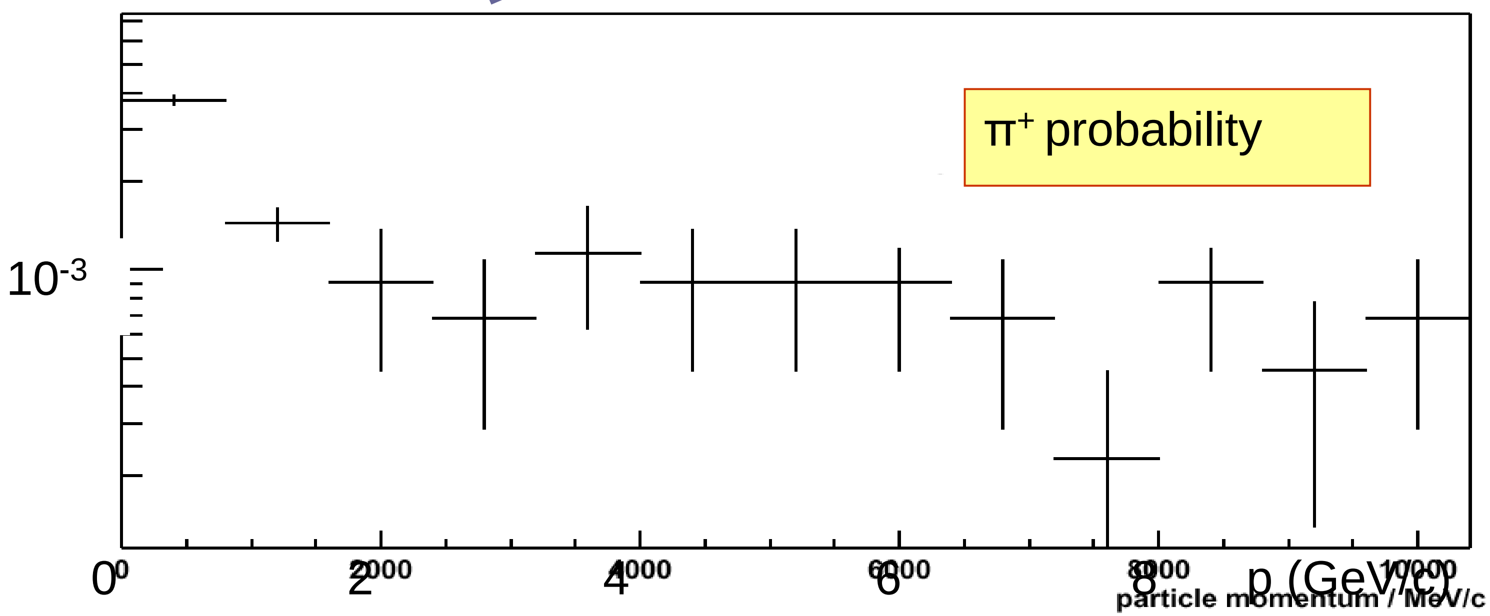


- **Forward Shashlyk**
- *(after dipole magnet)*
  - 350 channels
  - Readout via PMTs
  - $\sigma(E)/E \sim 4\%/\sqrt{E}$ + const.

EMC TDR http://arxiv.org/abs/0810.1216v1 from calorimeter



from tracking



electron/pion separation ≈ 10^{-3}

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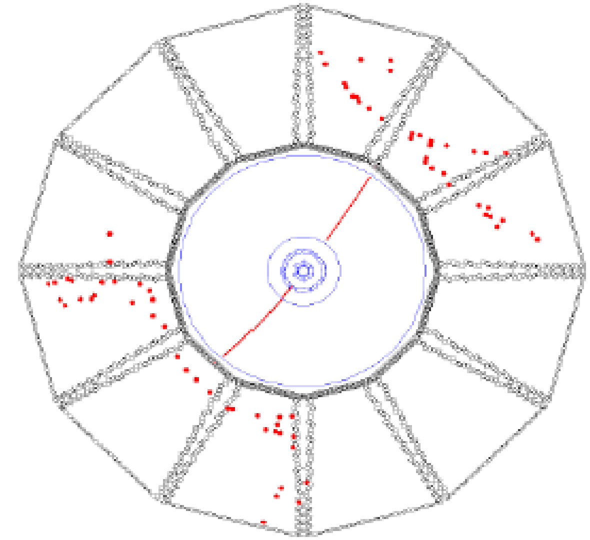
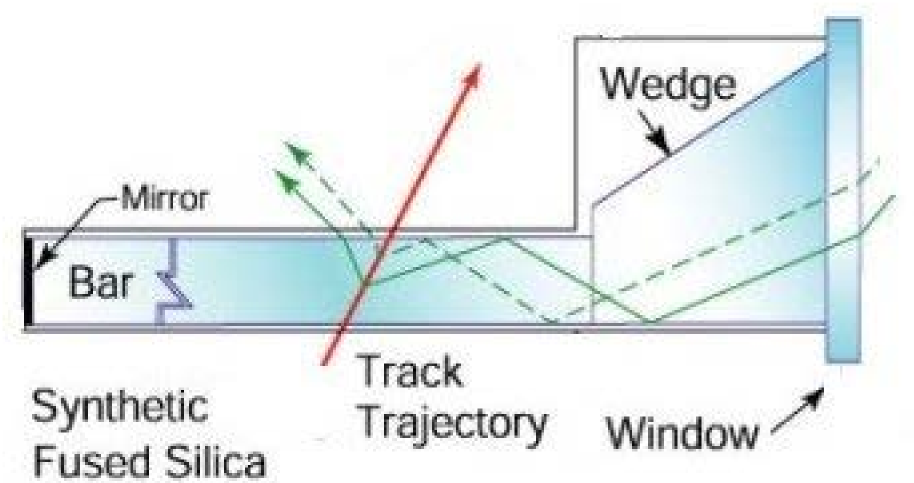
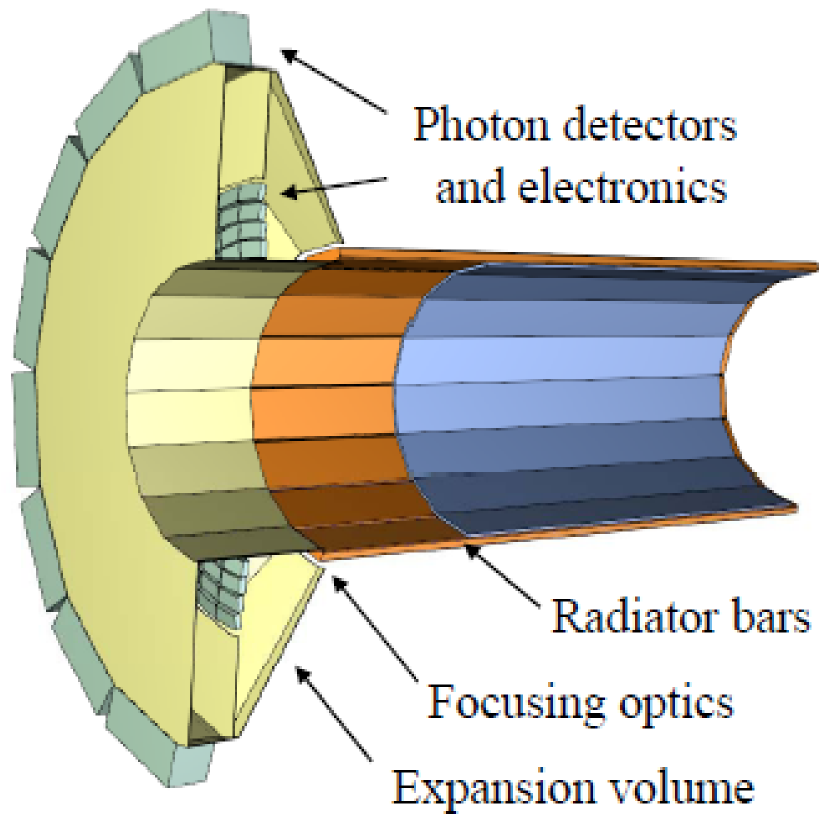
DIRC - barrel

