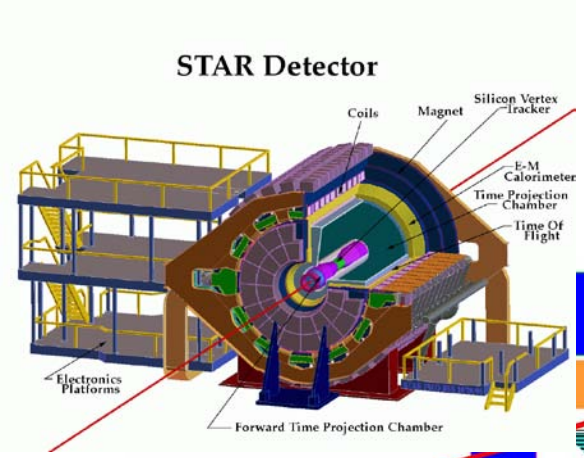
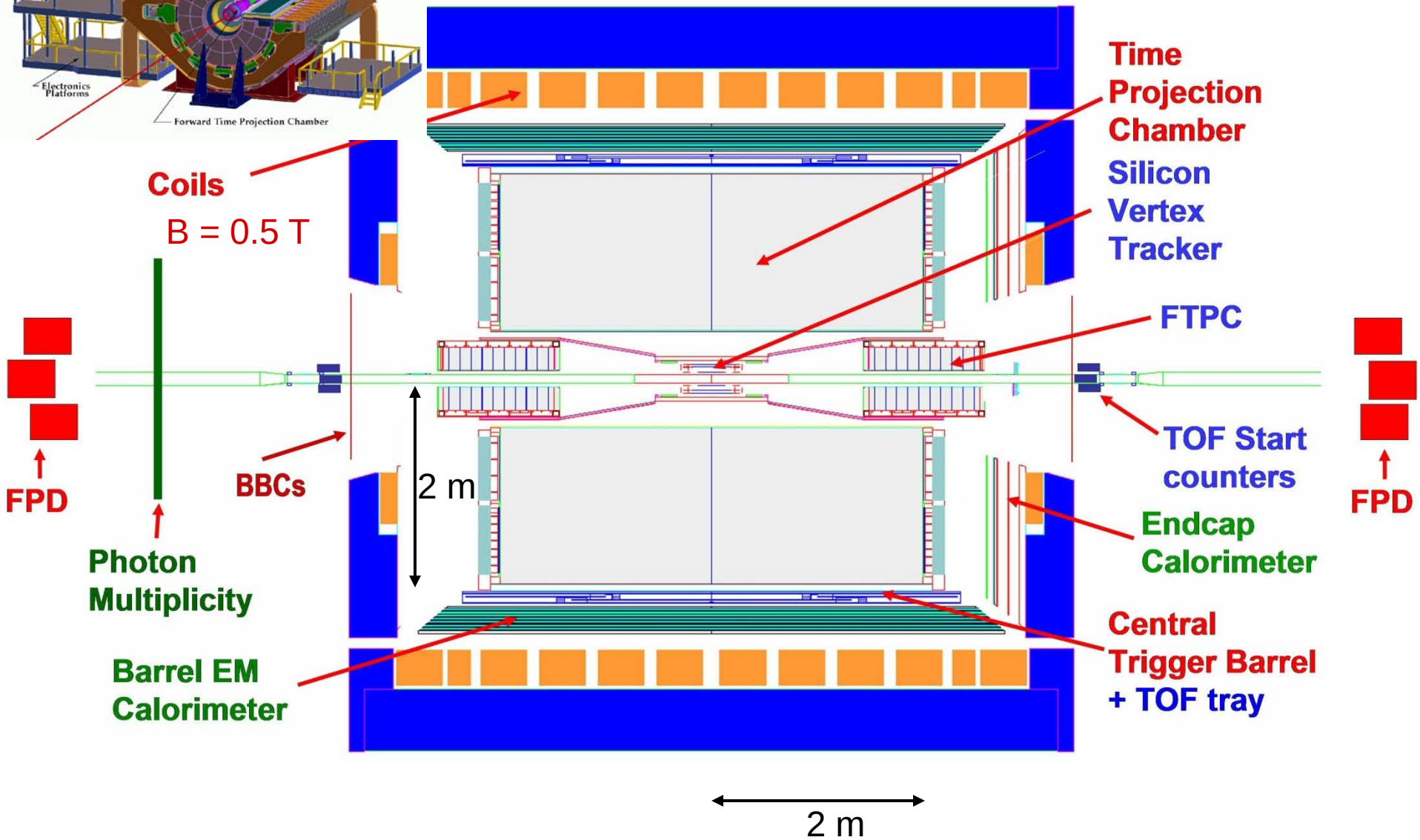
Particle identification.
RHIC (STAR), LHC (ALICE)
(status and future)

N.Smirnov.
Physics Department, Yale University

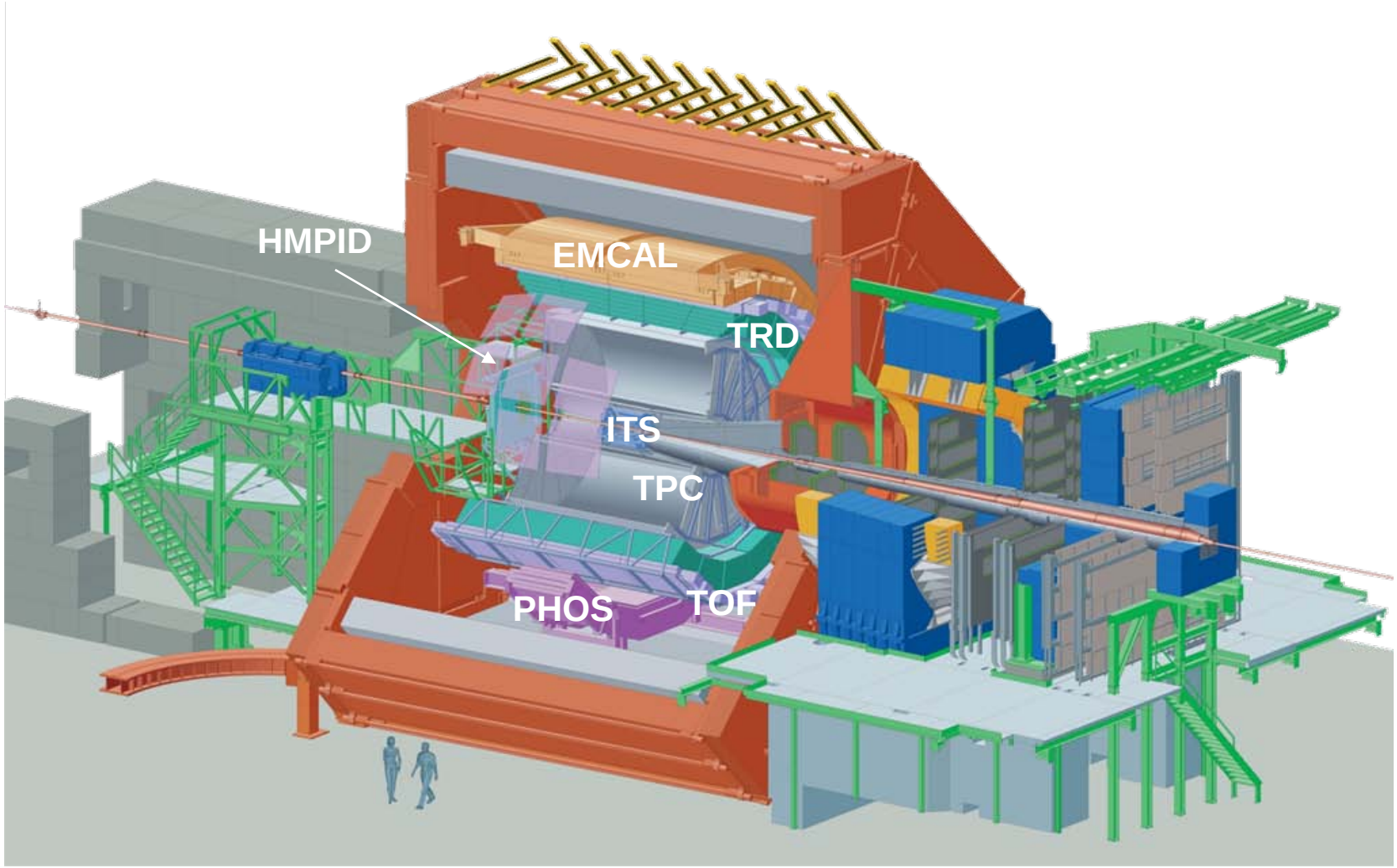
BNL, Detector workshop, December 14-16, 2010.

STAR Detector



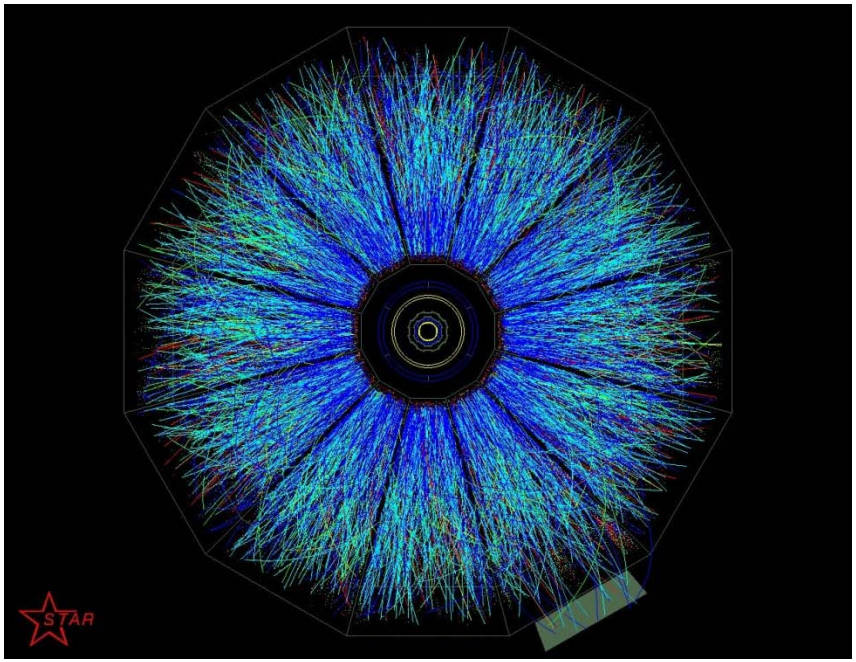


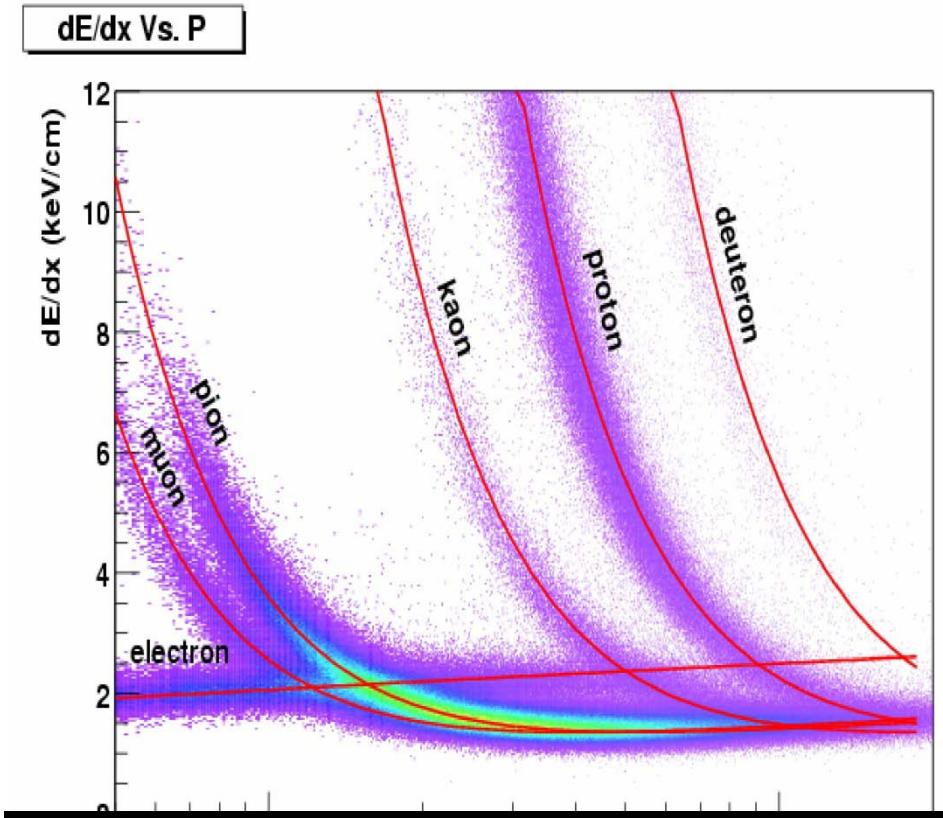
ALICE Detector



STAR; dE/dx at low pT

On-line TPC track reconstruction



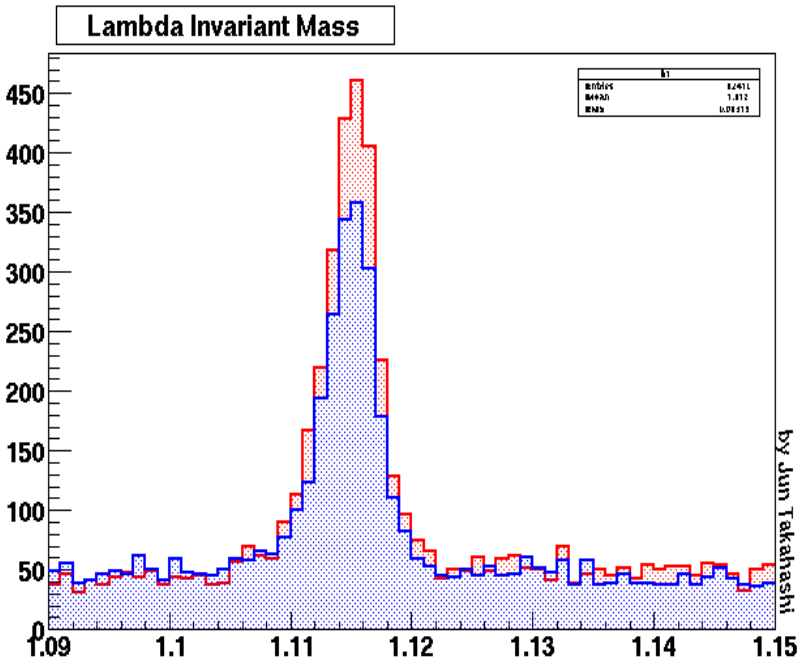


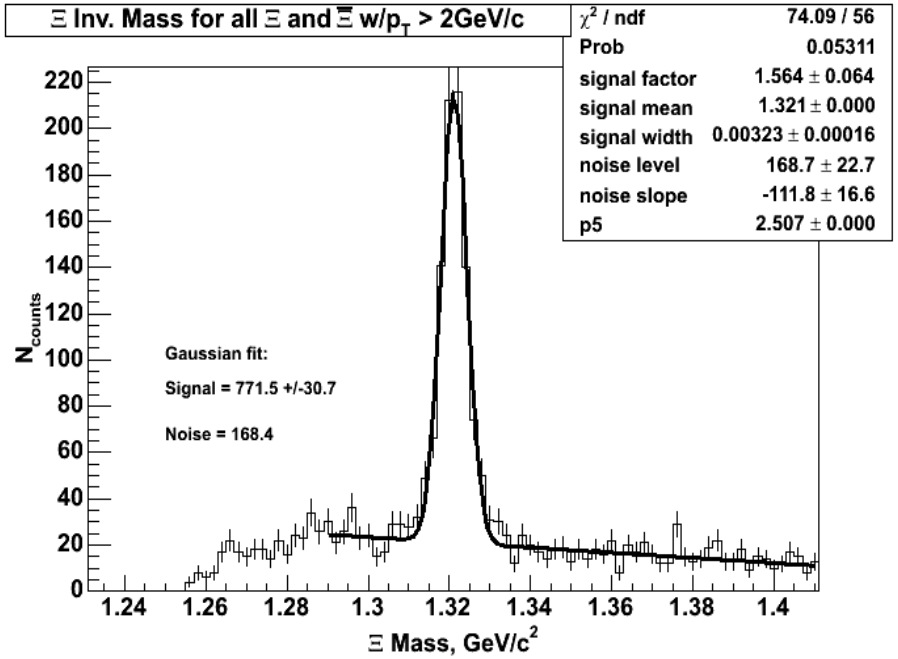
[redacted]

Time Projection Chamber: STAR: 45 padrow, 2 meters (radius), σ(dE/dx) ~8.2%,

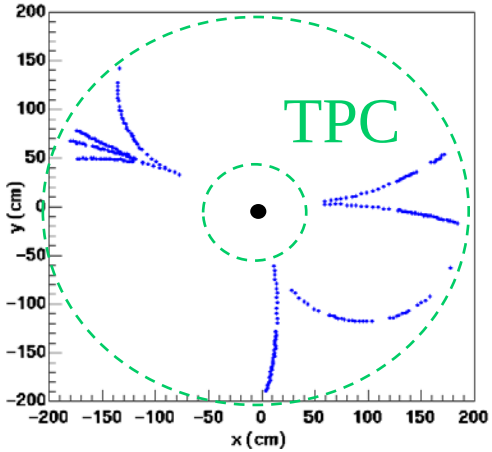
ALICE: 160 padrow, 2.5 meter (radius), σ(dE/dx) ≈ (5.8-7.)% -1<η<1

PiD, Topology and Mass Reconstruction (STAR)





- **Topology analysis (V0s,Cascades, γ-conversion, "kink"-events…)**
- **limitation in low pT, and stat.**



Gas detector (TPC) simulation.
Tracking and dE/dX performance

-- FVP approach *)

-- Monte-Carlo program was prepared to simulate number of interactions (and position along the particle track), and a transfer energy in each interaction as a function of a gas mixture parameters and particle momentum (βγ).

-- GEANT3, detail and careful detector response simulation

*) All details can be found:

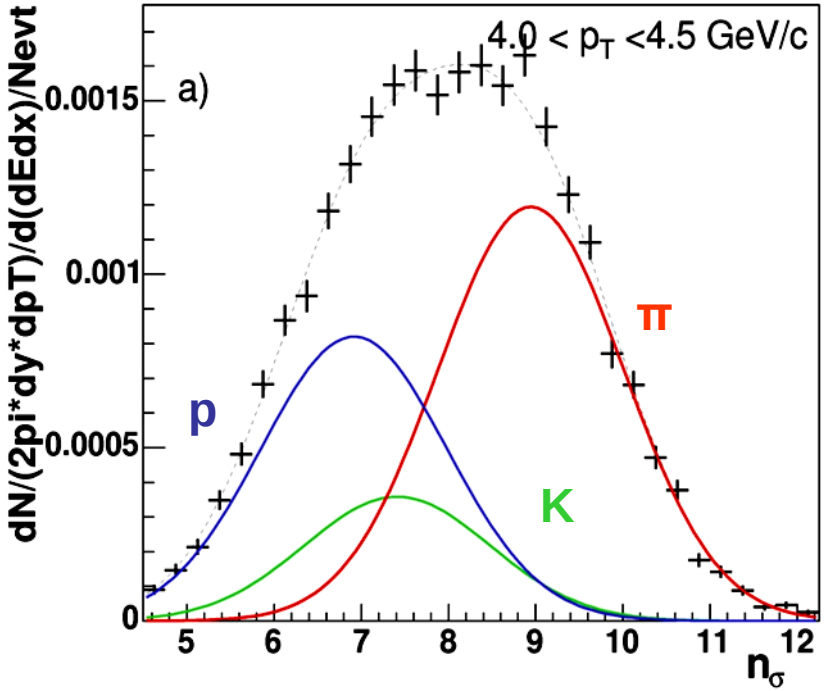
-- H. Bichsel, NIM A562 (2006) 154

-- http://faculty.washington.edu/hbichsel/

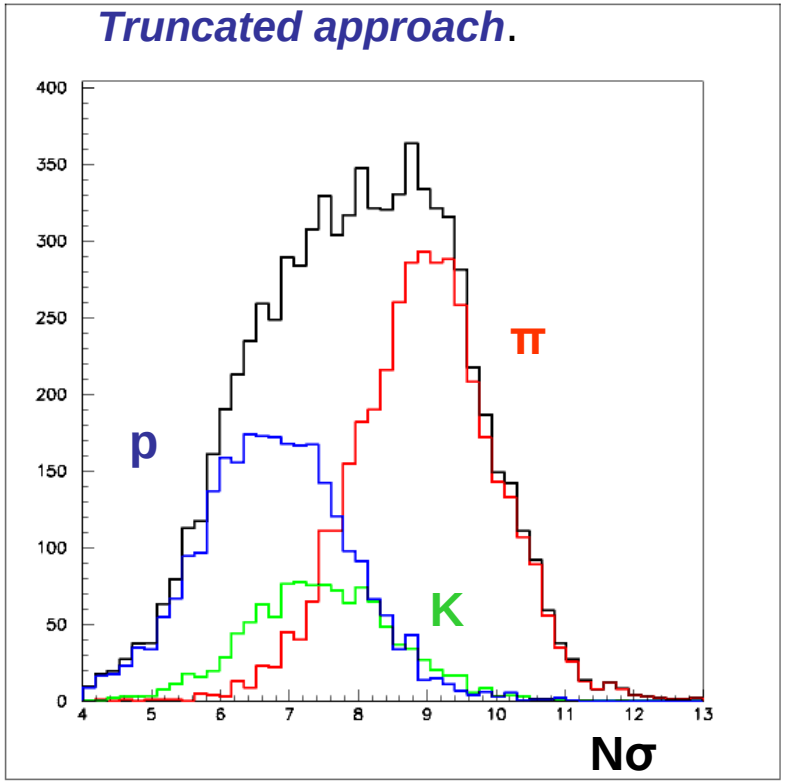
STAR TPC; experiment – simulation comparison

(dE/dX and PID analysis – in "N**σ**" for {log(q / <q>)/σ+9}.)

Data from O. Barannikova,
Proc. 21st Winter Workshop on Nuclear Dynamics (2005).

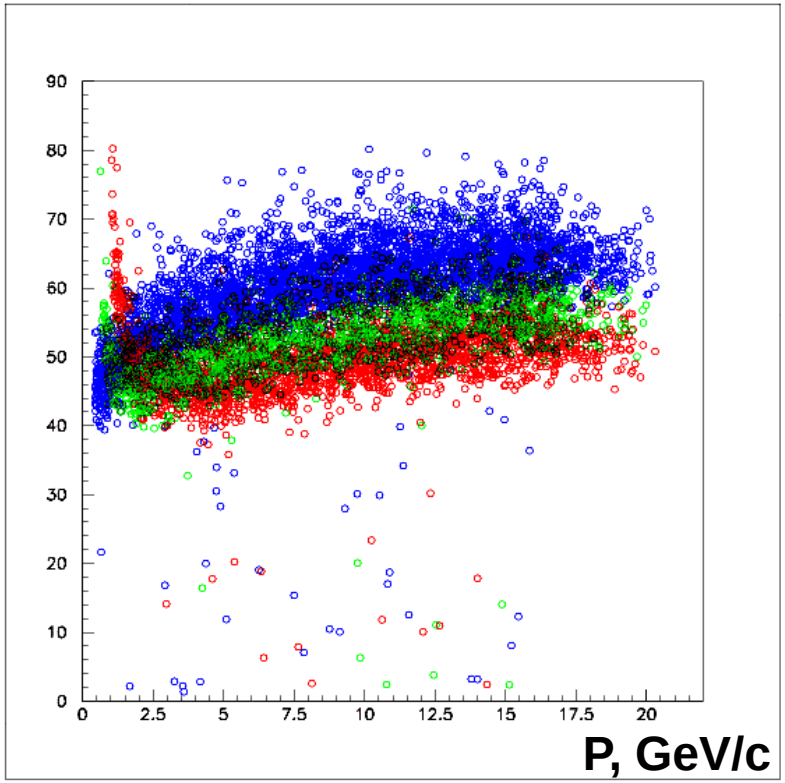


Simulation:
Try to be ACAP with number of Hits / track; and use the same Truncated approach.



Simulation result for ALICE TPC; the same approach, but 90% cluster finding efficiency and “optimal” truncated procedure

dE/dX as a function of momentum

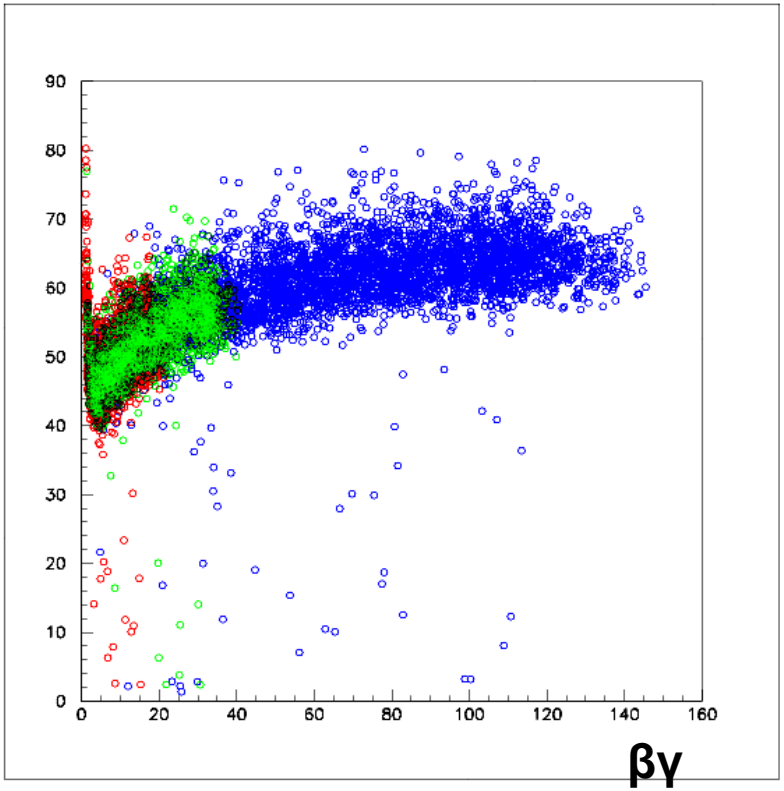


π

K

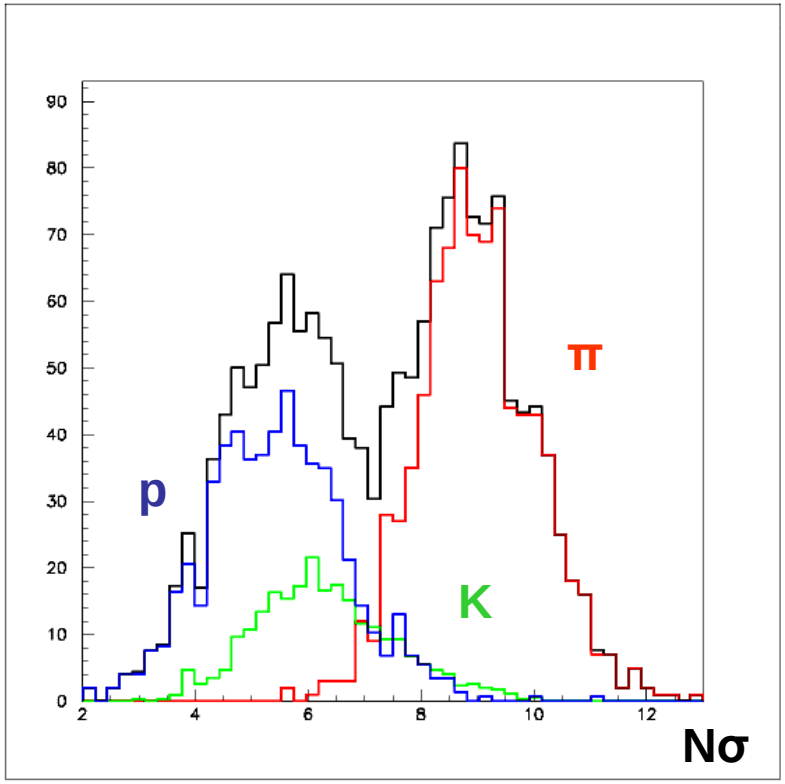
p

dE/dX as a function of βγ

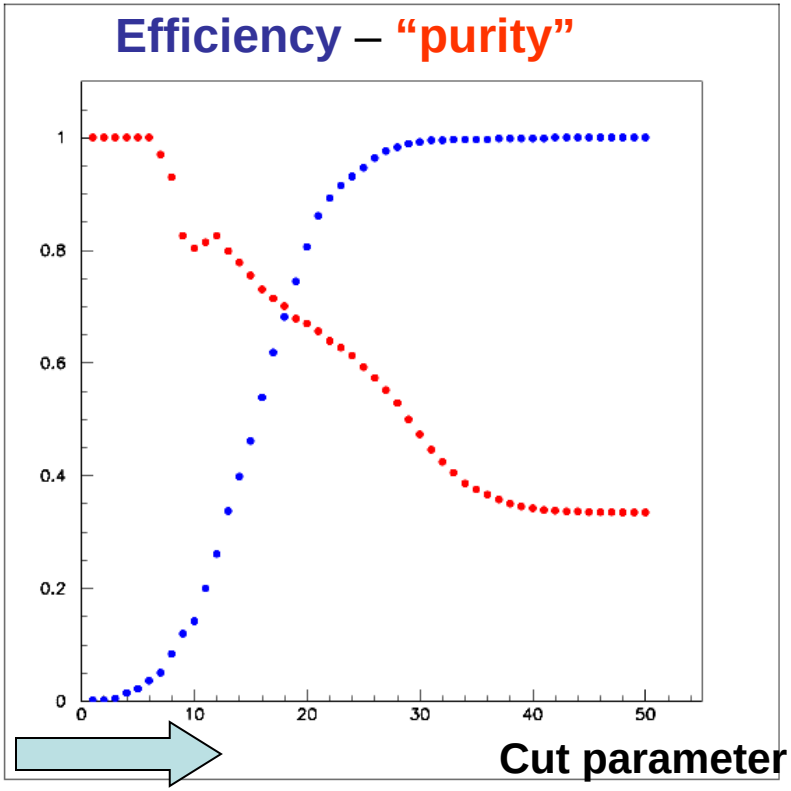


ALICE TPC; PiD performance (on a “track level”)

Particle momentum – 4. GeV/c



Proton identification:



For 70% efficiency – 70% “purity”

Preliminary conclusion (personal opinion)

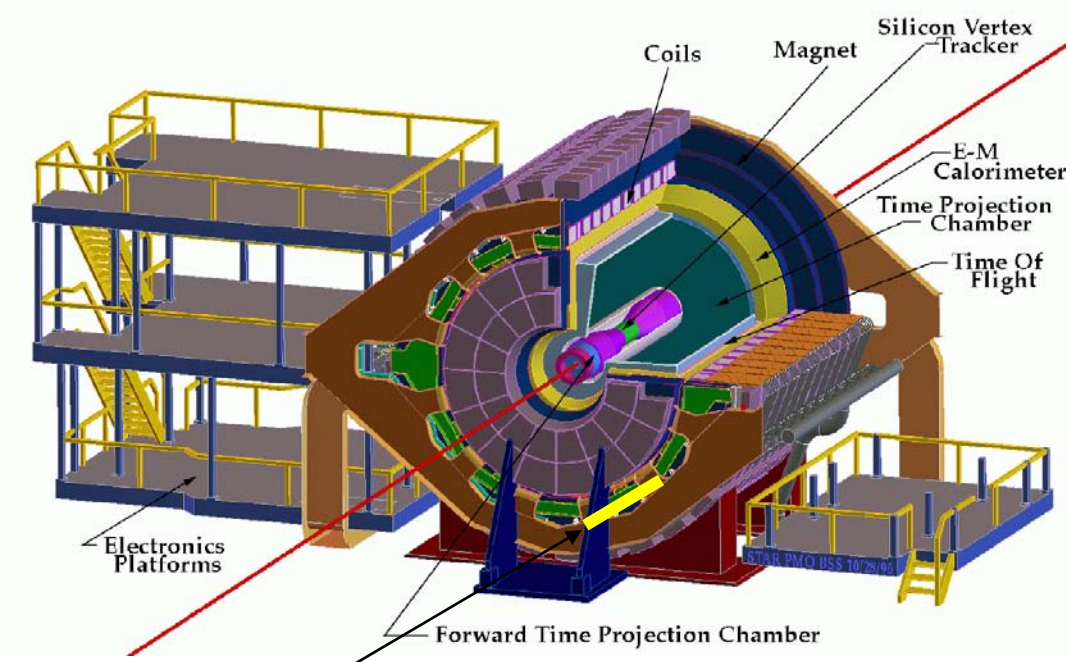
- ALICE TPC PiD performance is not good enough to get high Pt (>10 GeV/c) Proton identification on a “track level”.
- Most probable – simulation results are too optimistic
- In “real” experiment:

  -- cluster finding and track reconstruction is not easy busyness. It is never can be done perfect because of track overlaps, background, distortions.

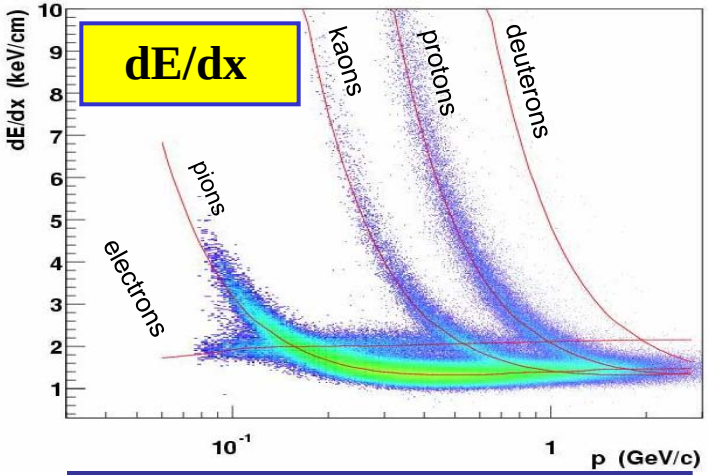
  -- gas amplification and noise have “additional” variations (along wire, wire-to-wire, P/T, …) and should be careful calibrated and under control.
- My forecast is “60 – 60”. But the first run will demonstrate.
-

STAR Detectors

run II Au+Au @ 200 GeV



STAR Time Projection Chamber



$|\eta|<1.5$ and $\Delta\phi = 360^o$

CERN-STAR Ring Imaging Čerenkov Detector Prototype (ALICE, small acceptance)

$r \sim 235$cm, $s \sim 1.1 m^2$
$|\eta|<0.3$ and $\Delta\phi = 20^o$

dE/dx PID range:
[σ (dE/dx) = .08]

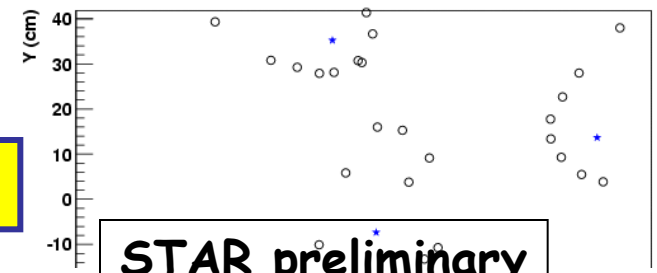
p → ~ 0.7 GeV/c for K/π

→ ~ 1.0 GeV/c for p/x

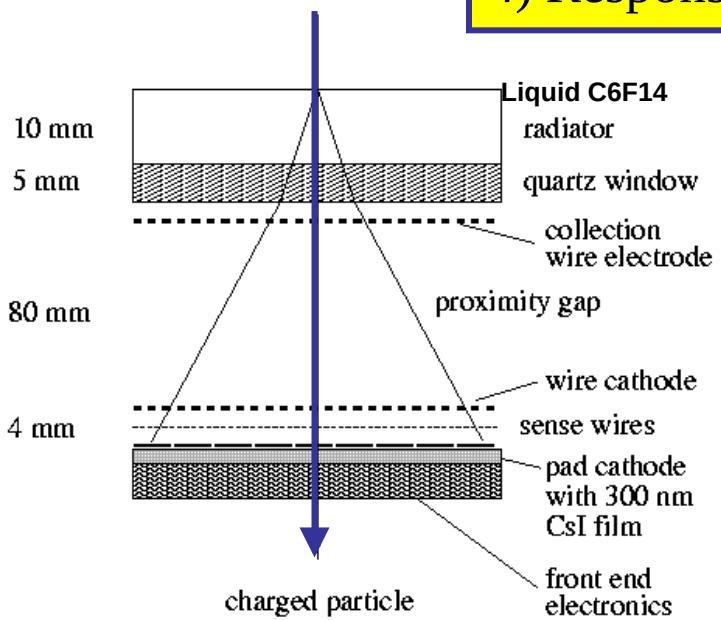
RICH Identification

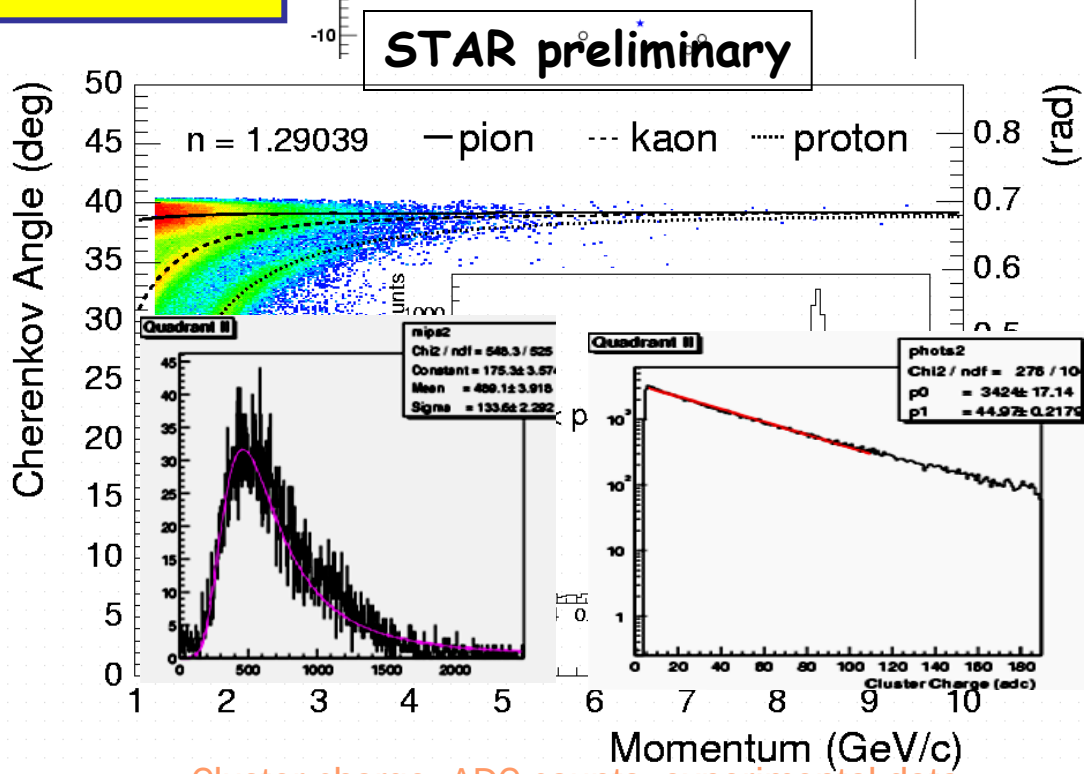
1) Charged particle through radiator
2) MIP and photons detection