Detection of Internally Reflected Cherenkov light



- Different Cherenkov angles give different reflection angles



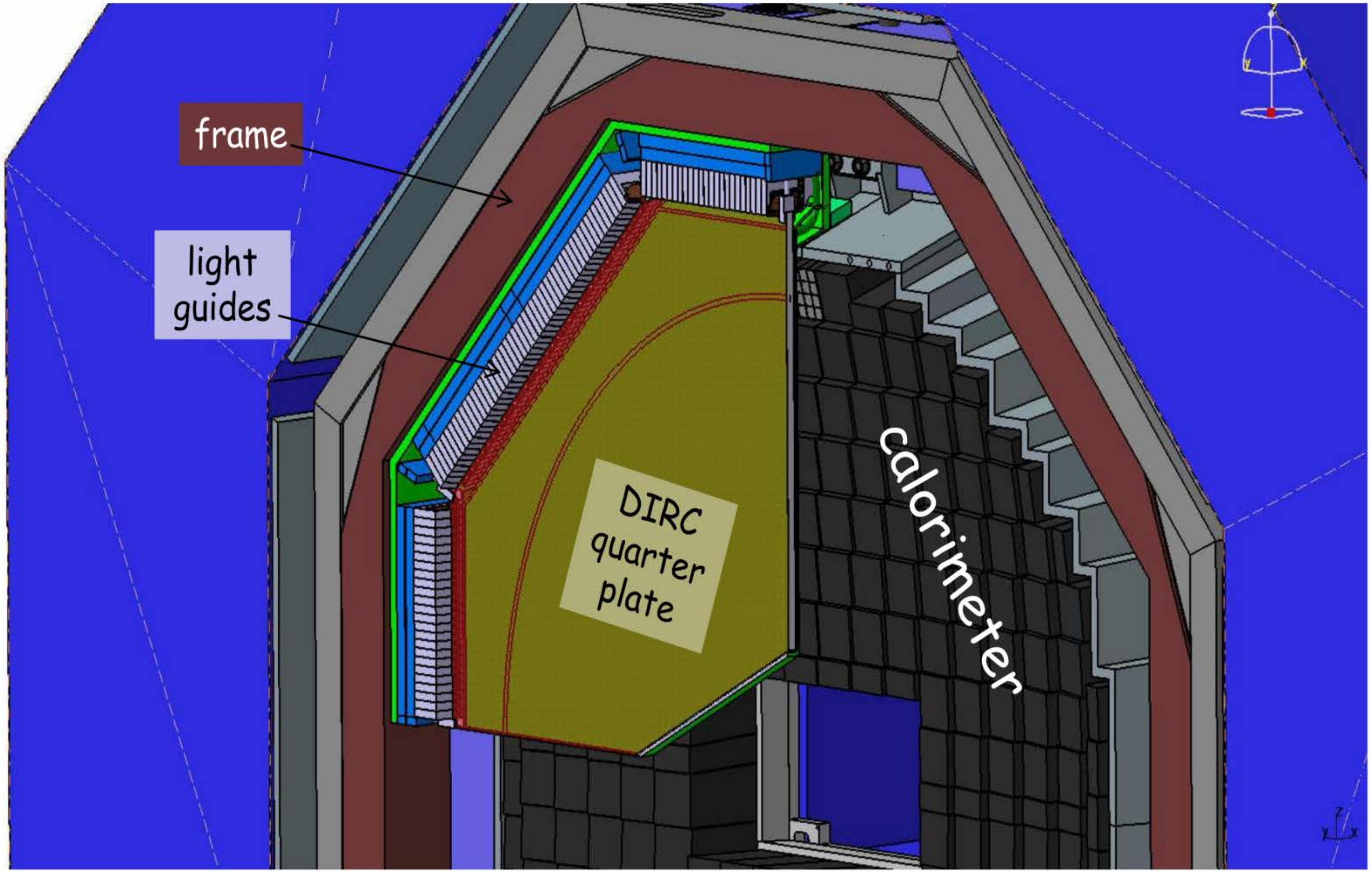


PANDA DIRC similar to BaBar

- 80 Fused silica bars, 2.5m length
- Oil tank & MCP-PMT (10k-15k pixels)
- *Alternative readout:* (x,y,t), mirrors, lenses

Frontend DIRC

Univ. Giessen



M. Düren, DIRC11, April 5, 2011

- Fast and small pixel detectors: SiPMs or MCPs
- Angle measurement by small focussing light guides und multi-pixel detectors
- ToP measurement by small light guides and fast photo detectors
- Dispersion handling by dichroic band pass filters

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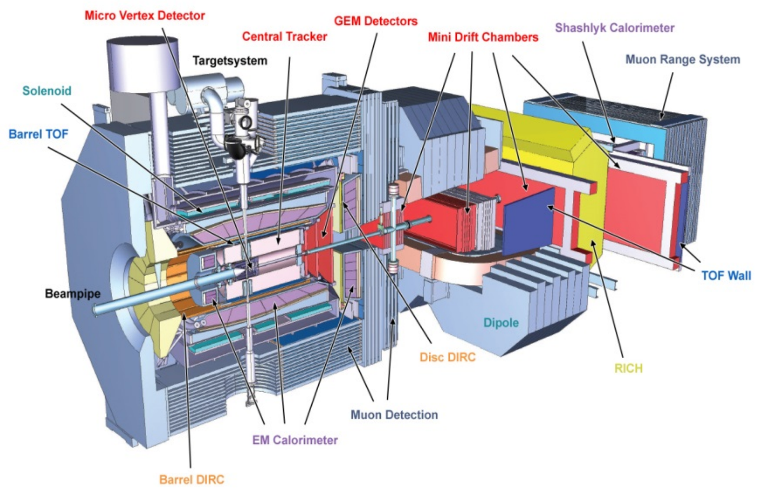
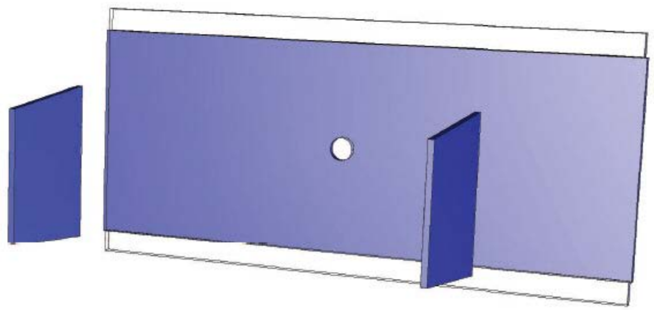
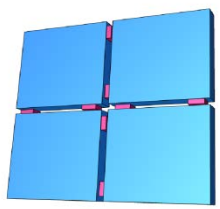
Time of Flight System