3) Ring reconstruction



4) Response simulation



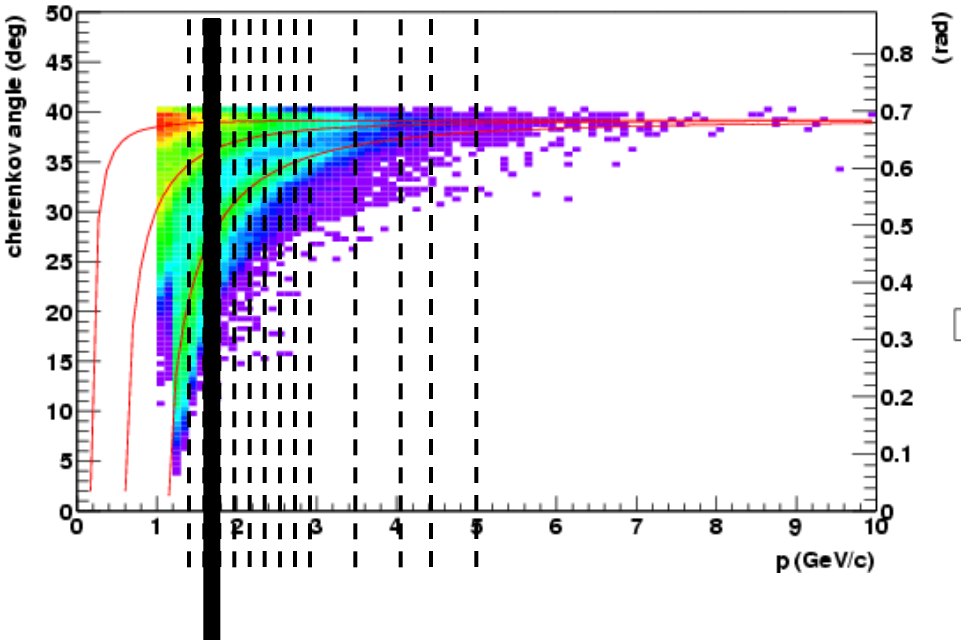


Cluster charge, ADC counts, experimental data

RICH PID range:
1 ~3 GeV/c for Mesons
1.5 ~4.5 GeV/c for Baryons

Cherenkov distribution and Fitting: integrated method

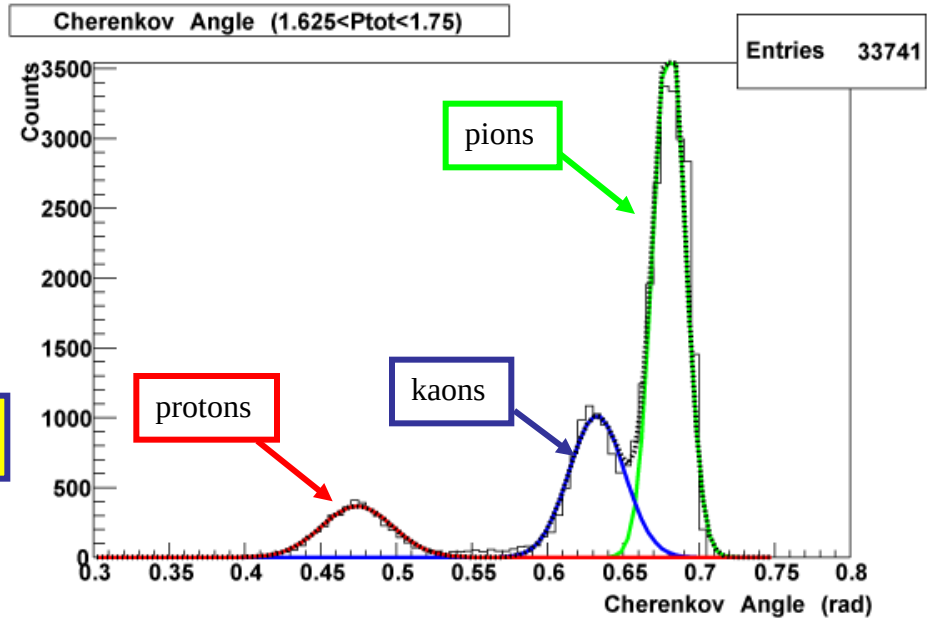
Cherenkov angle distribution in momentum bins



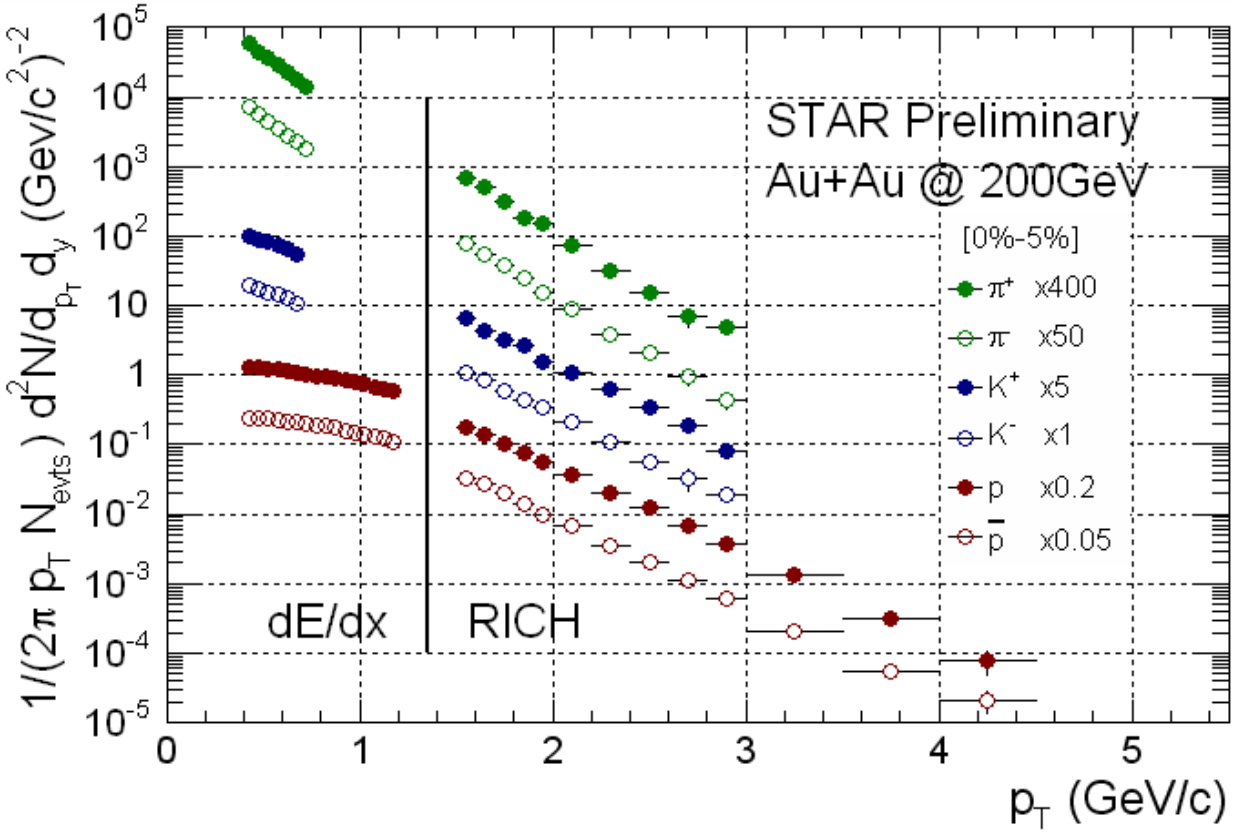
3 Gaussians fit:

- ⇨ 8 (= 9-1 constraint) parameters.
- ⇨ constraint: integral = entries.
- ⇨ fixing parameters with simulation

⇨ Separate species for each momentum slice:

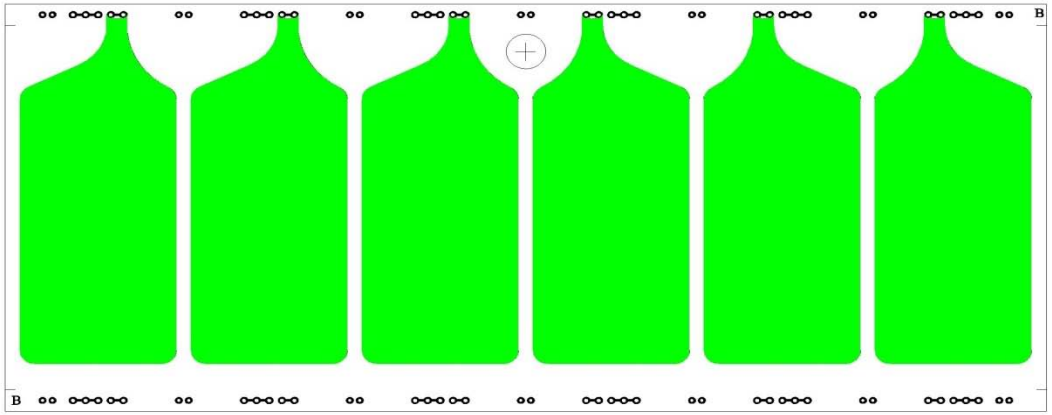


Identified particle p_T spectra

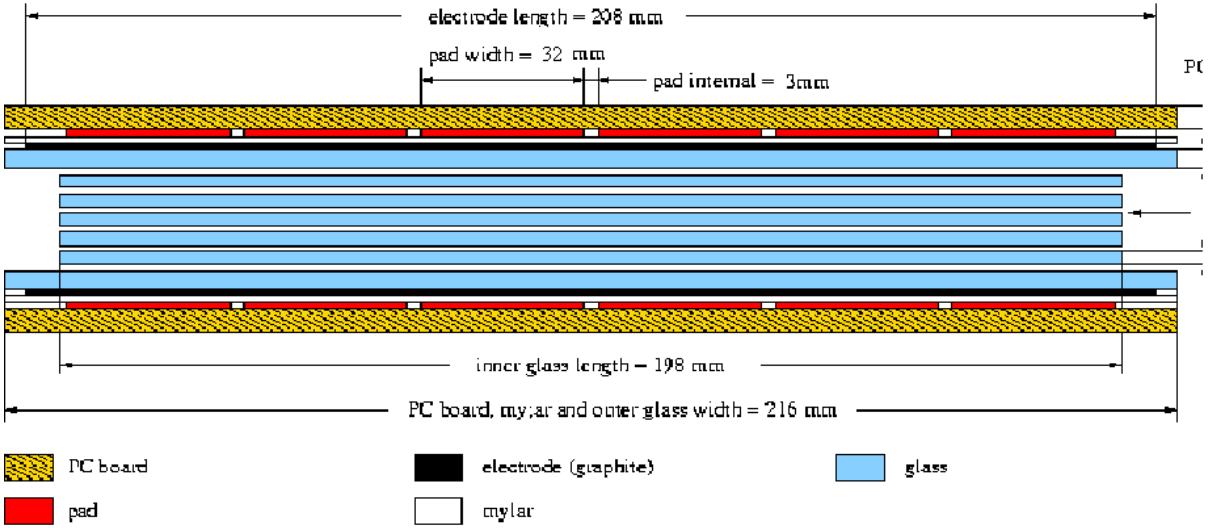


9 such detectors are working in ALICE

Multigap Resistive Plate Chamber
MRPC Technology developed at CERN



Read out pad size:
3.15cm×6.3cm



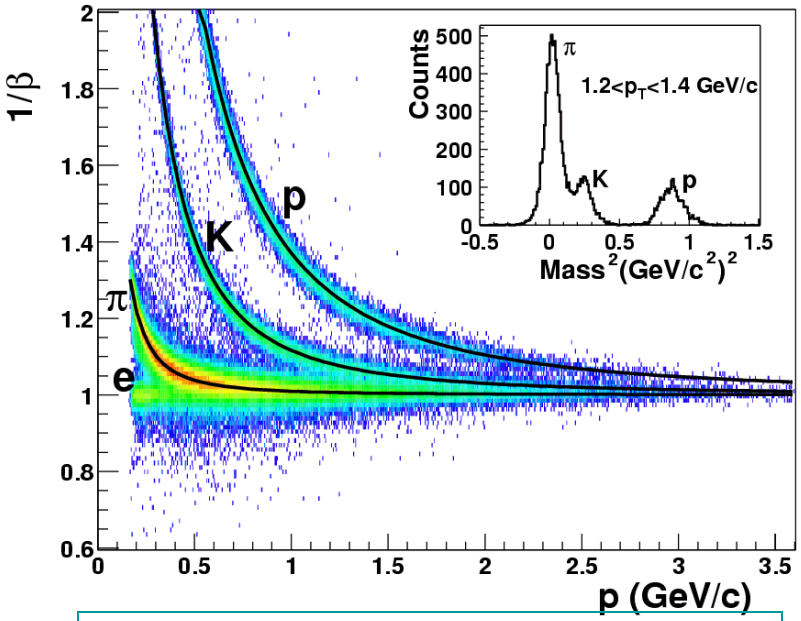
Gap: 6×0.22mm

95% $C_2H_2F_4$
5% Iso-butane

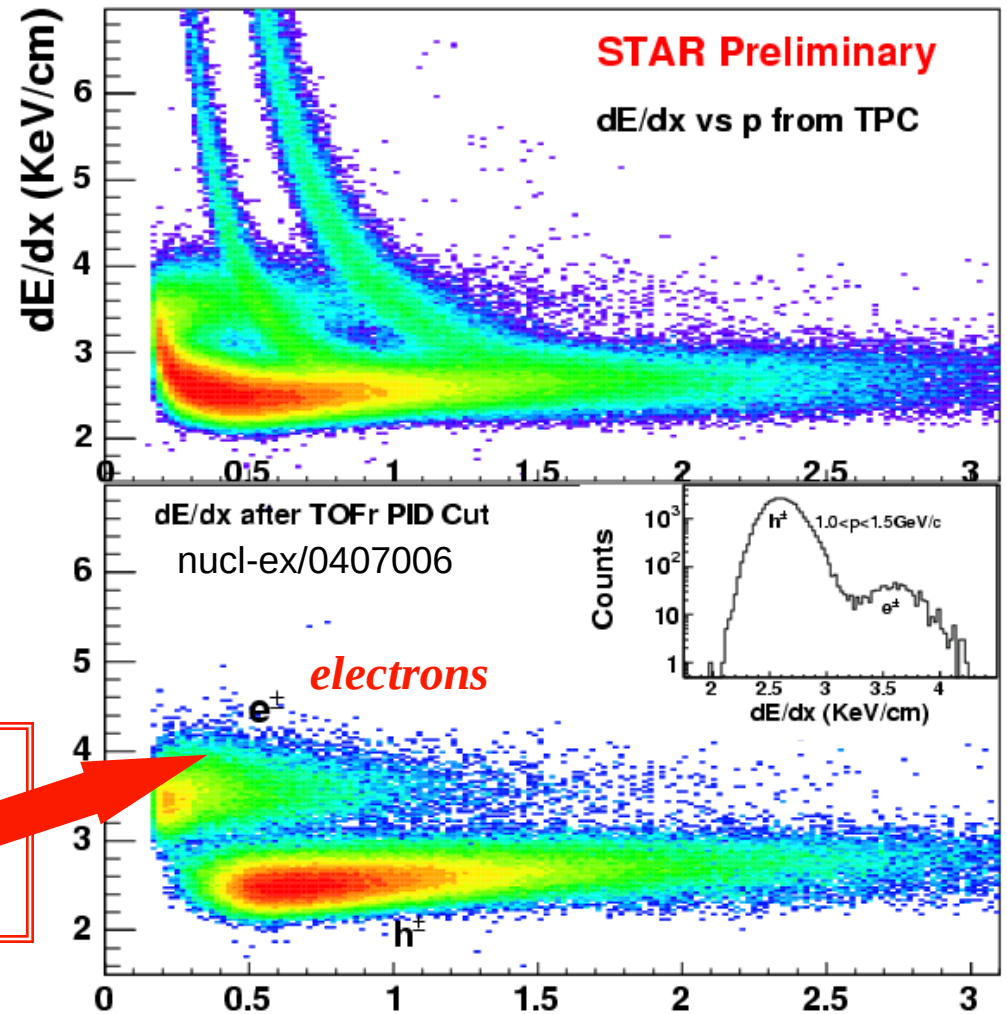
3800 modules, 23,000 readout chan. to cover TPC barrel

Multi-gap Resistive Plate Chamber TOFr: 1 tray (~1/200), σ(t)=85ps

ToF + dE/dX: “e / hadron PID”



Hadron identification:
STAR Collaboration, *nucl-ex/0309012*



Electron identification:

TOFr |1/ß-1| < 0.03

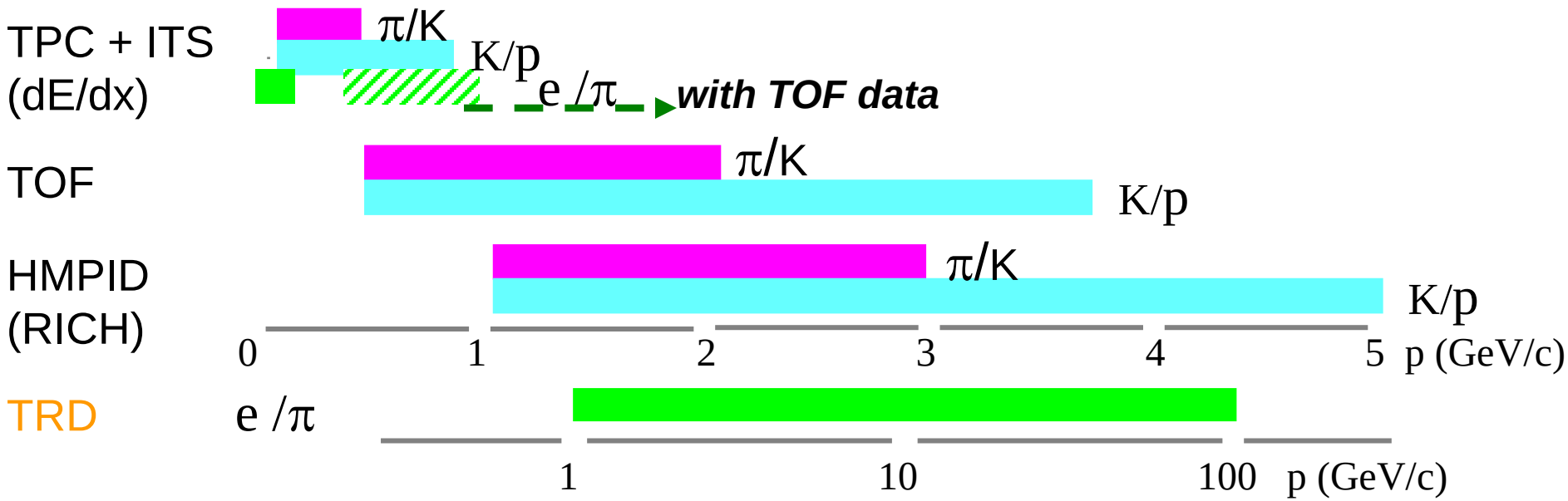
TPC dE/dx electrons!!!

It works together with EMCal (e+/-) + γ, π^0 (barrel and end cap)

ALICE experiment

ALICE has a unique capability, among the LHC experiments, of charged particle identification, due to the exploiting of different types of detectors:

- ITS + TPC : low p_T identification (up to p = 600 MeV/c).
- TOF : covers intermediate p_T region.
- TRD : electrons identification.
- HMPID : high p_T region (1÷5 GeV/c).