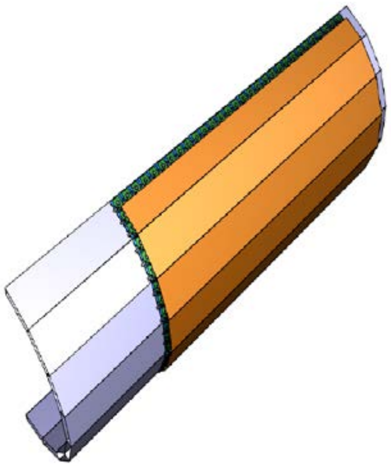


Forward TOF



- PANDA: no hardware trigger
- Motivation
  - Event timing/ event building/ software trigger
  - Conversion detection
  - Charged particle TOF (relative timing)



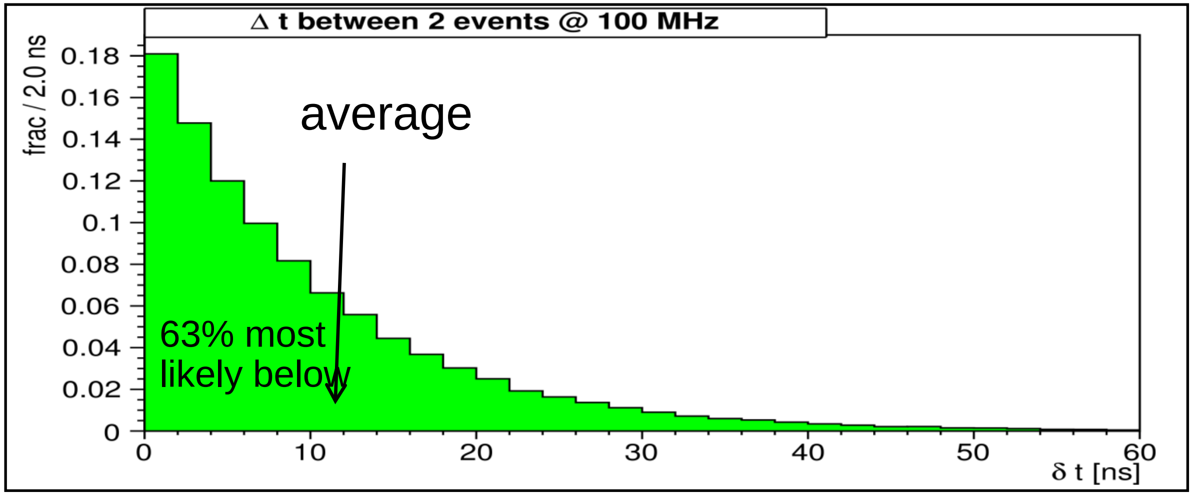


Barrel TOF : SciTil

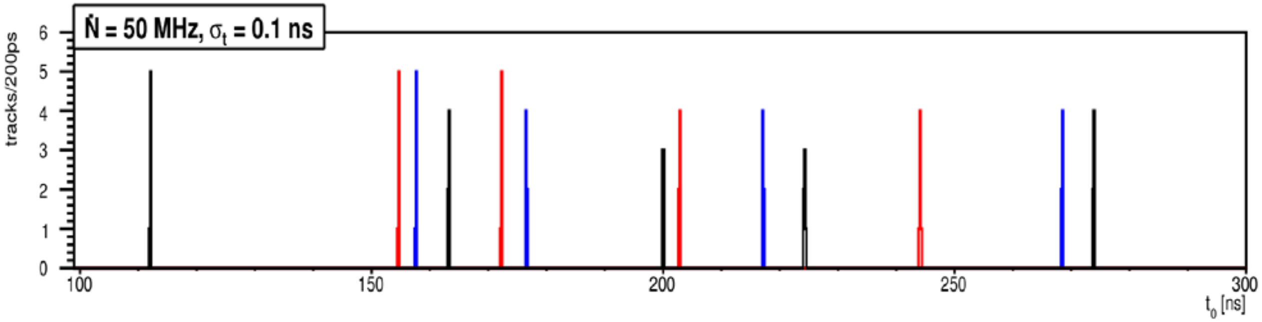
Event timing

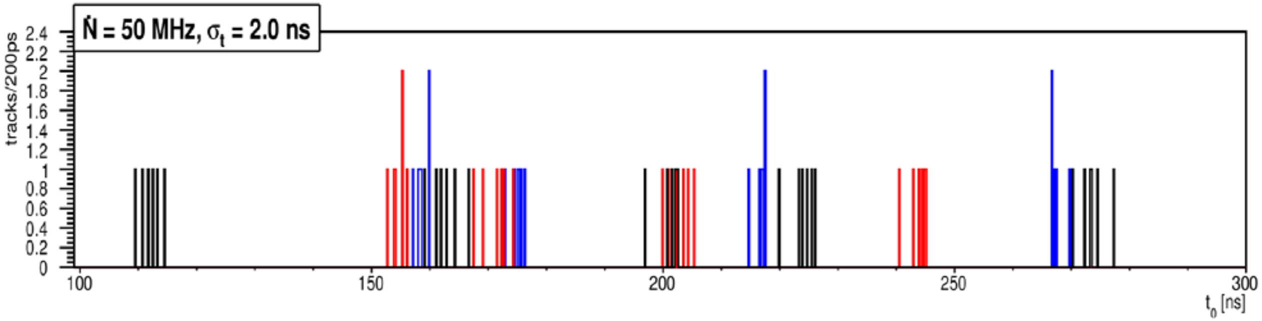
- Time between successive events are **not equally spaced** but follow a **exponential distribution : avg ~ 10 ns**

  On this time scale : all data collected to form data package



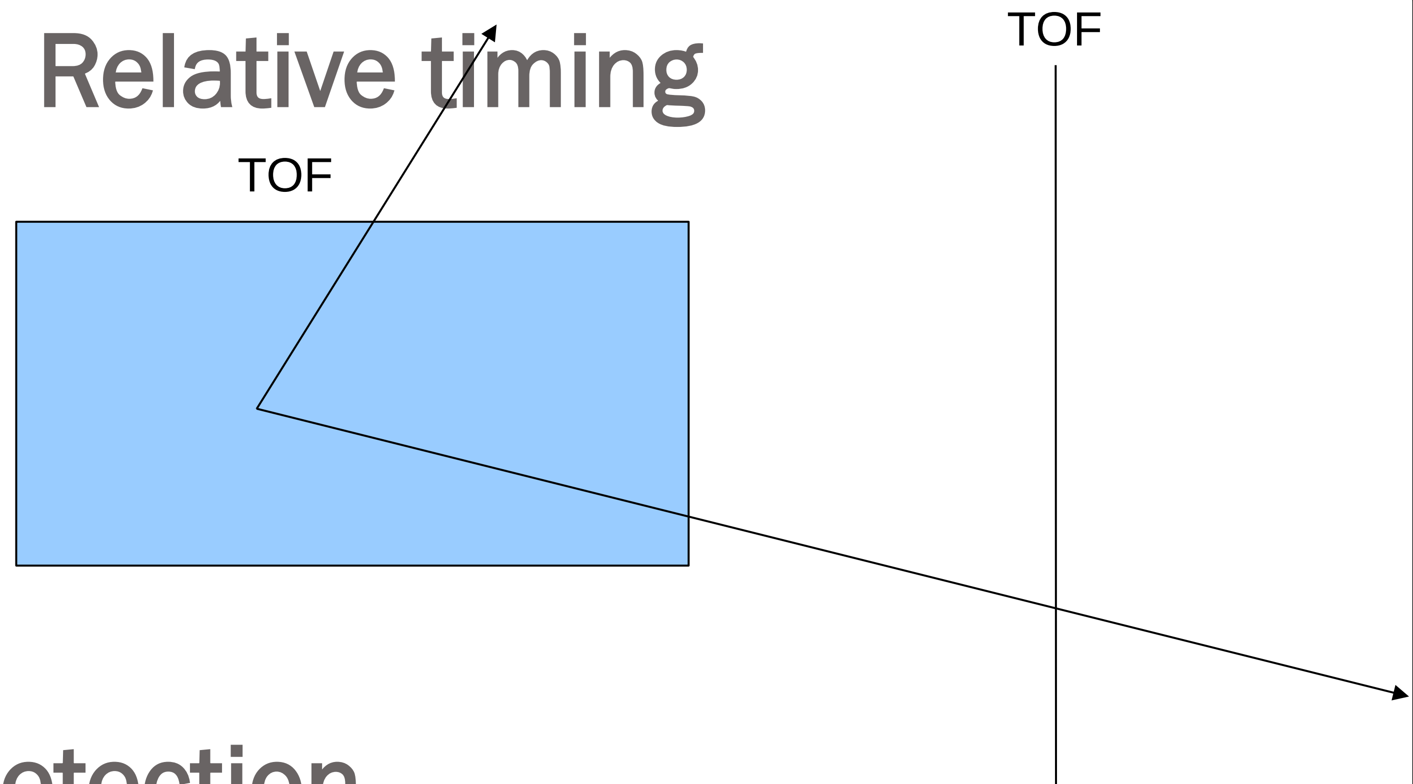
- Events 1,2,3,4,5,6,7,8... for 50Mhz interaction rate with 6 tracks





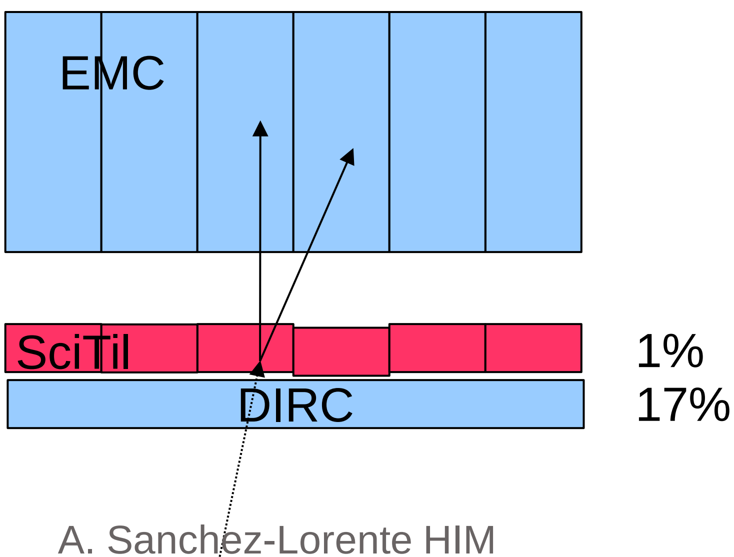
Klaus Götzen,Influence of Particle Timing on Event Building PANDA collaboration meeting March 2011, GSI

Relative timing



PANDA has
no start detector
SciTil important for
relative timing and PID

Conversion detection



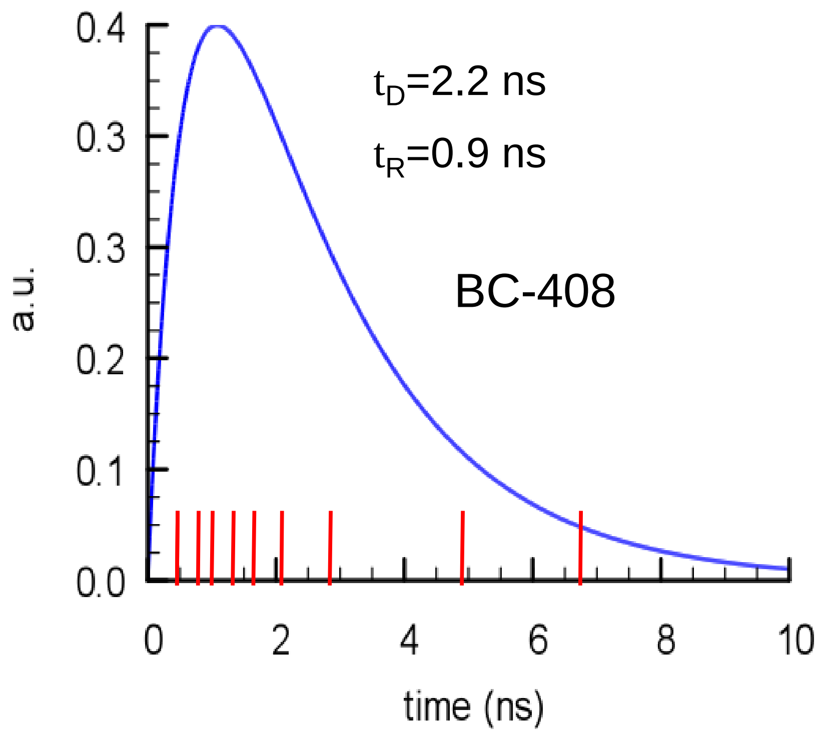
Conversion of gammas within the DIRC can be detected with the SciTil

Choice of Scintillator Material

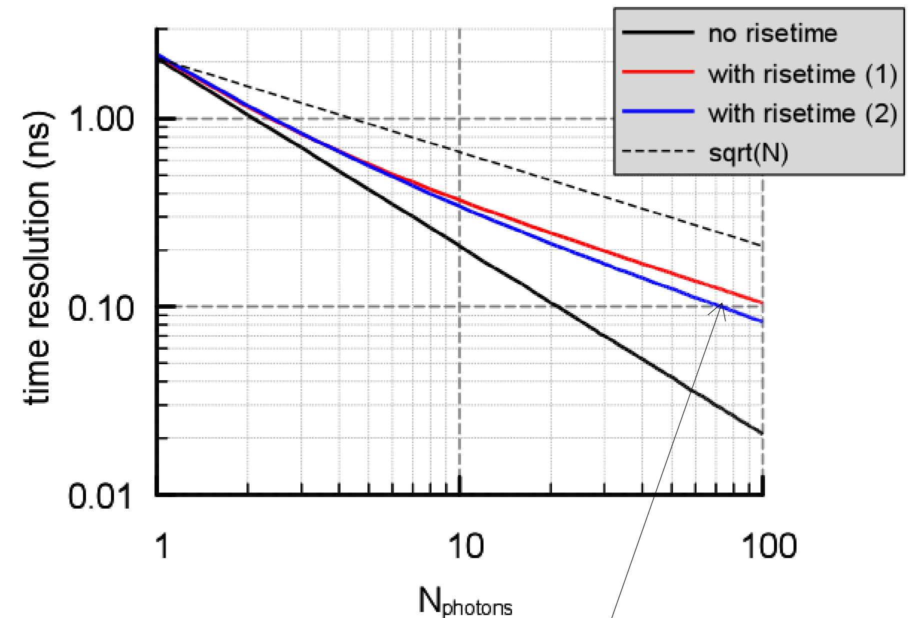
For subnanosecond timing: timing on first arriving photon
→ Time resolution depends on number of photons.