- Definition of “high Pt”

- Experience from RD26; HMPID R&D, construction and utilization in STAR and ALICE
- Experience to work with micro-pattern gas detectors

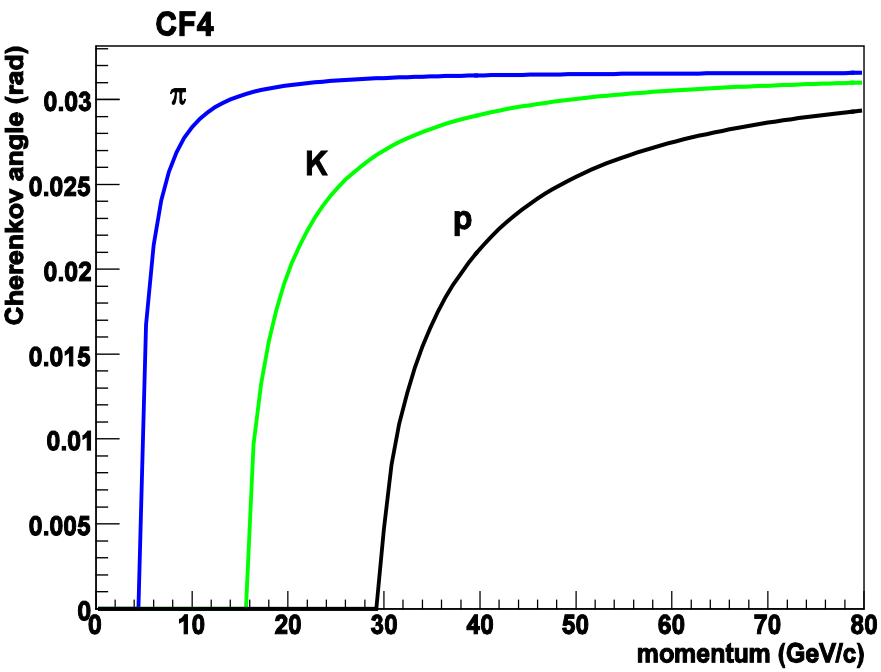
- RICH R&D results from BRAHMS, LHCb and COMPAS

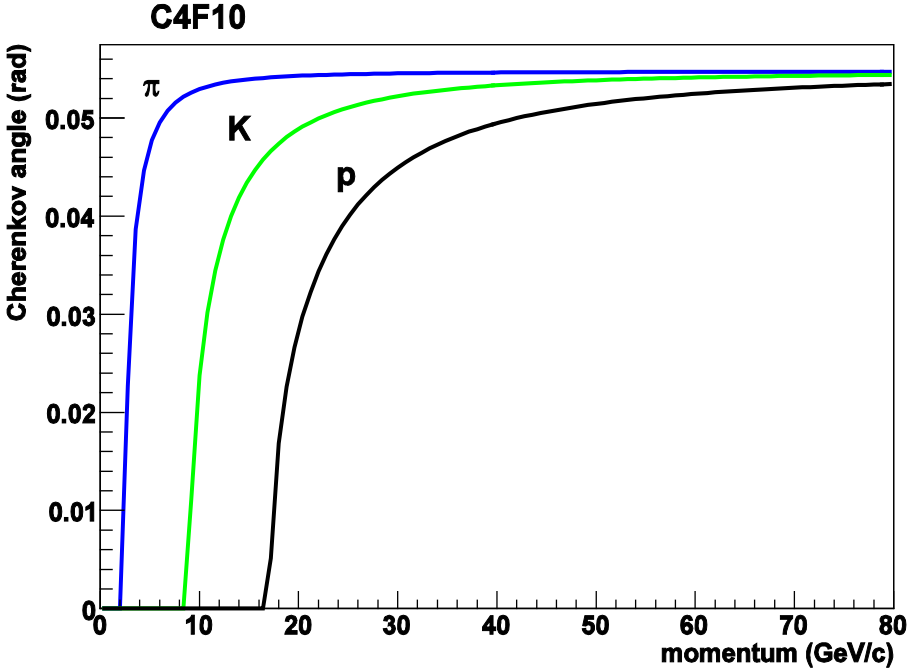
Experiment	*Radiator Gas and Length*		*UV detector*	*Pad size*
BRAHMS	**C4F10 (+)**	**150 cm**	**Ph. Tubes**	**1.1x1.1 cm^2**
COMPAS	**C4F10**	**300 cm**	**MWPCH+CsI**	**0.8x0.8 cm^2**
LHCb (RICH 1)	**C4F10 + AG**	**85 cm**	**HPDs**	**.25 x .25 cm^2**
(HERMES)				

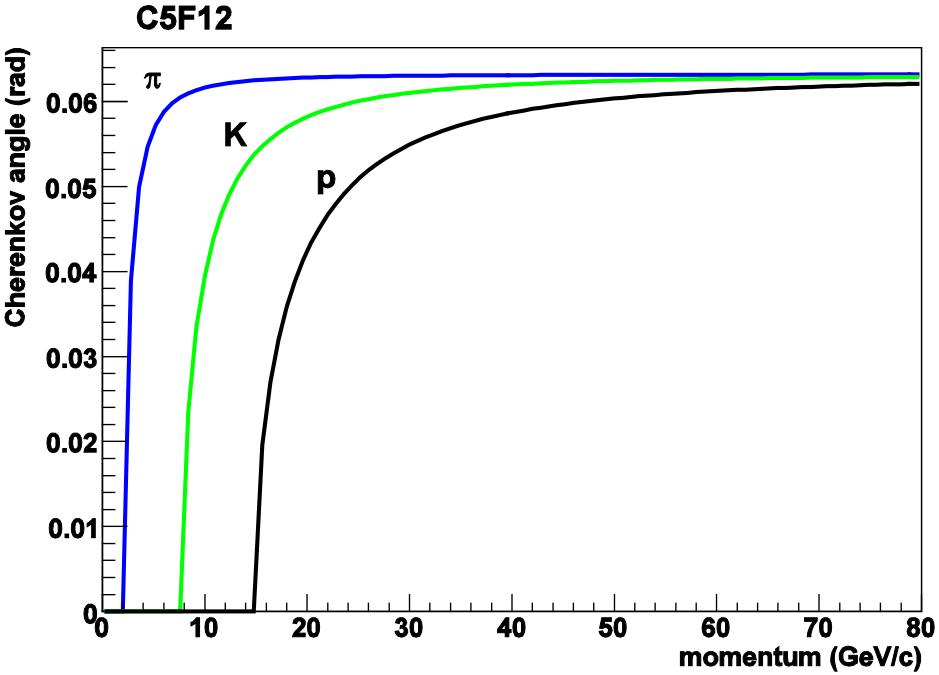
- ***Reliable Detector response simulation***
- ***Gas quality and Index of refraction controls***

ALICE VHMPID design constraints

- Charged hadrons (π, K, p) identification in 10 - 30 GeV/c
  - Focusing RICH with gaseous radiator
  - High Pt trigger
- Limited available space in ALICE
  - Filling factor (acceptance), radiator length
- Limited time for R&D and (possibly) detector construction
  - HMPID heritage and know-how: CsI, MWPC, FEE,…







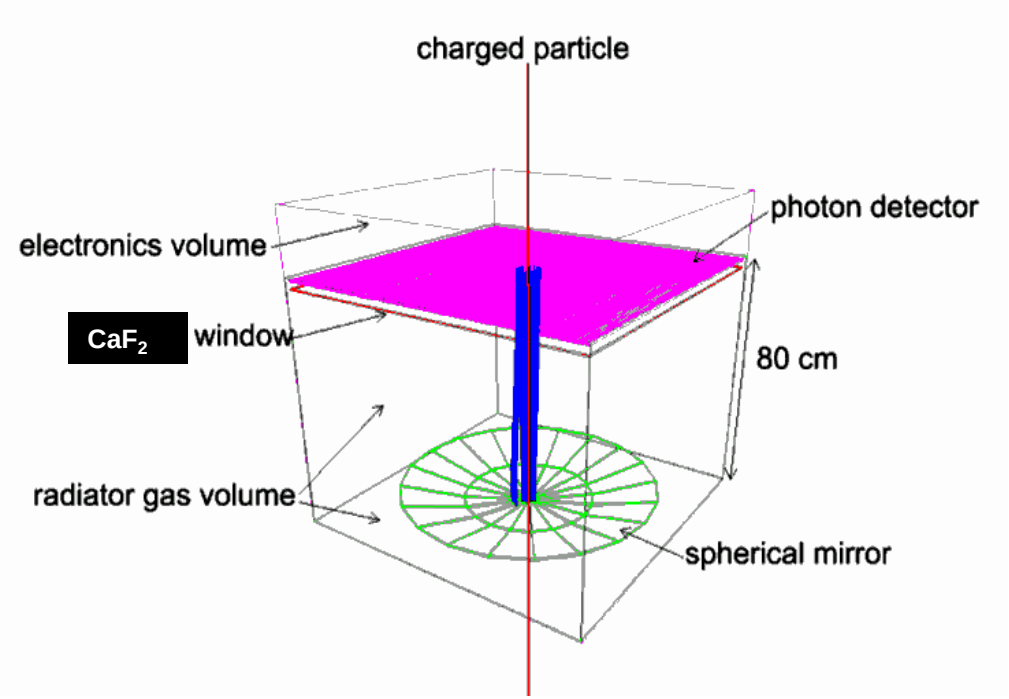
Radiator gas

CF4 ($n \approx 1.0005$, $\gamma_{th} \approx 31.6$) has the drawback to produce scintillation photons (Nph ≈ 300/MeV), that increase the background.

C4F10 ($n \approx 1.0015$, $\gamma_{th} \approx 18.9$)

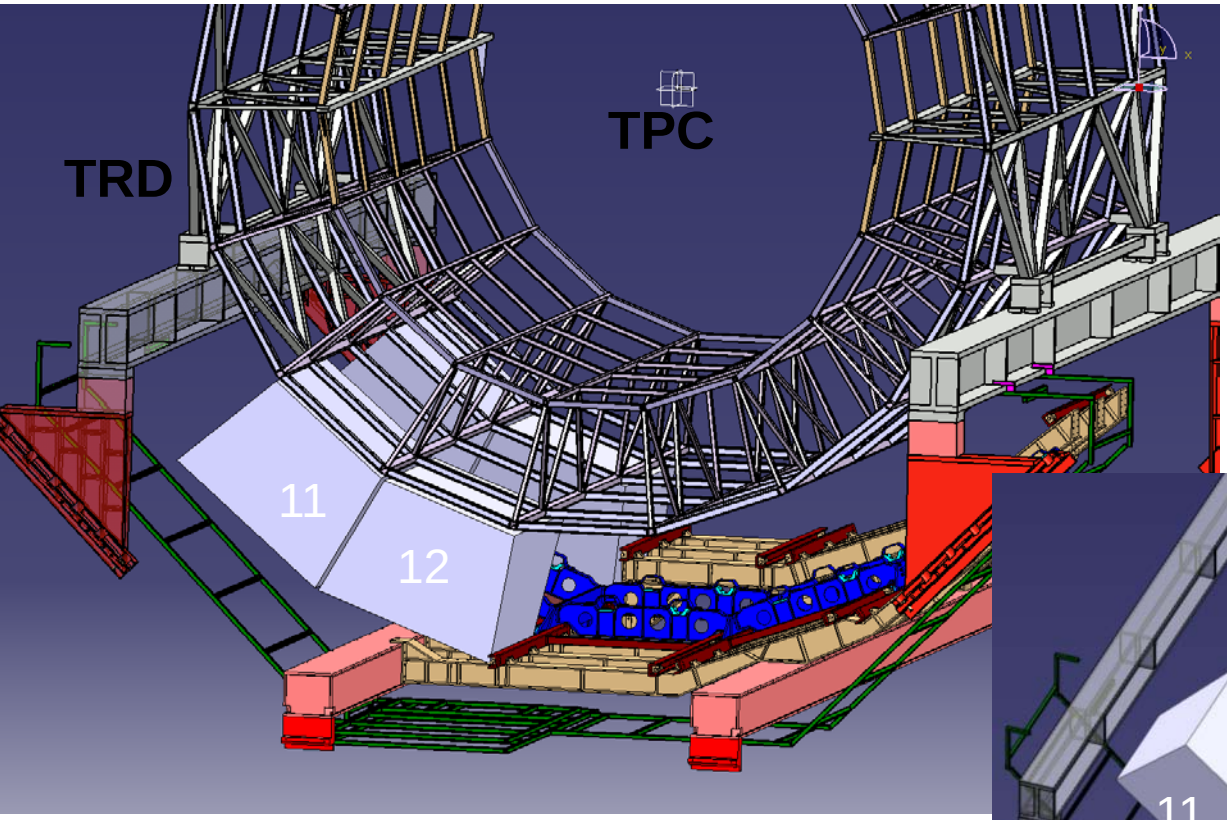
C5F12 ($n \approx 1.002$, $\gamma_{th} \approx 15.84$) this gas has been used in the DELPHI RICH detector

Detector principle scheme

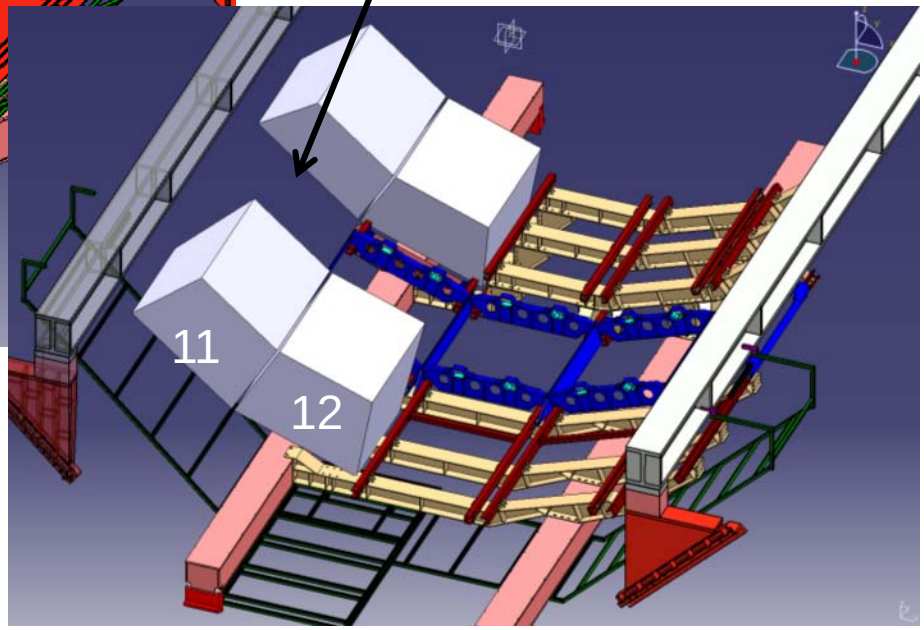


- Focusing RICH, C_4F_{10} gas radiator L~ 80 cm
- Photon detector *a la* HMPID, baseline option: MWPC with CsI pad (8x8 mm) segmented photocathode; alternative: CsI-TGEM or GEM
- Spherical (or parabolic) mirror, composite substrate, Al/MgF2 coating
- FEE based on HMPID Gassiplex chip, analogue readout for localization via centroid measurement

Integration in ALICE



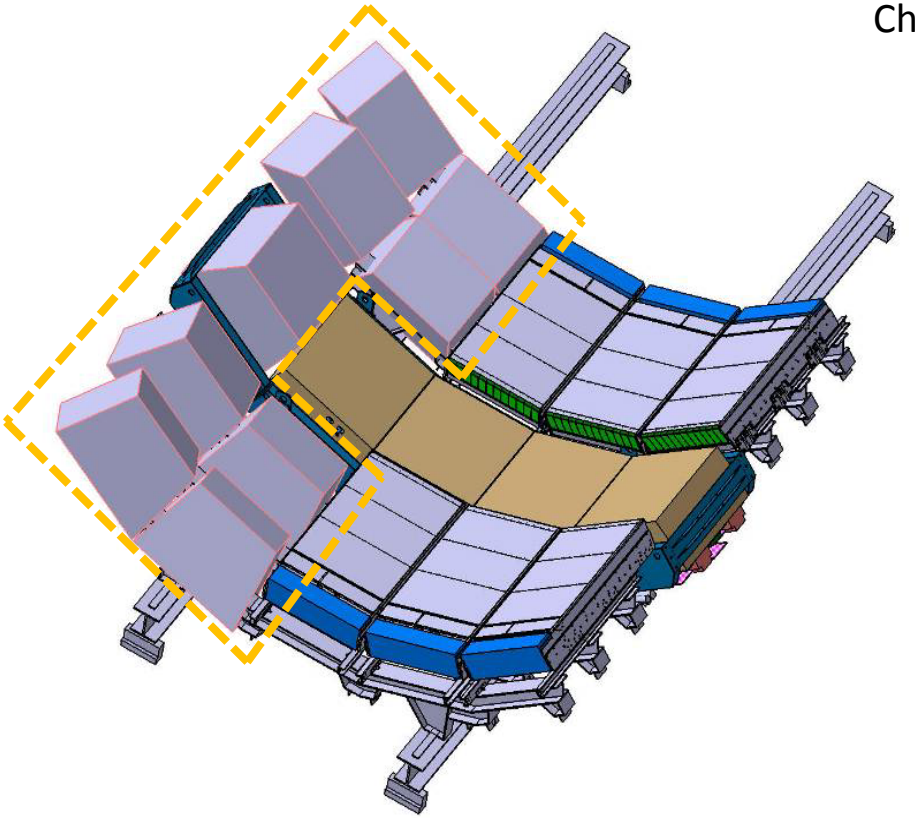
Free slot for prototype
~ ½ supermodule

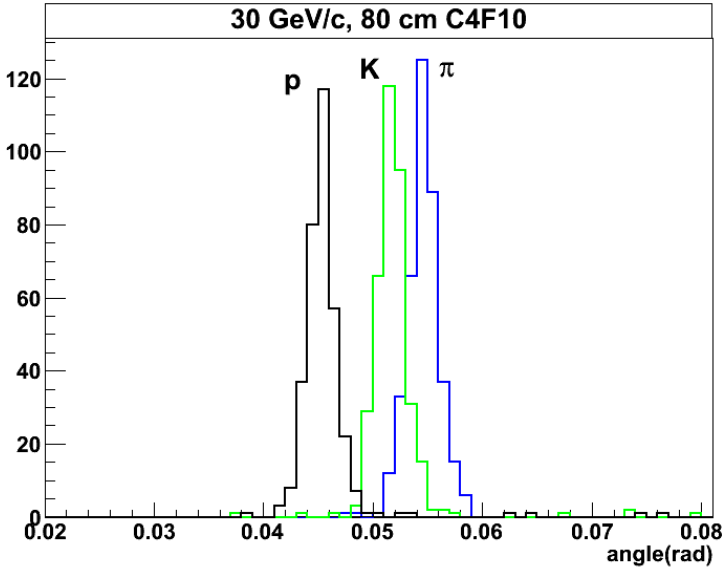


- 7% acceptance wrt TPC
- 12% wrt TPC in |η | < 0.5 (jet fully contained)

Expected performance

PID performance from Cherenkov angle resolution studied in ALIROOT overlapping single particle Cherenkov events to HIJING background