Rise time comparable to wanted time resolution
→ Additional smearing of first photon

Rise time + exponential:



Simulation

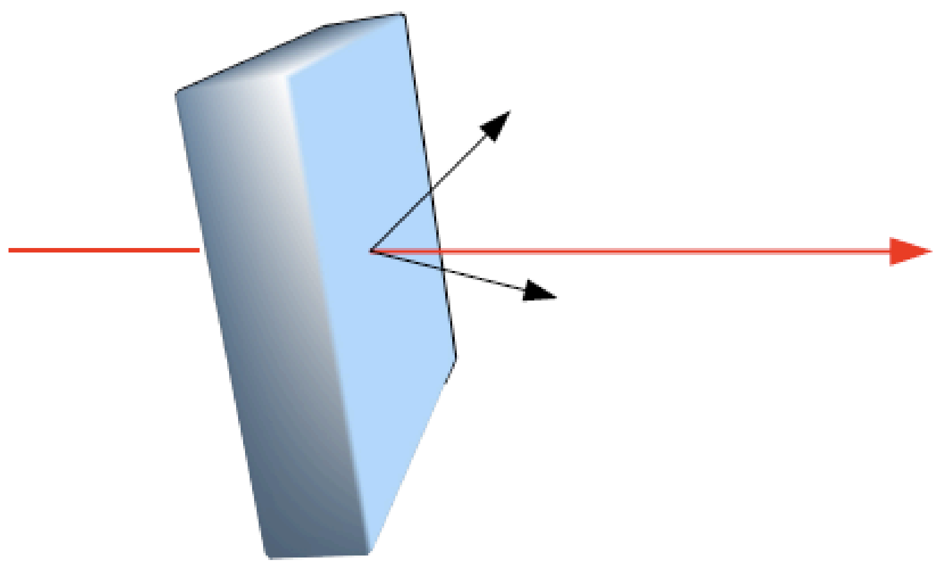


BC-408: 100 ps
100 photons

Time spread of first photon (RMS) for many events ~1/sqrt(N)

Photon number

Tile 30 x 30 x 5 mm^3



Minimum ionizing particle

ΔE = 1 MeV
= 10^4 photons — generated

70% hit rim
= 7000 photons — on rim

PD area = 18 mm^2
rim area = 600 mm^2

= 210 photons — geometry

55% PD efficiency — PDE

= 115 photons

30 x 30 x 5 mm^3 → 115 photons
20 x 20 x 5 mm^3 → 180 photons

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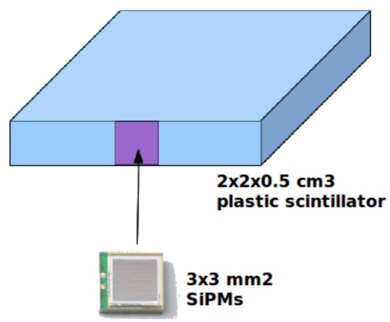
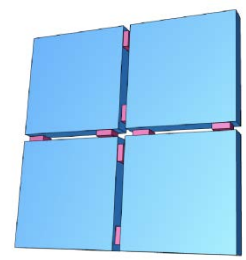
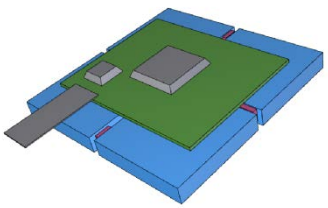
Scintillator Tile Detector Geometry

- Low material budget :1% radiation length

1. Four tiles arranged with their SiPMs for densest packing:
2. A quad module with a R&D PCB based on 8-channel readout ASIC and a data transfer chip.

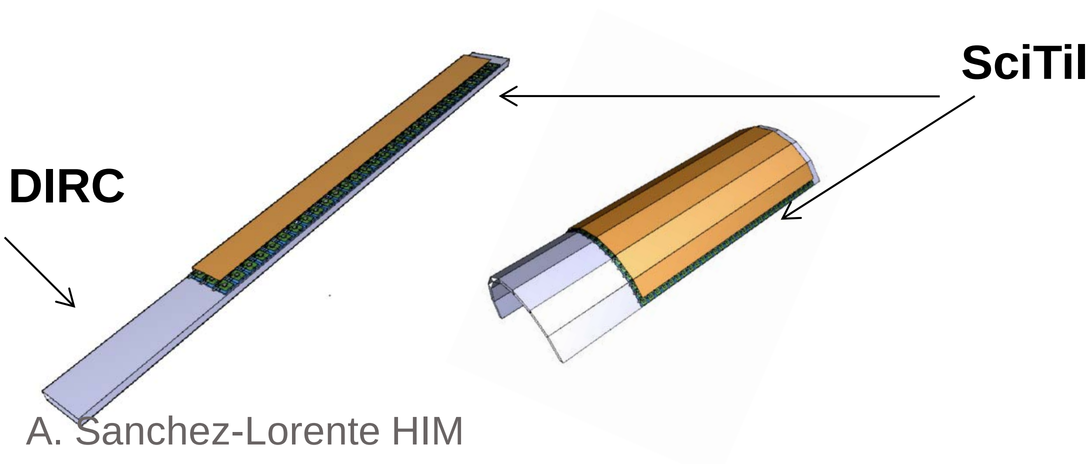




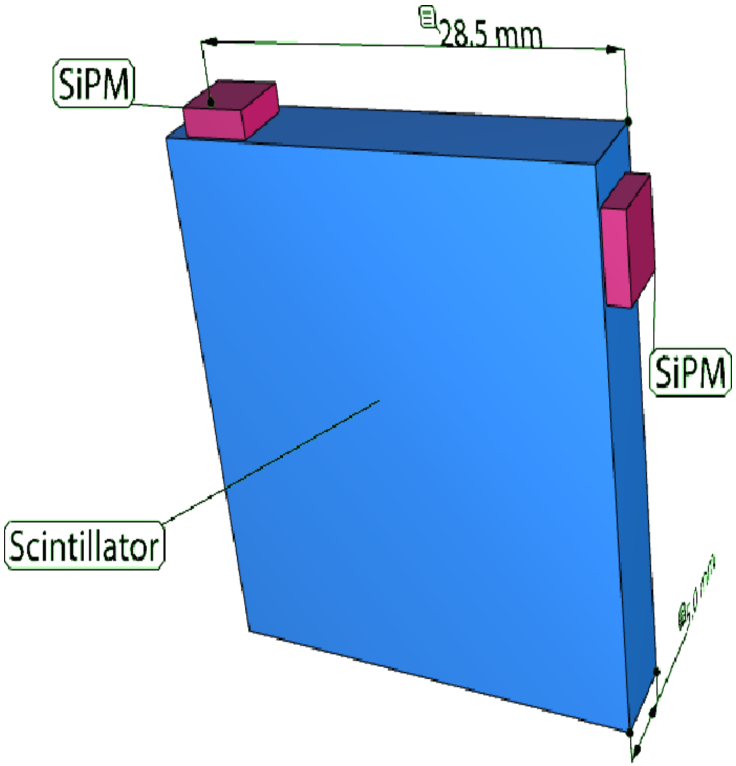


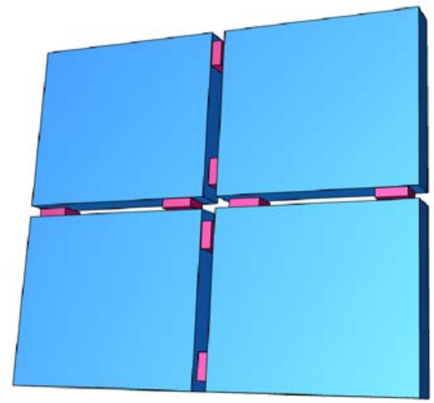
1. Supermodule : (3X30) 90 quad modules on top of a DIRC bar box.

1. Entire SciTil half barrel composed of 8 super-modules

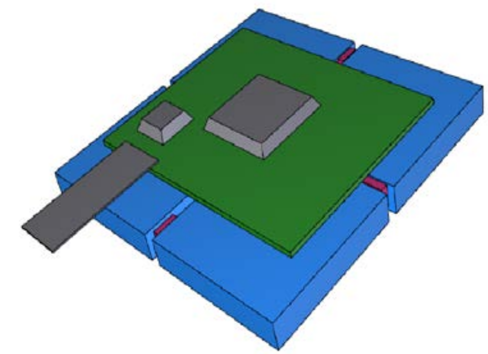


Mechanics





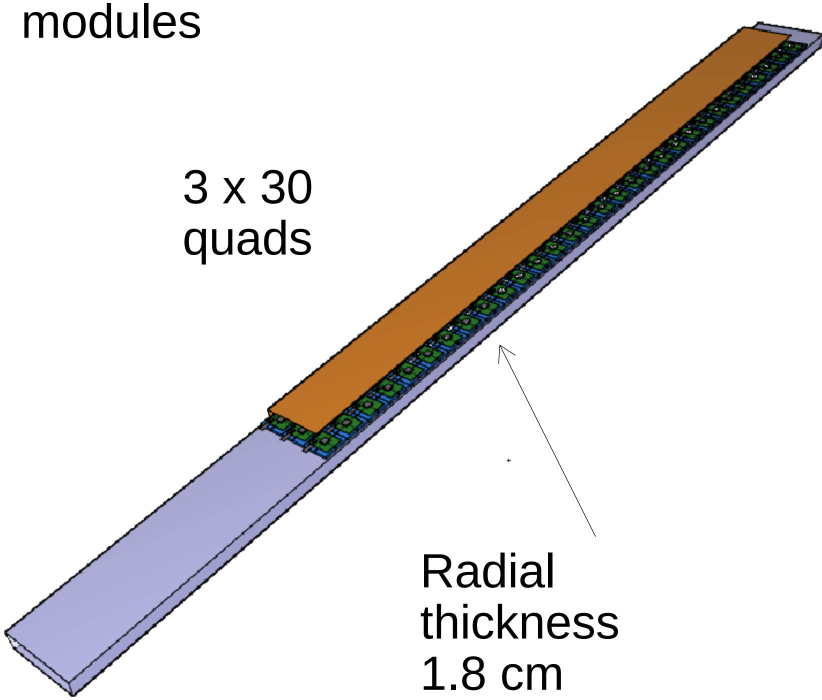
Quad
module



With electronics
8 ch. ASIC
data transfer IC

Readout at two positions
- more photons
- less light path fluctuations
- larger detection efficiency