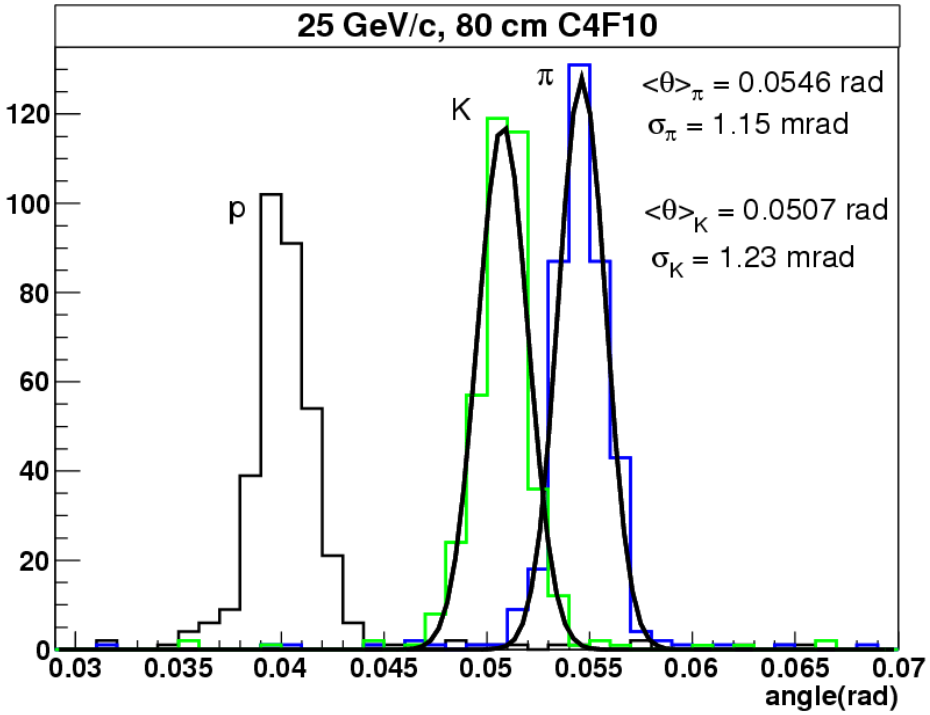




	Signal (GeV/c)	Absence of signal (GeV/c)
π	4-16	
K	11-16	
p	18-30	11-18

The detector consists of 9 modules of 1.4 m^2 corresponding to an acceptance of ~ 10%

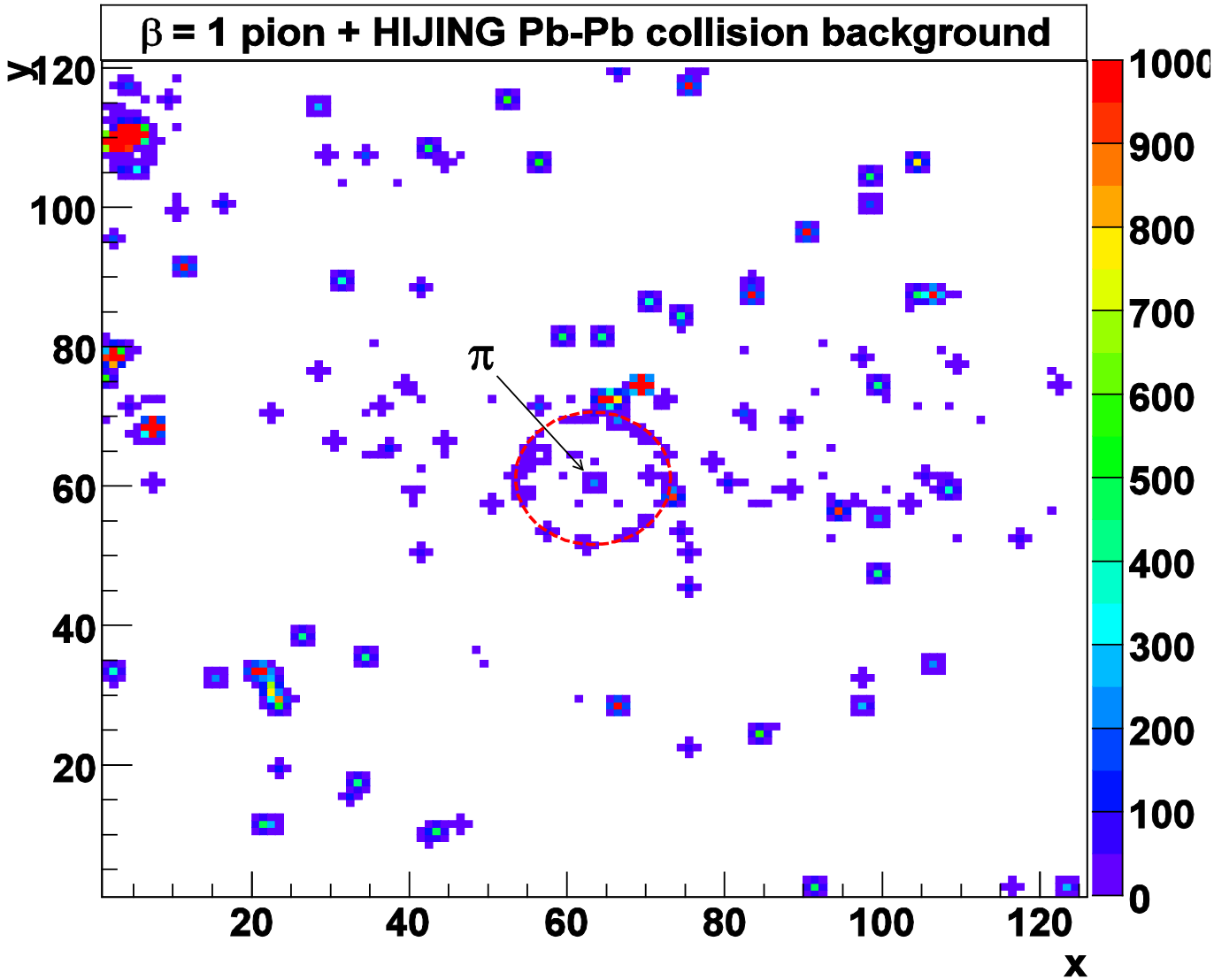
PID performance: ID range



	Signal (GeV/c)	Absence of signal (GeV/c)
π	4-24	
K	11-24	
p	18-38	11-18

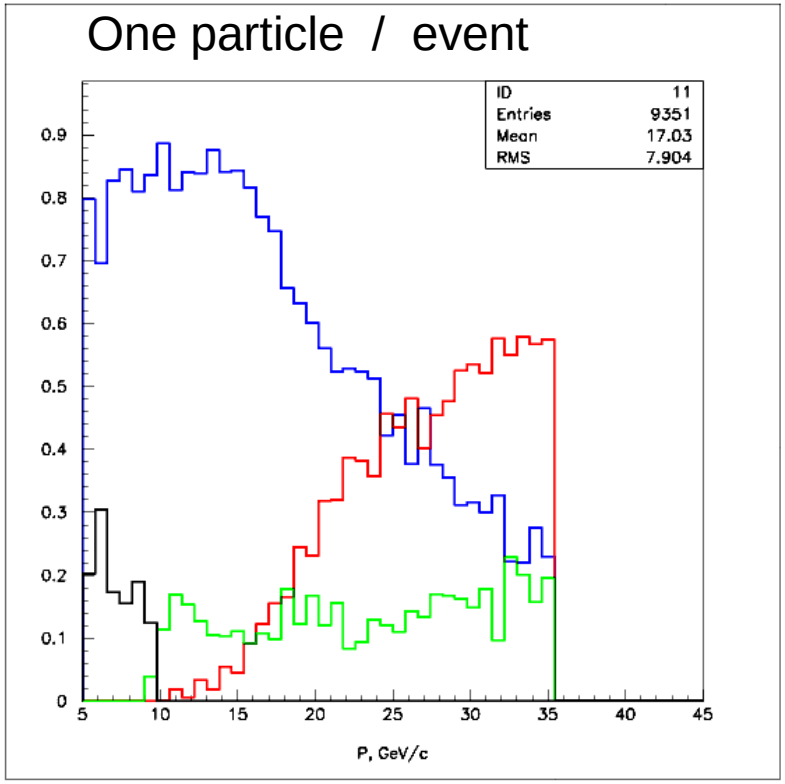
Lower limit: Cherenkov threshold
Upper limit: 3σ separation

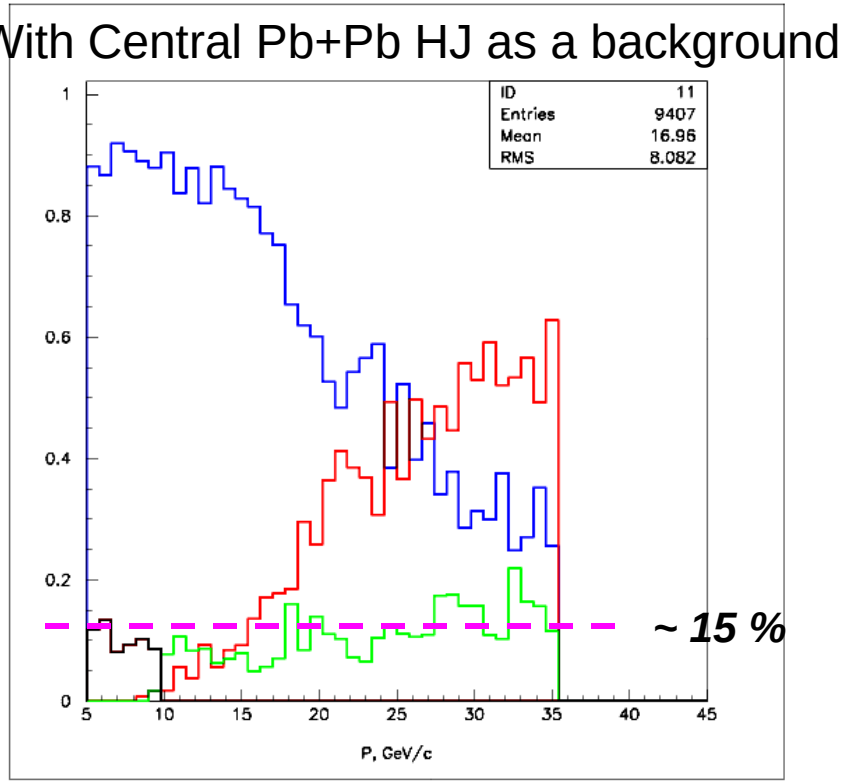
Simulation results: Pb-Pb background



HIJING generator $dN_{ch}/d\eta$ = 4000 at mid rapidity: maximum foreseen

Option I; PID for π

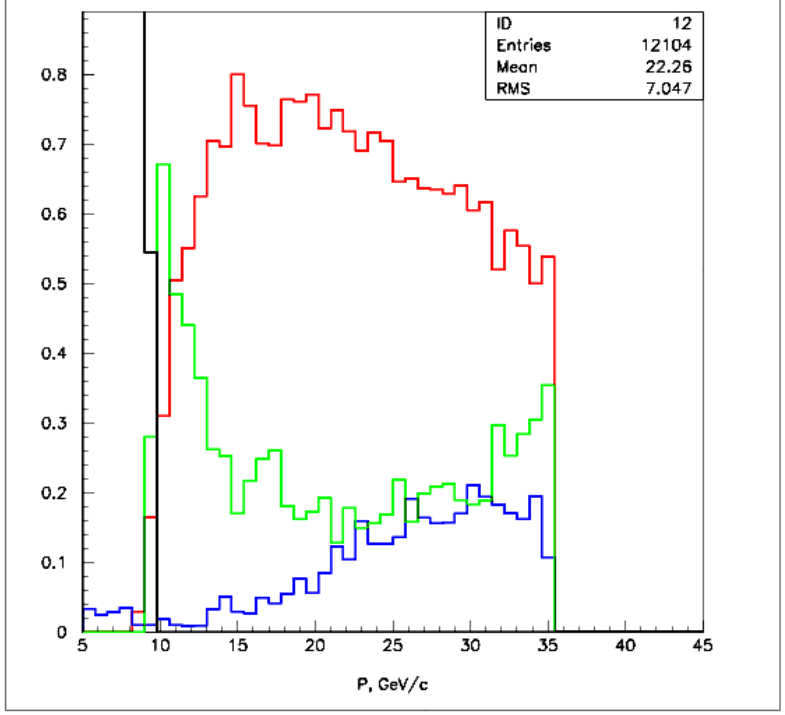




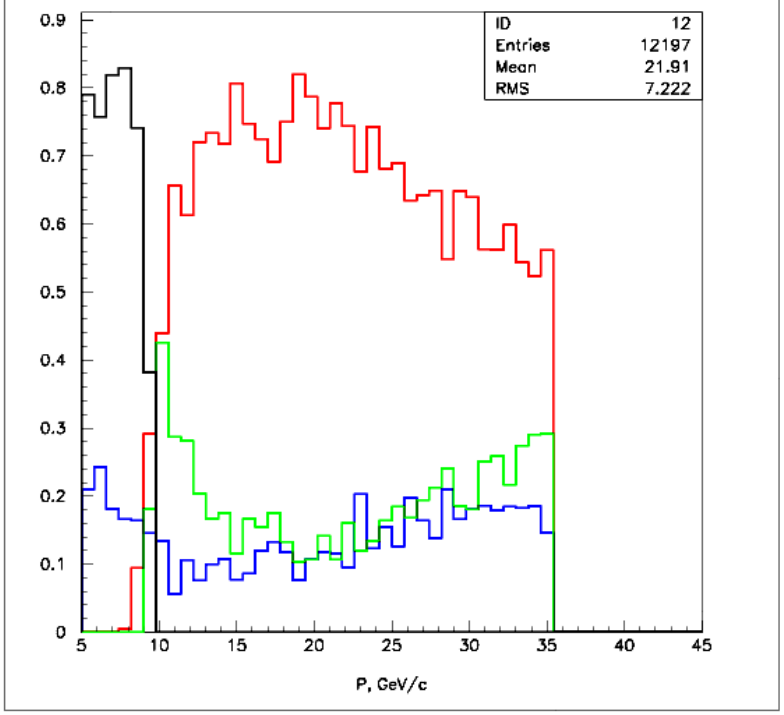
Particle was identified as π (Blue), k - Red, p – Green, No PID - black

Option I; PID for K

One particle / event

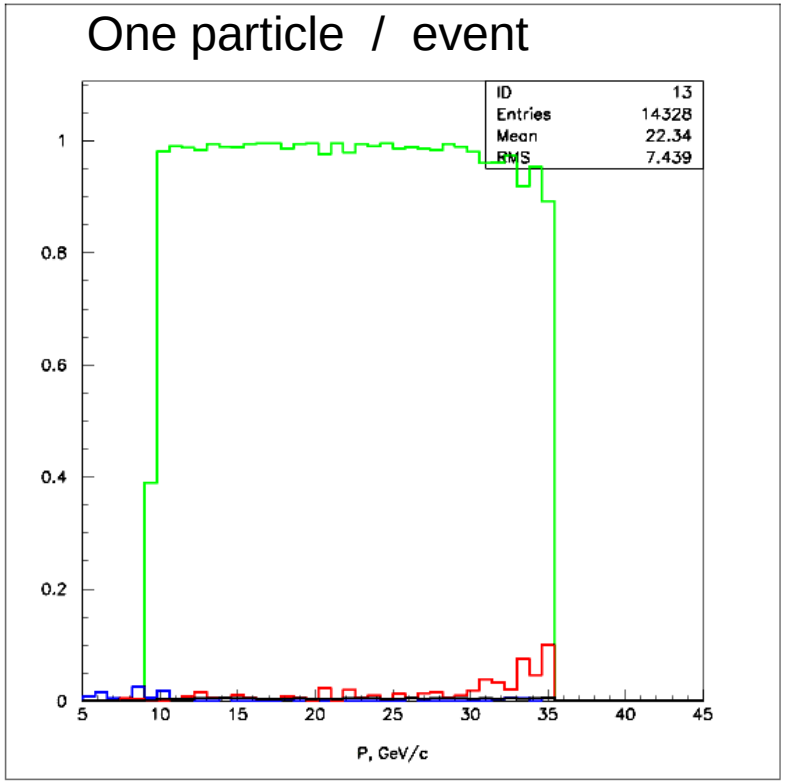


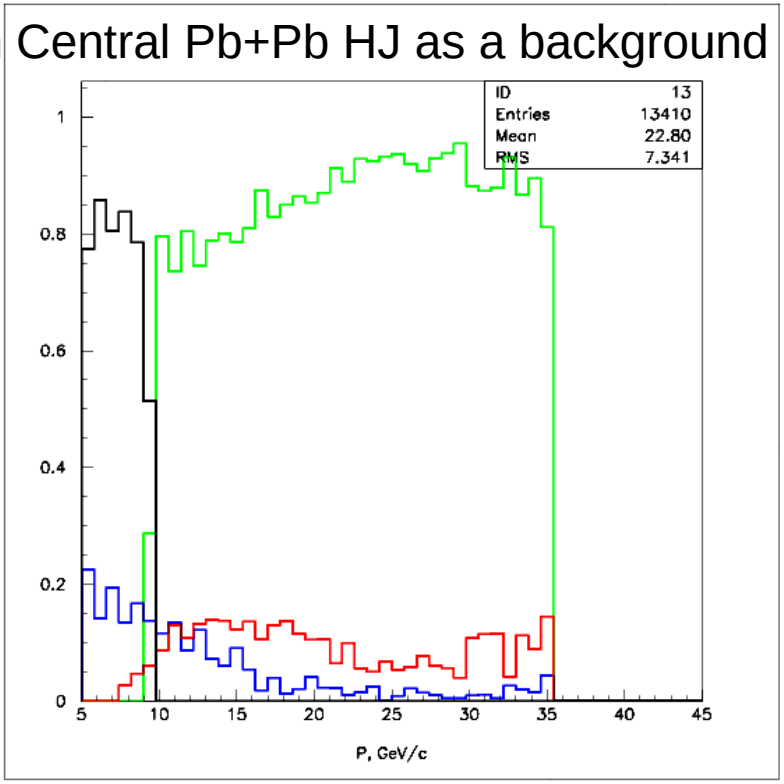
With Central Pb+Pb HJ as a background



Particle was identified as π (Blue), k - Red, p – Green, No PID - black

Option I; PID for p



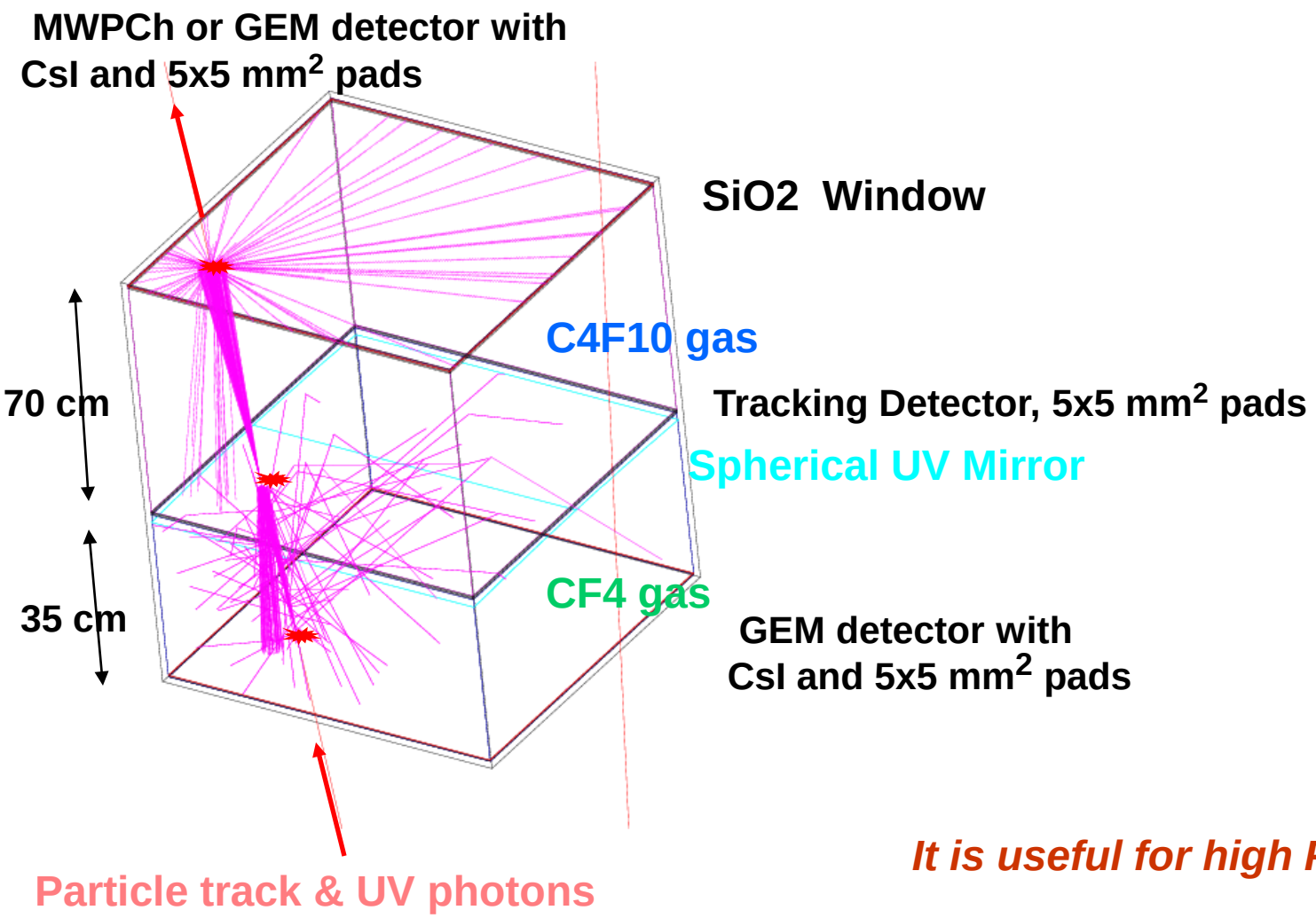


Particle was identified as π (Blue), k - Red, p – Green, No PID - black

Proposed option II.