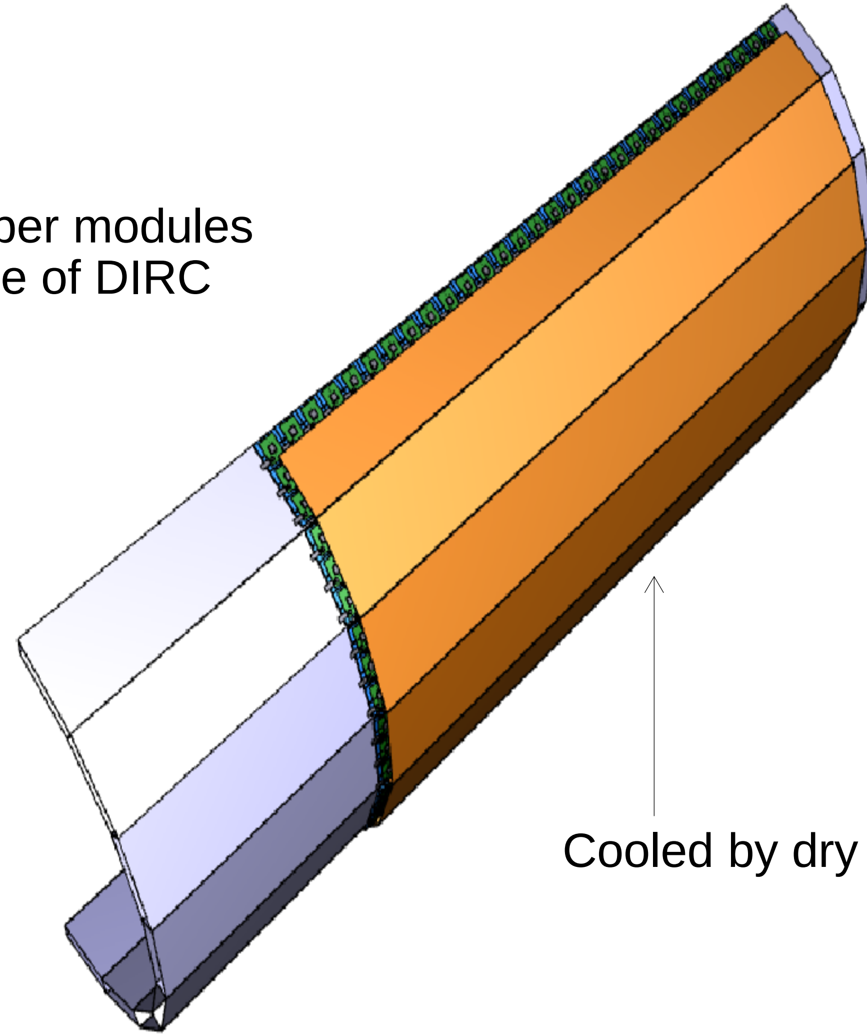
Super-module = 90 quad modules



3 x 30 quads

Radial thickness 1.8 cm

16 super modules outside of DIRC barrel

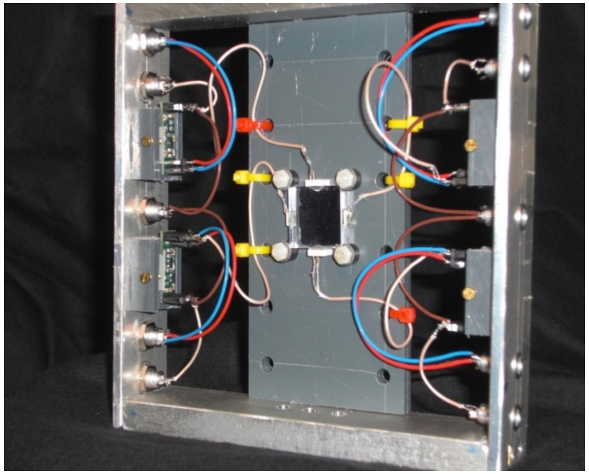


Cooled by dry air

Total

5760 SciTils

SciTil prototypes

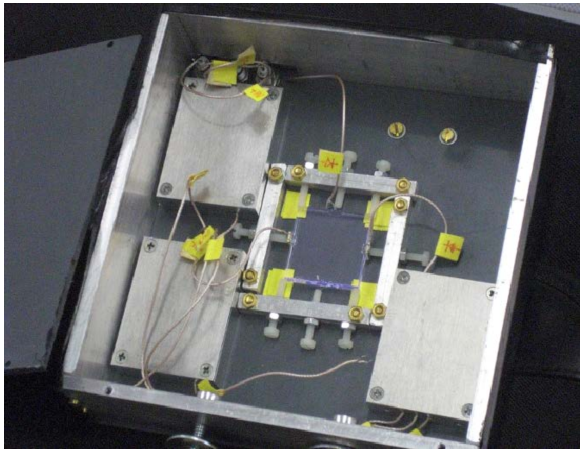


BC408
20 x 20 x 5 mm3

Hamamatsu SiPM
S10931-050P
S10362-33-050C

Photonique
Fast amplifier 611

Readout
NINO + HADES TRB



BC408
Coupled with BC606

Hamamatsu SiPM
2x S10931-050P
1x S10362-33-050C
1x Ketek 3x3 60A2

Photonique
Slow amplifier 604
INR Moscow-Amplifier
(F.Guber)

Readout
NINO + HADES TRB

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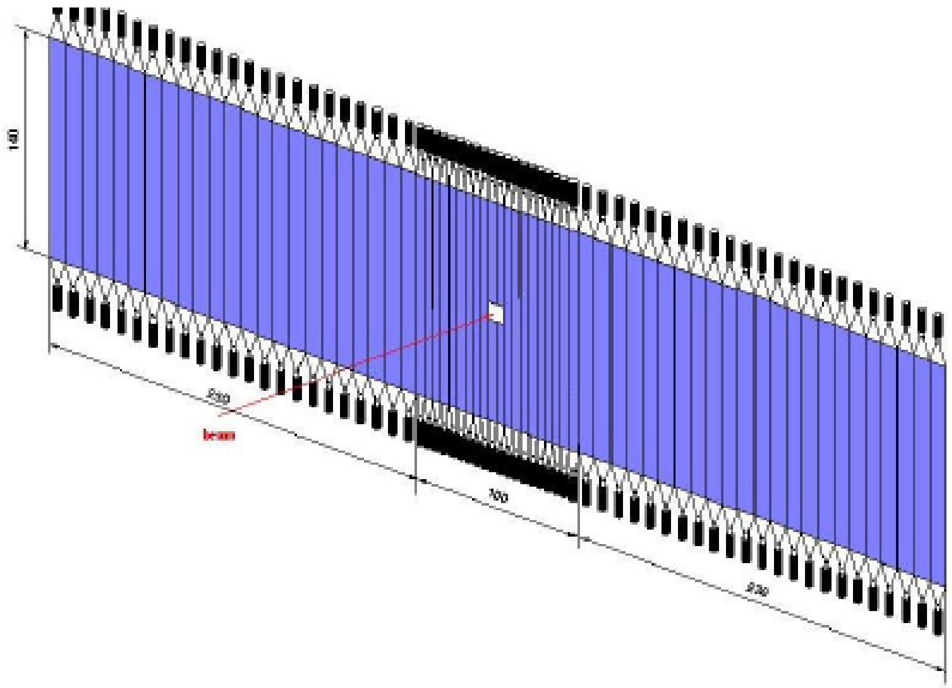
Forward TOF



FTOF

TOF WALL 560cm x 140cm

Distance from I.P. 7m

46 slabs 140*10*2.5 cm3

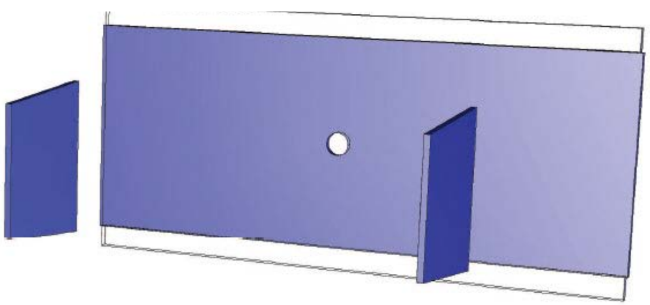
20 slabs 140* 5*2.5 cm3

$$\theta_x = \pm 10\,\mathbf{deg.} \quad \theta_y = \pm 5\,\mathbf{deg.}$$

TOF Side

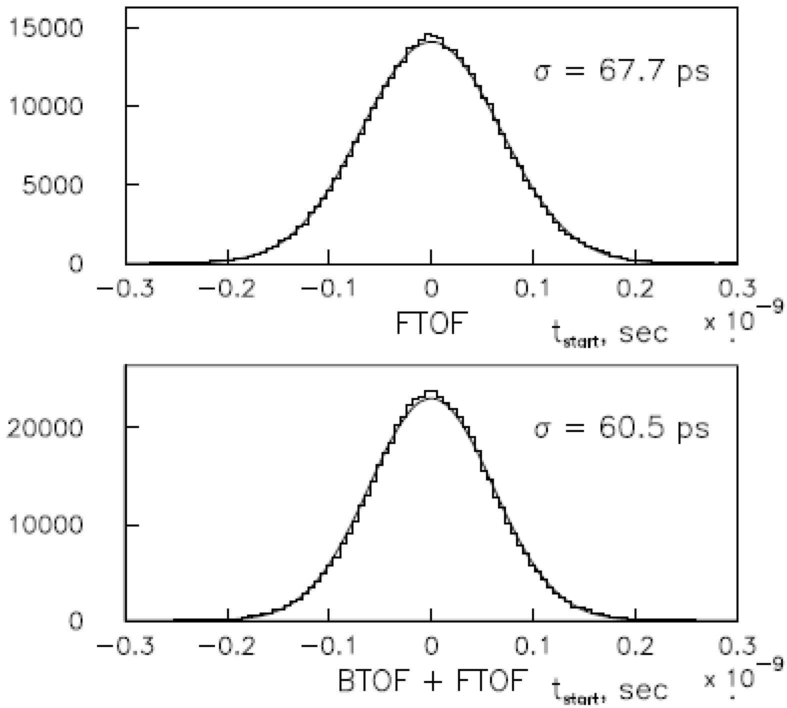
14 slabss 100*10*2.5 cm³

SiPM

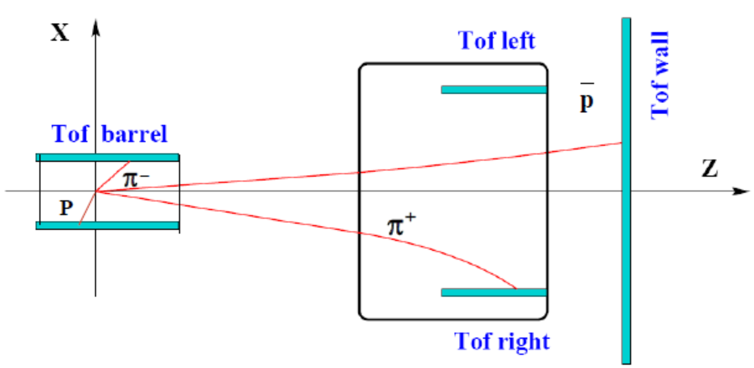


Start time resolution

S. Belostotsky et al. PANDA CM 2011



$\sigma < 100$ps !!



Event l contains **k** tracks

with $\mathbf{t_{stop,k}}$, $\mathbf{p_k}$, $\mathbf{L_k}$

For each track $\mathbf{t_{start,ki(k)}}$

calculated under assumption

$\mathbf{m = m_i \quad i =}$ $\mathbf{p}, \pi, \mathbf{k}, \mu, \mathbf{e}$

$$\min \Psi_l(t_{start}) = \sum_k \frac{\left(t_{start} - t_{start,ki(k)}\right)^2}{\sigma_k^2}$$

$\Rightarrow t_{start}$ for a given combination

using χ^2 distribution

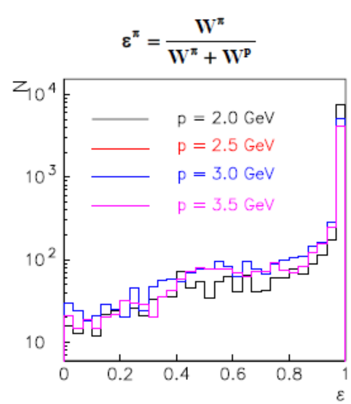
probability function W

of a given combination calculated

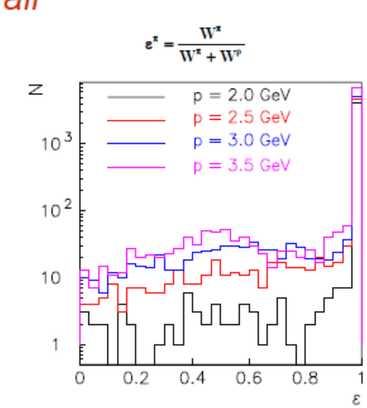
$$\varepsilon^\pi = \frac{W^\pi}{W^\pi + W^p}$$

is built for each track

Probability function to be a pion for forward TOF wall

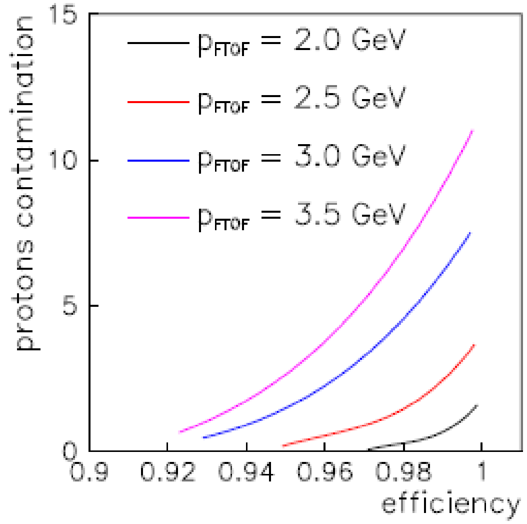


FTOF

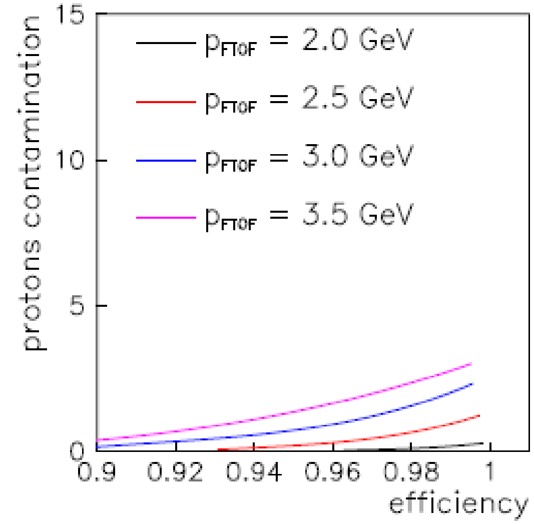


FTOF +BTOF

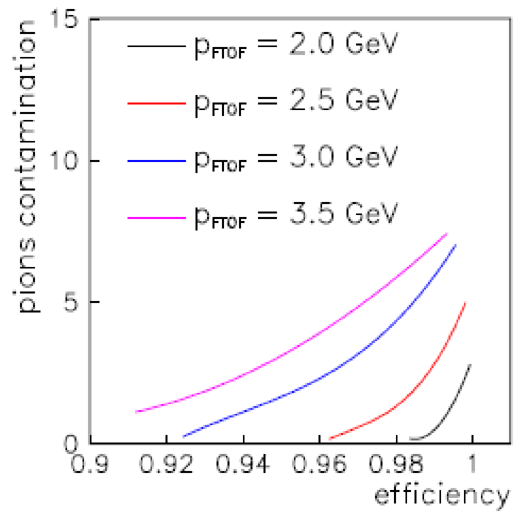
Proton-pion separation for FTOF and FTOF +BTOF in "pion sample"



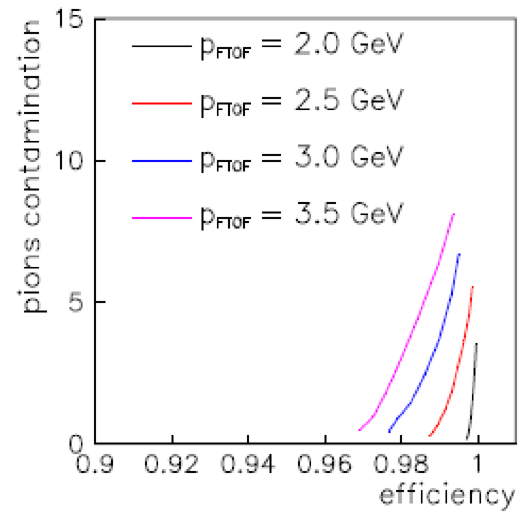
FTOF



FTOF + BTOF



FTOF



FTOF+BTOF

A. Sanchez-Lorente HIM

Conclusion & Outlook

- PANDA offers a high capability Particle Identification thanks to a complete set of innovative detectors *Physics Book arxiv:0907.0169*
  - A highly granular electromagnetic calorimeter.
  - Charged particles will be identified in the low momentum region by their energy deposit and ToF, in all other momentum regions by innovative DIRC detectors.
  - Forward spectrometer to detect high-momentum particles and by surrounding muon detectors.
  - Bayesian Particle Identification $\Rightarrow$ available, flexibility at the analysis stage
  - TOF system :Time resolution of ~100 ps seems feasible : more R&D test experiments are necessary
- Relative timing by combining barrel and forward tof provides a reliable time resolution extremely important for an event building procedure.

Panda Detector

PANDA interaction rate:
Average 20MHz
Peak 50-100MHz