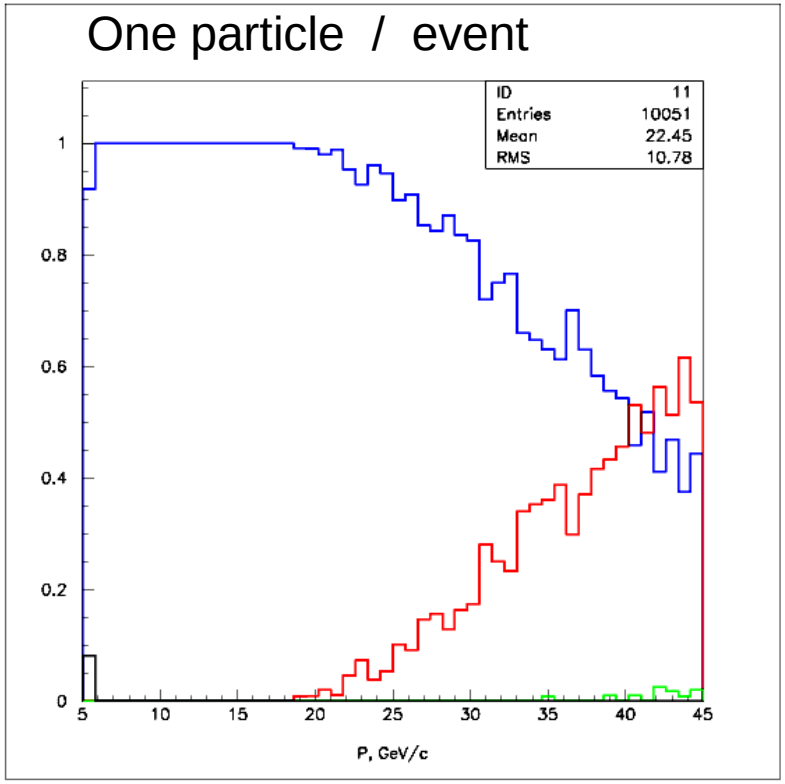
- ✓ Three detectors in the same space available
- ✓ RICH with CF4 and windowless GEM+CsI pad read-out
- ✓ Gas micro-pattern tracking detector with pad-readout.
- ✓ Threshold Cherenkov detector with C4F10 + quartz window + GEM pad-readout

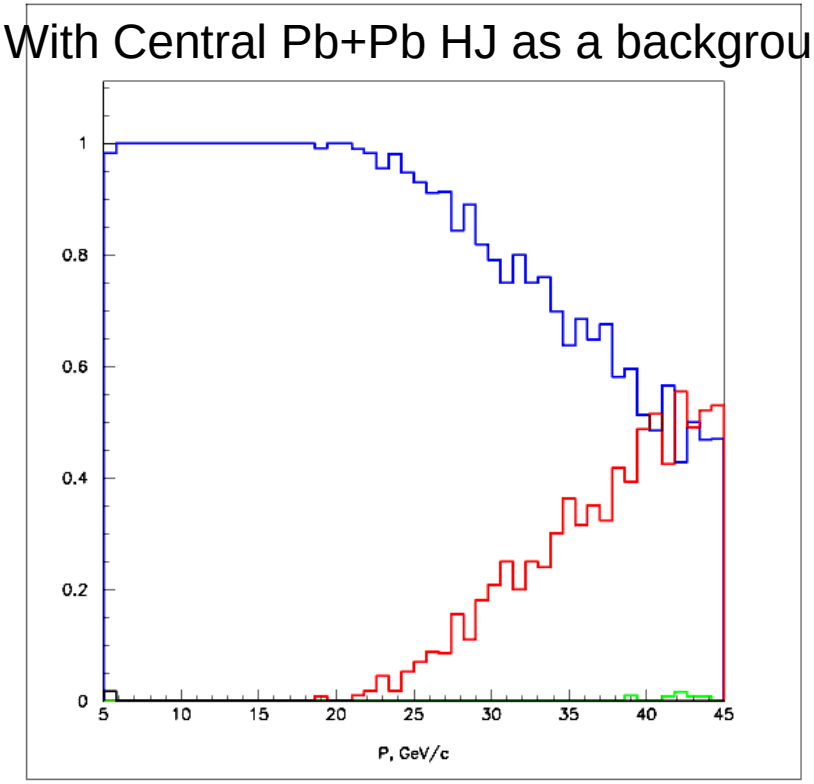
Option II; Two detectors (RICH with CF4 and Cherenkov with C4F10) plus additional tracking detector.



It is useful for high Pt trigger

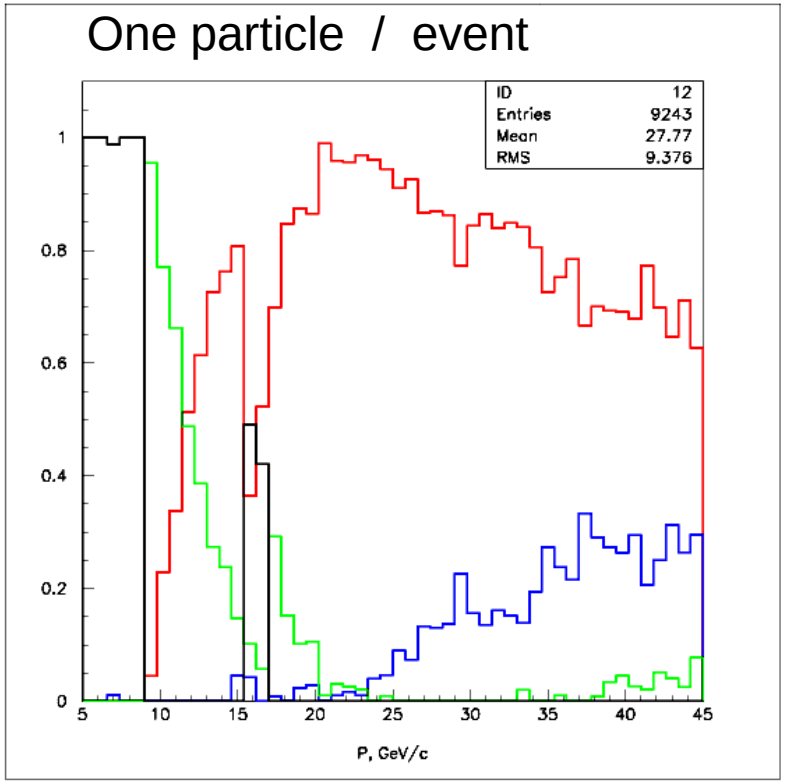
Option II; PID for π

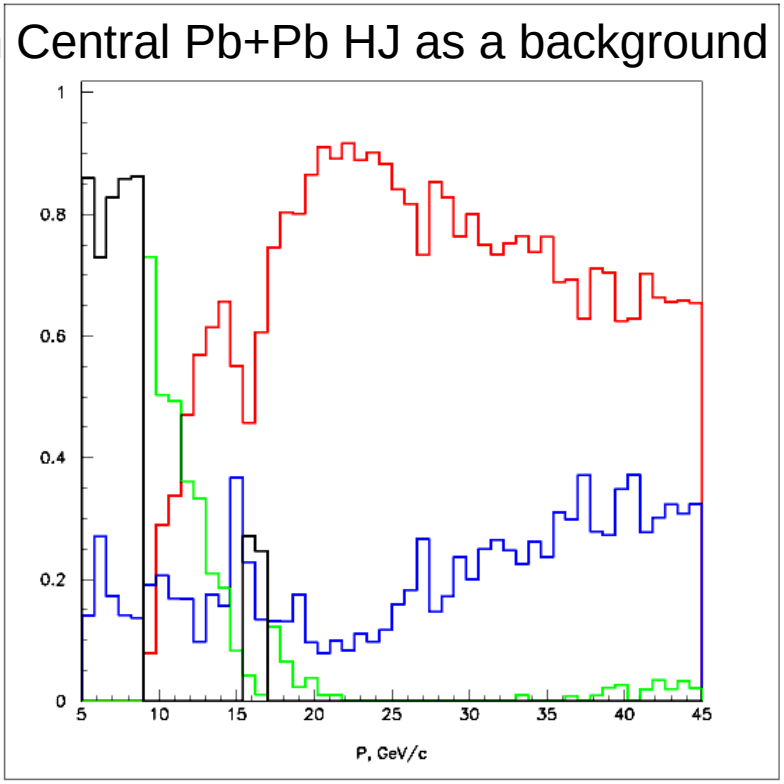




Particle was identified as π (Blue), k - Red, p – Green, No PID - black

Option II; PID for K

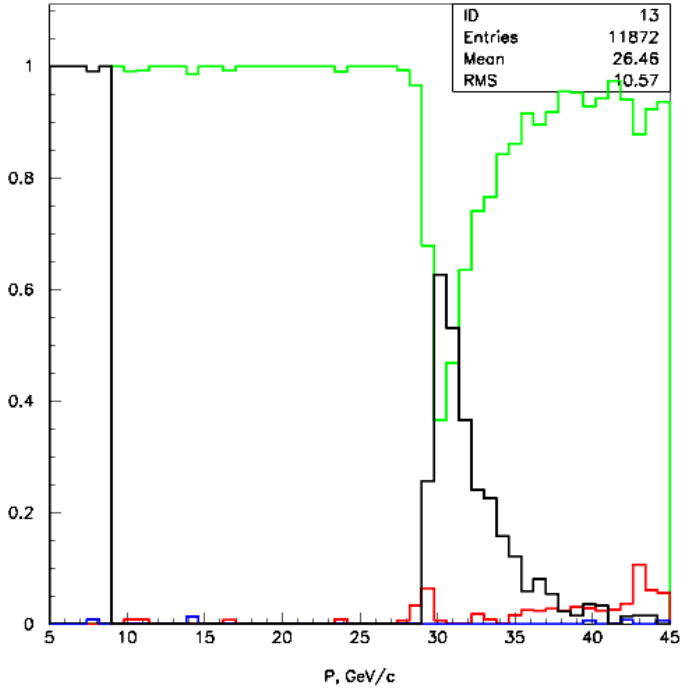




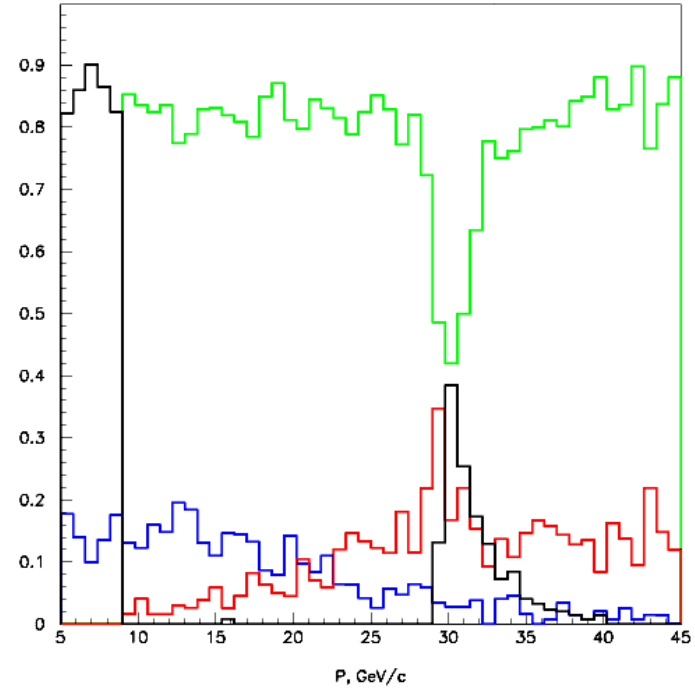
Particle was identified as π (Blue), k - Red, p – Green, No PID - black

Option II; PID for p

One particle / event



With Central Pb+Pb HJ as a background

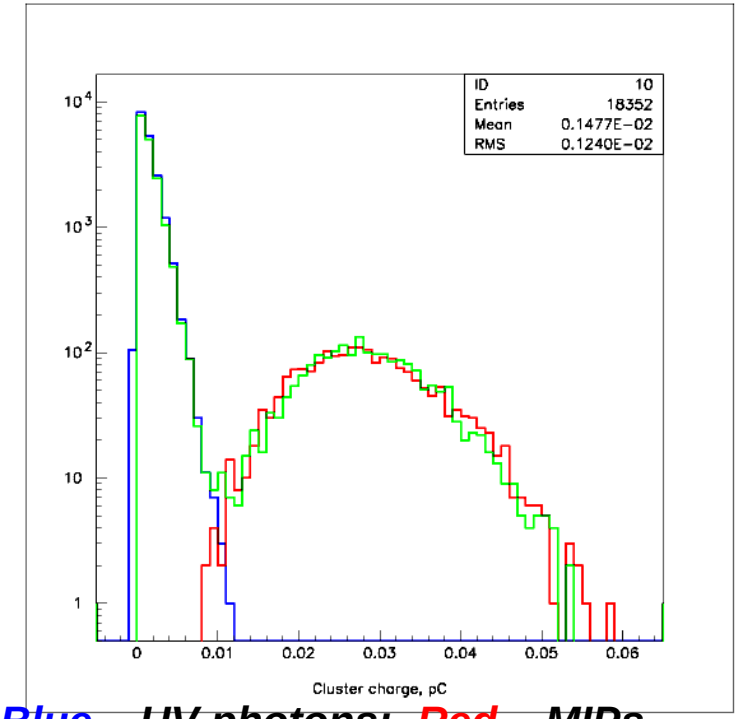


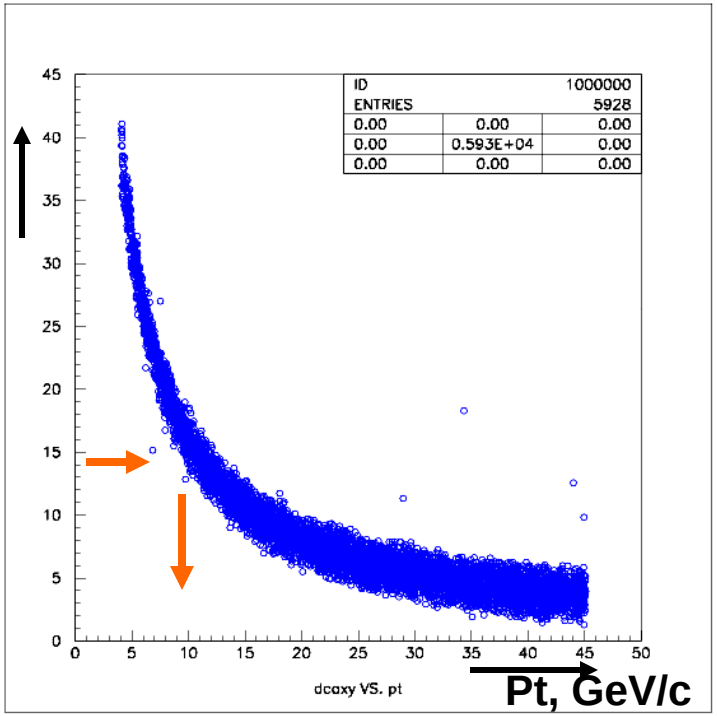
Particle was identified as π (Blue), k - Red, p – Green, No PID - black

Option II;
detector response (cluster charge) for UV photons and MIPs; and High Pt trigger possibility

Three reconstructed MIP hits were matched as a track,
Line fit in (XY) and (RZ)
DCA to (0., 0.) in (XY), cm

Cluster charge, pC





Blue – UV photons; Red – MIPs
Green – No FEE Noise

With cuts selected to get 98% efficiency for "one high Pt track / event"
-for Central HIJING event the probability to get false trigger

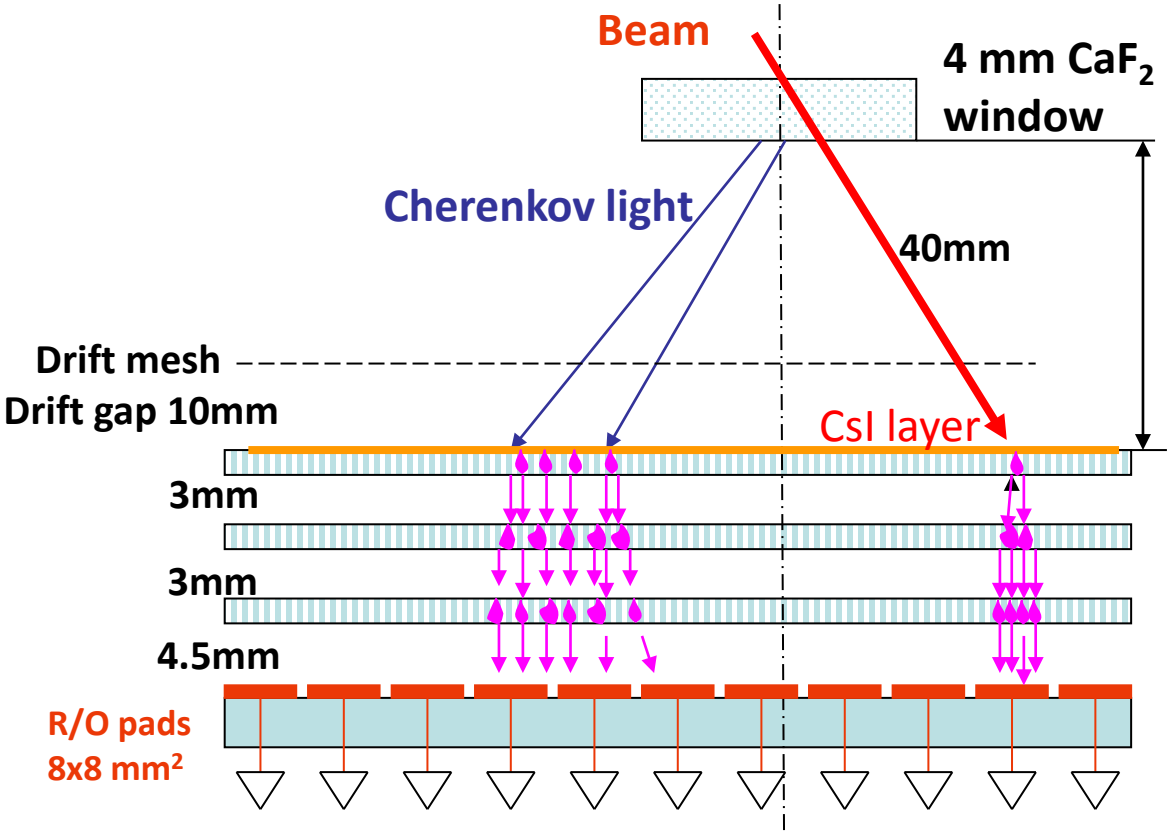
("DCAxy < 15. cm") is smaller than 4% / detector

Beam tests of CsI coated TGEM
(Nov 2009, CaF2 as a radiator; Nov 2010 , with C5F12 (liquid) radiator)

10x10 cm prototype layout:
Triple Thick GEM with CsI coated top element, CaF_2 window
Cherenkov radiator, pad readout

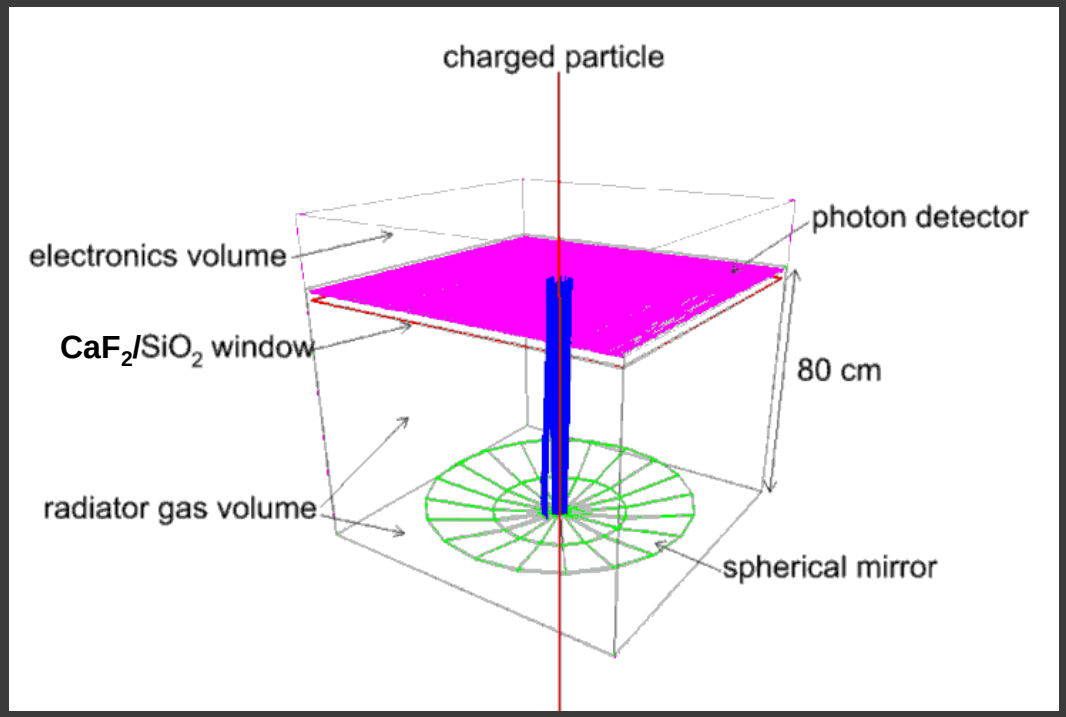
Goals of the first tests:
- Gas mixture % optimization (Ne/CH_4)
- HV settings/gain optimization
- FEE setting for readout of e^- induced signal
- Response of CsI layer evaporated on TGEM
- Prove working principle: simultaneous detection of single UV photons (Cherenkov radiation) and MIPs

The second:
-- Cherenkov ring reconstruction as a function: P, angle, gas amplification.



Front end electronics
(Gassiplex + ALICE HMPID R/O + DATE + AMORE)

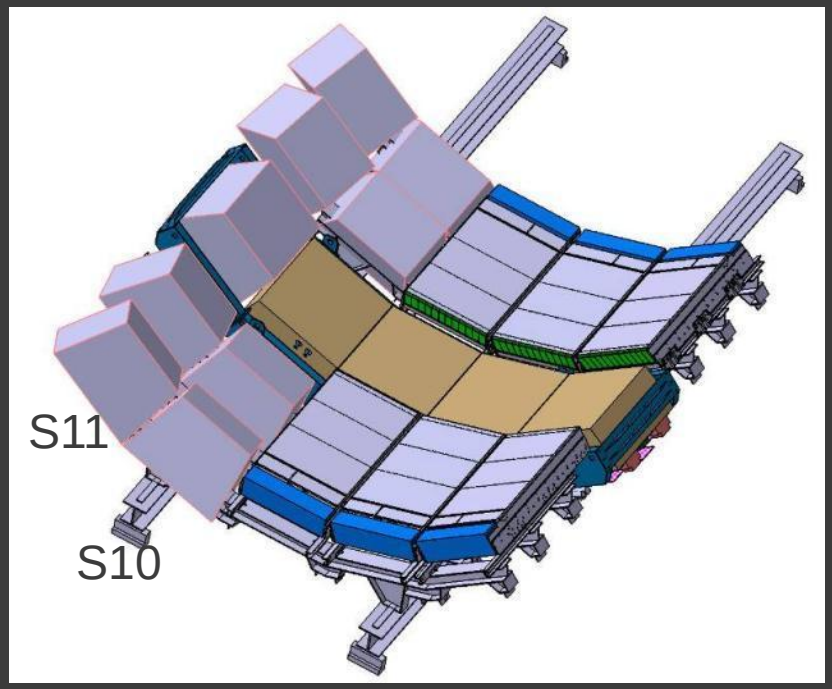
Detector layout (reminder)



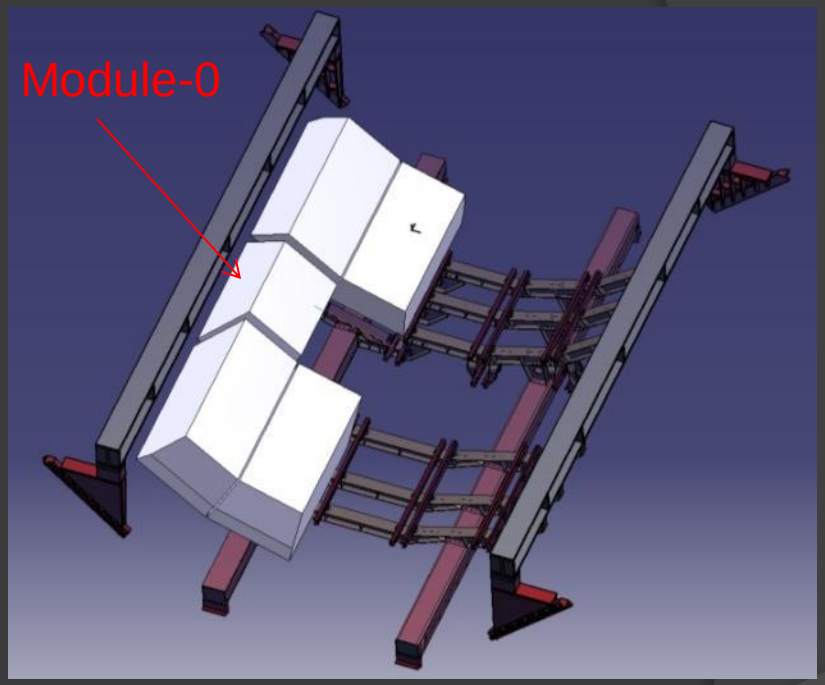
- Focusing RICH with spherical (parabolic) mirrors
- C_4F_{10} gas radiator L=80 cm
- Photon detector baseline option: MWPC with CsI photocathode; alternative: CsI-TGEM
- HMPID FEE (Gassiplex)
- Focusing geometry: separation of photon detection and MIP detection ⟶
  - Reduced photo-sensitive area (increased granularity, less electronics channels, smaller windows hence possibility for CaF_2)
  - Cheaper MIP detection layer (larger pads hence less electronics channels)

Integration in ALICE

2009 layout: projective geometry

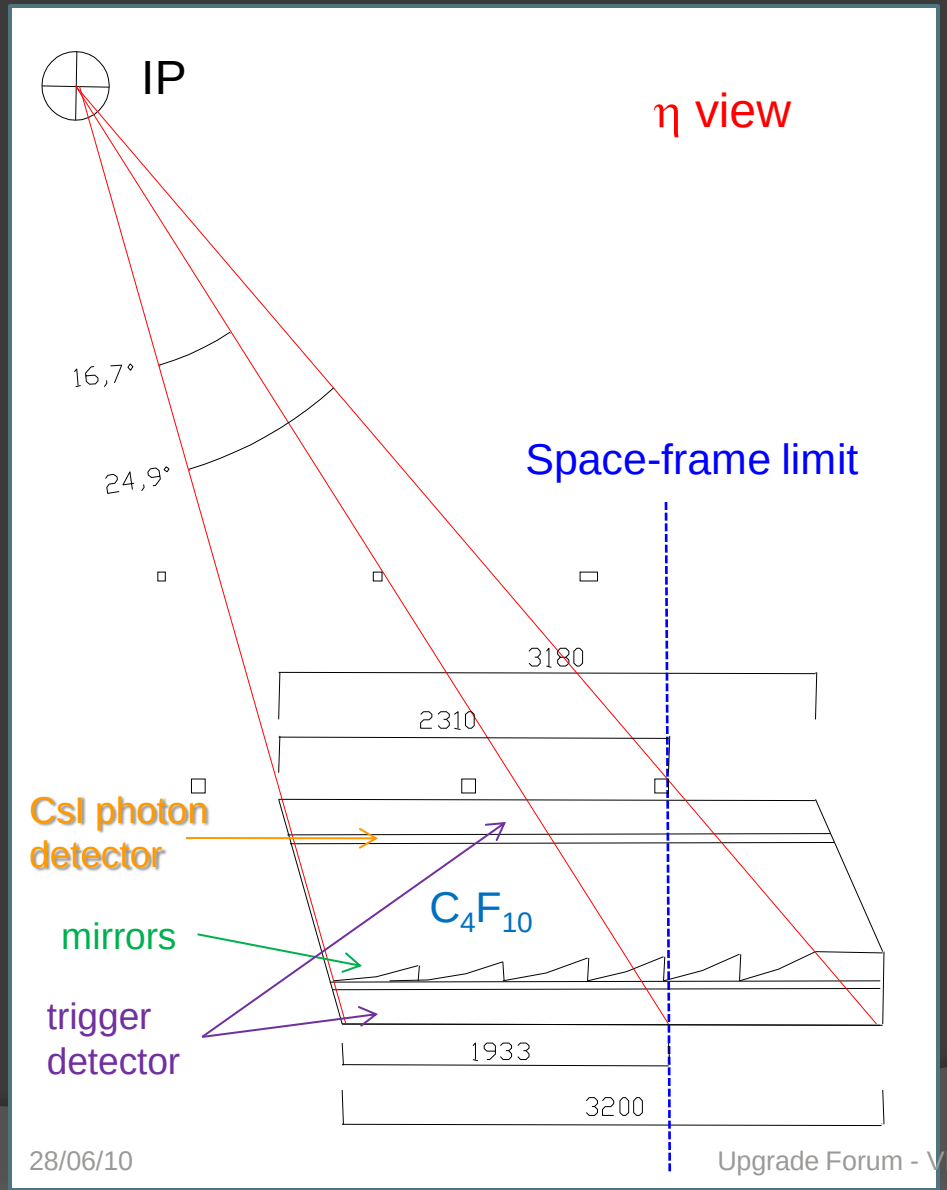


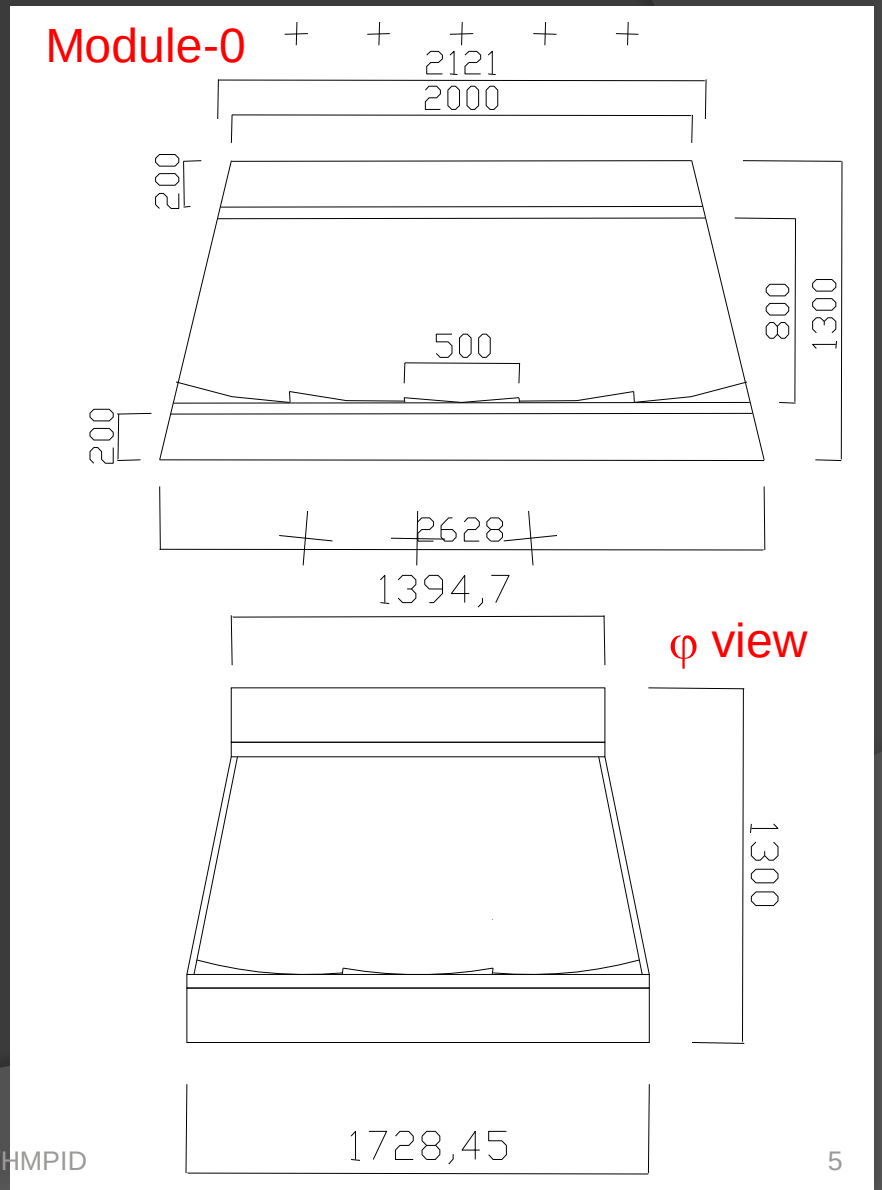
new layout, super-modules



- Detector design constraint: exploit all available space to maximize acceptance
- Limited space: evolution from tilted single modules (problems with different clearance in S10 and S11, acceptance ~ 5% wrt to TPC in $|\eta| < 0.5$ (jet fully contained)) to “super-modules” layout (h=130 cm fully exploited, acceptance 7%)
- Module-0 size increased due to new PHOS support structure (i.e. no cradle in S11)

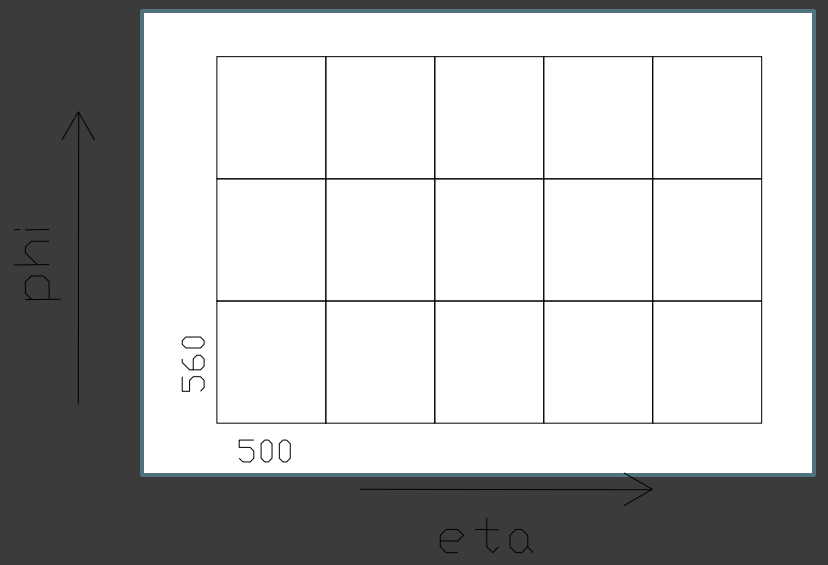
Supermodule layout



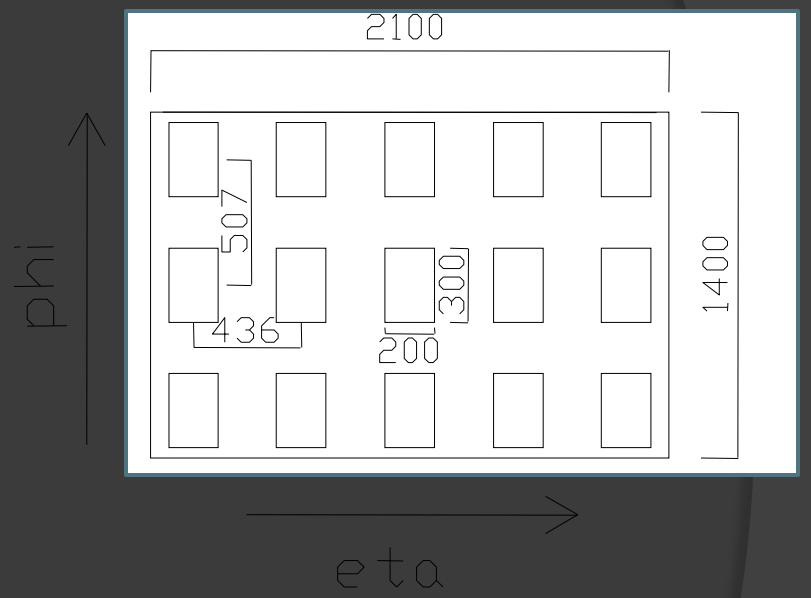


Module-0 layout

Mirrors:



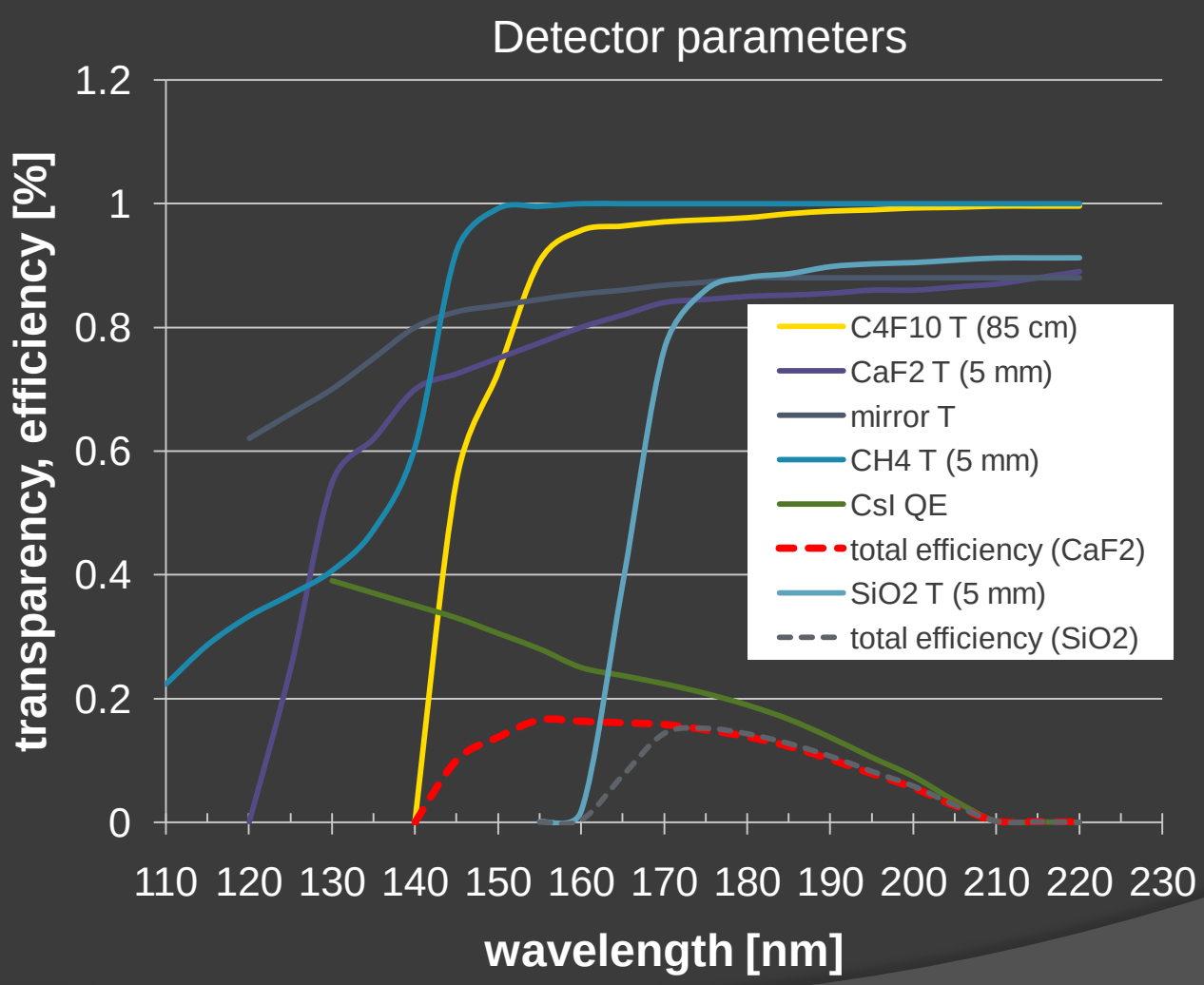
Windows:

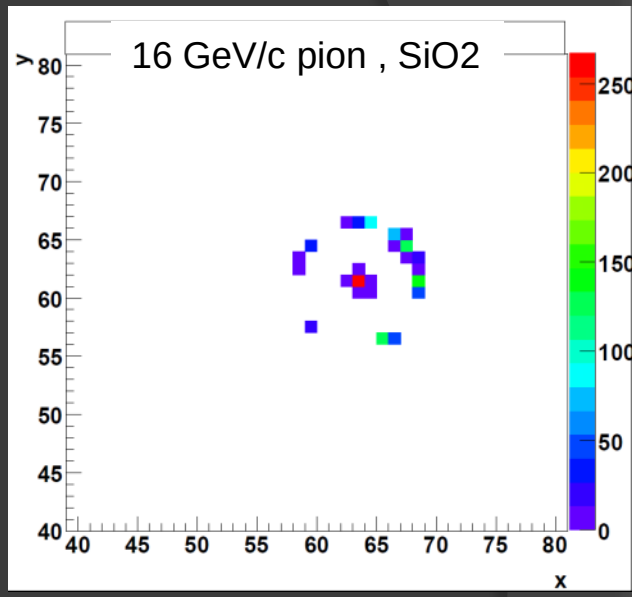


Under study:

- Mirror type (spherical or parabolic), segmentation and orientation: resulting total photon detector area
- Photon detector granularity/pad size: Cherenkov photons reconstruction, close rings separation
- Optical window, CaF_2 vs SiO_2: balance cost – PID performance

Performance studies



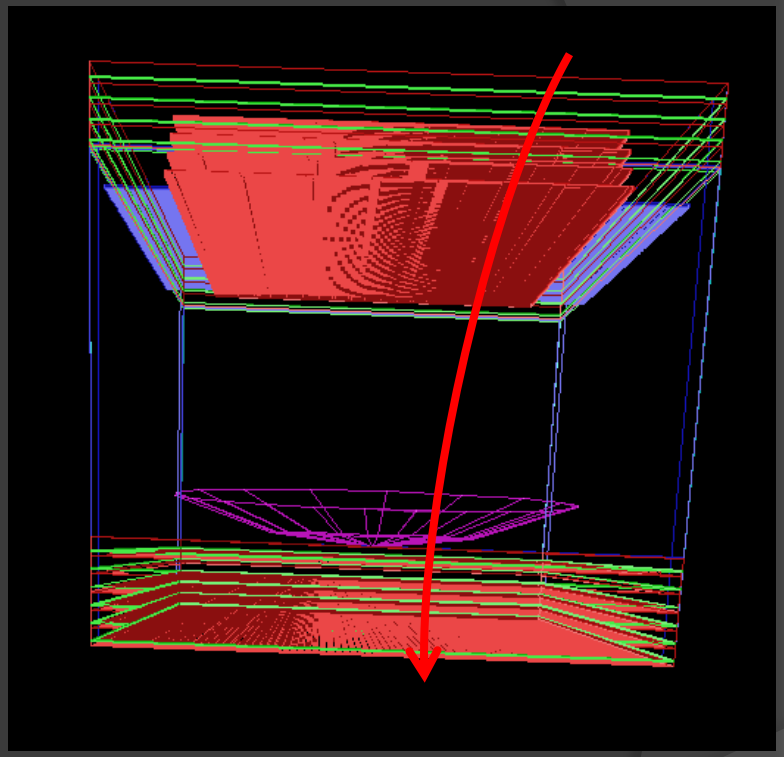


Pad size + ring radius ⟶
Photons geometrical overlap
N_{rp} (reconstructed photons)
< N_{pe} (photoelectrons)

Window	N_{rp}
SiO_2	7.2
CaF_2	10

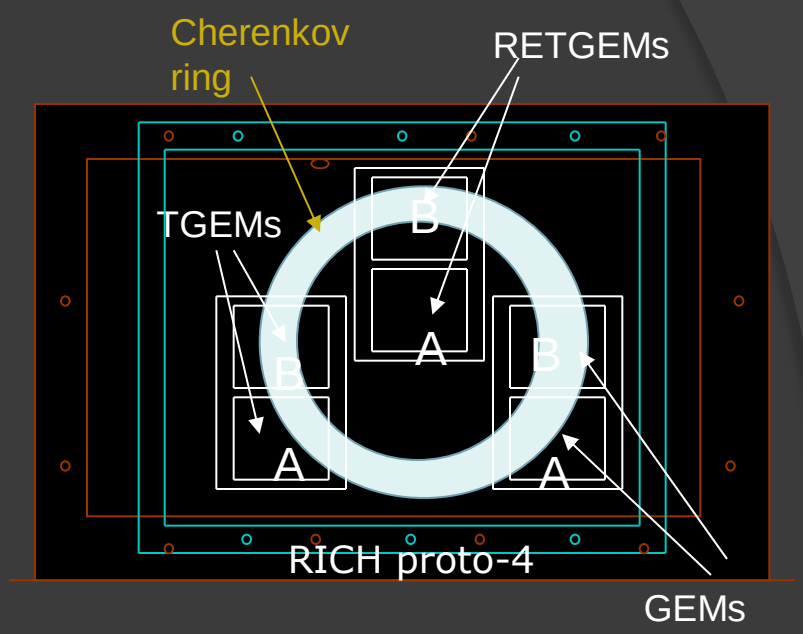
High P trigger (reminder)

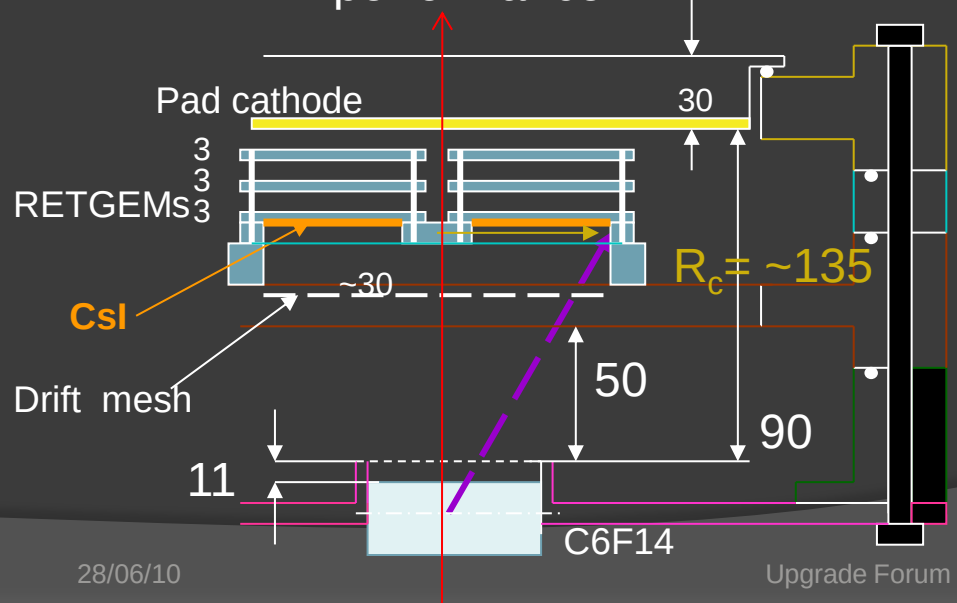
- The baseline solution as high momentum L1 trigger: TRD.
- R&D on a dedicated HPTD (High-P Trigger Detector) based on track angle measurement for tracks crossing the VHMPID: CCC (Close-Cathode-Chamber), layers of MWPC with ~ 1 mm gap and strips digital readout
- Fast L0 trigger (mostly relevant for the p+p environment) to tag the presence of tracks in the momentum range > 1.5-2 GeV allowing to access the 100 KHz event rate
- L1 trigger to select tracks in the high-p_T range, with a tunable cut-off 8-15 GeV from high granularity track measurement, with suppression of combinatorial background in the high multiplicity Pb+Pb environment
- New feature: included MIP detection layers

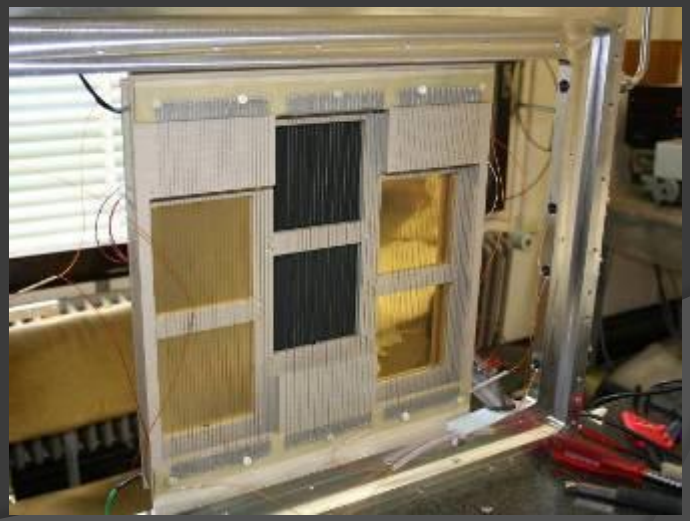


TGEM beam test

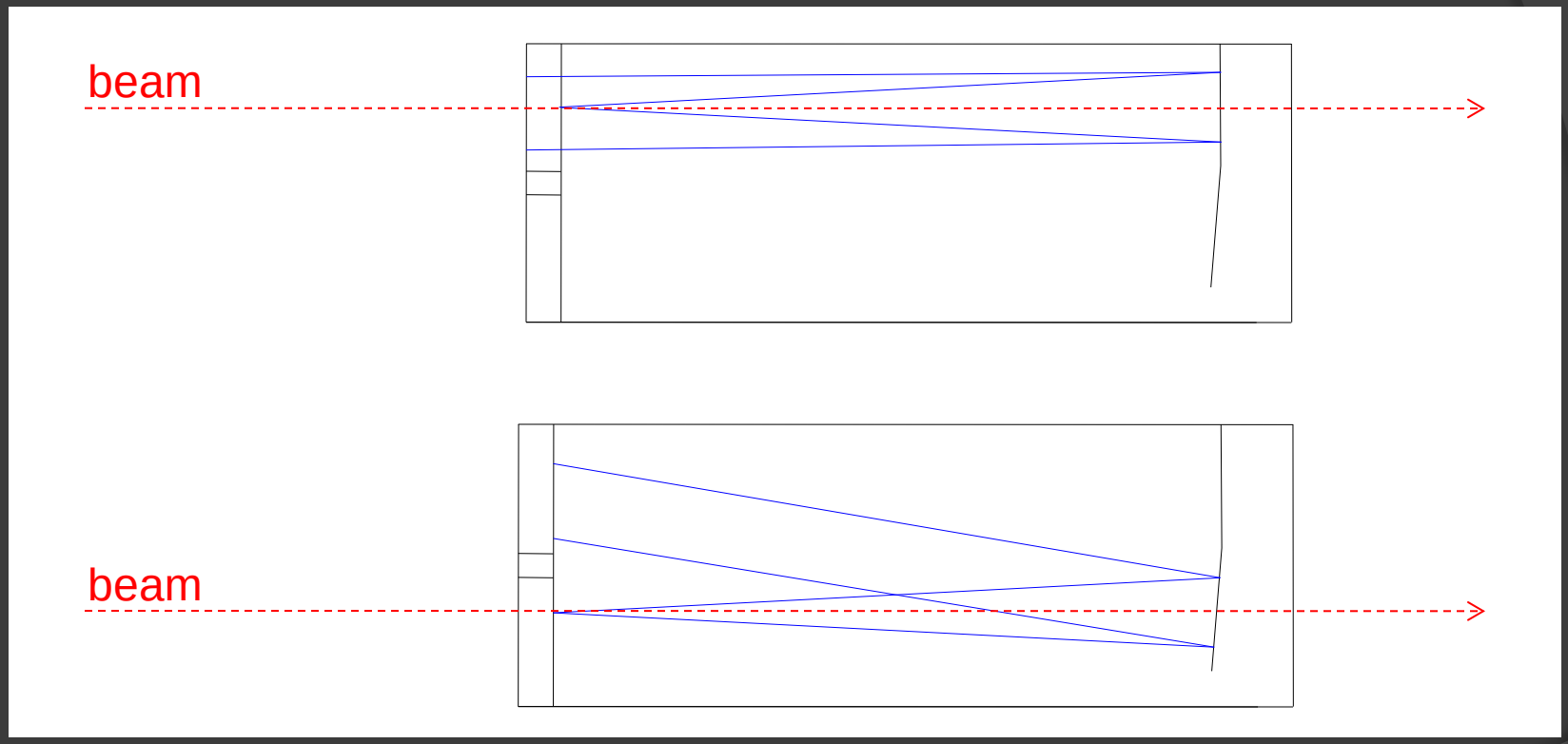
- After Nov 09 successful test of 10x10 cm^2 prototype, test larger detector with TGEM, RETGEM and normal GEM with CsI coating, using 60x40 cm^2 pad cathode (8x8 mm^2 pads with Gassiplex FEE)
- Usage of C_6F_{14} liquid radiator and proximity focusing geometry for direct comparison with HMPID performance







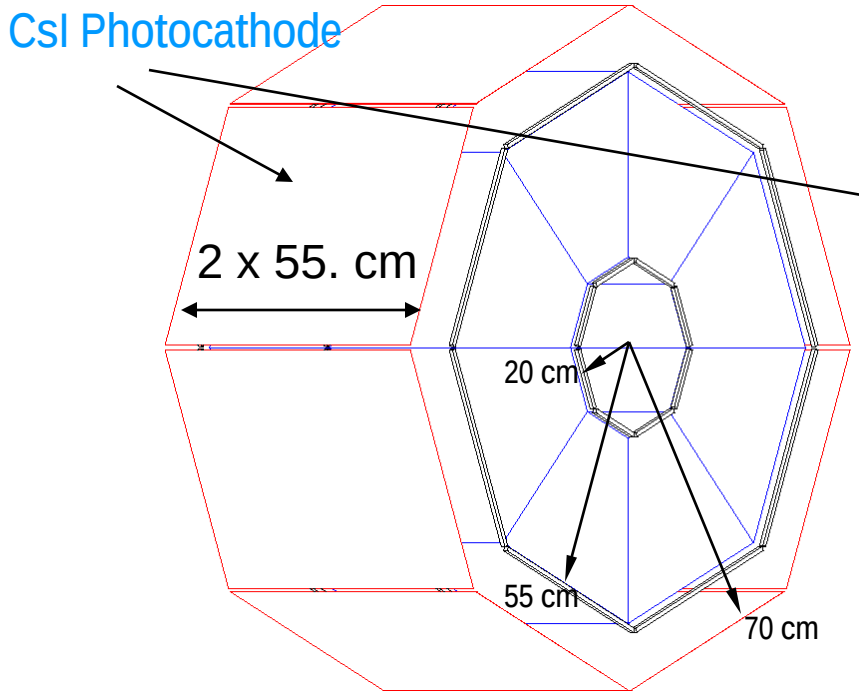
Small prototype beam test

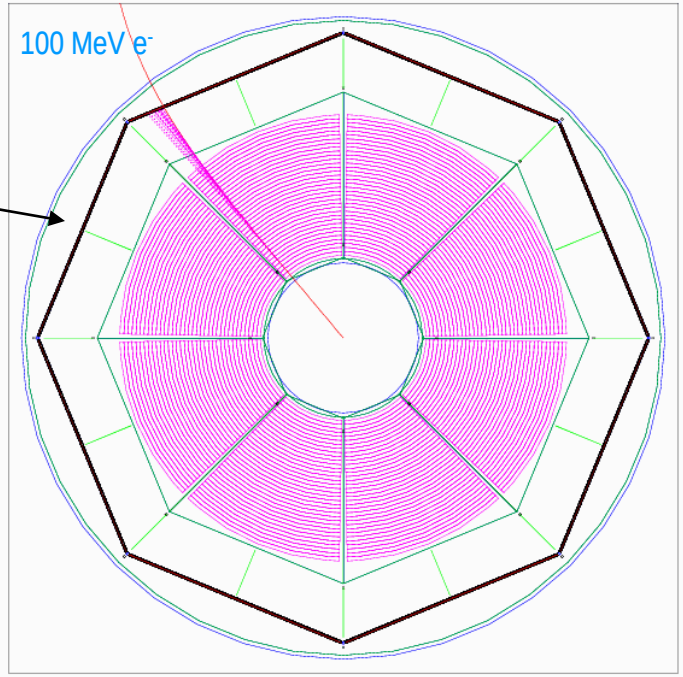


Conclusion

Cherenkov Detectors at RHIC and LHC are working and will be used in upgraded and new experimental setups.

Fast, Compact TPC with enhanced electron ID capabilities





16 identical modules with 35 pad-rows,
double (triple) GEM readout with pad size: 0.2x1. cm².
Maximum drift: 40-45 cm. "Working" gas: fast, low diffusion, good UV transparency .

If you will not use PID ….