R&D FOR THE UPGRADE OF THE HIGH MOMENTUM PARTICLE IDENTIFICATION DETECTOR FOR ALICE AT LHC

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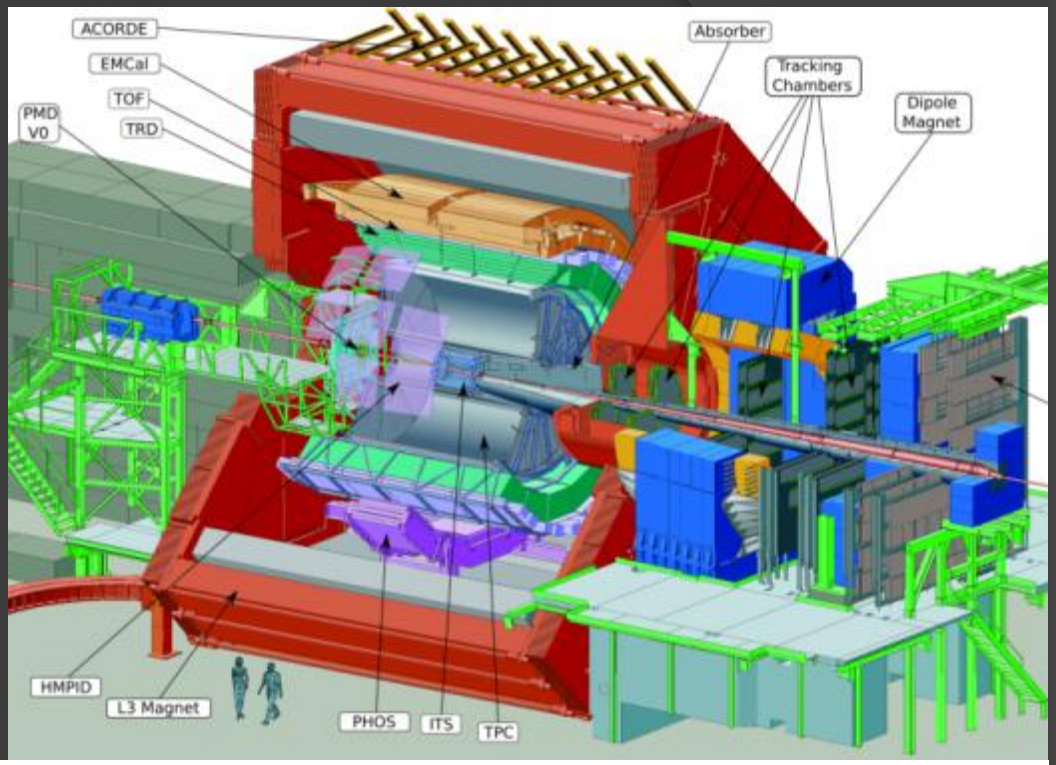
on behalf of the ALICE/VHMPID collaboration

Outline

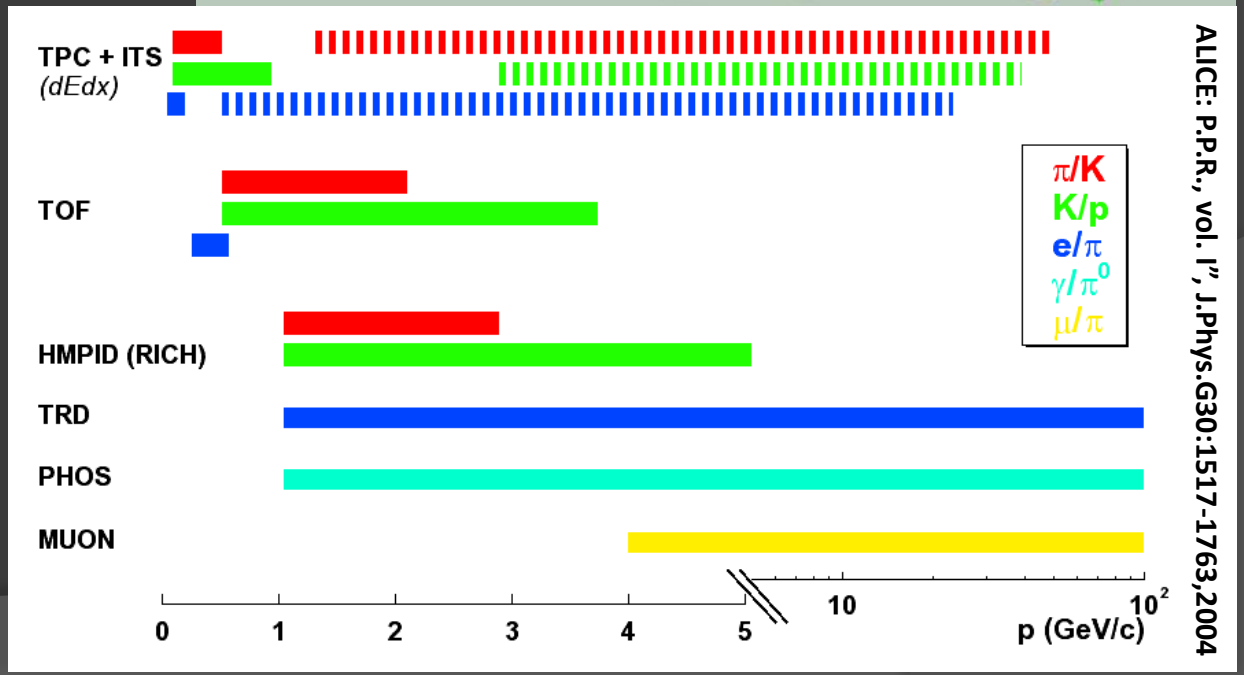
- Physics motivation for a Very High Momentum PID upgrade
- New design specifications and related R&D
- Expected performance
- Testbeam studies
- Summary

PID in ALICE

- ALICE specifically designed to study Quark-Gluon Plasma in “heavy ion collisions” at LHC, pp studies relevant part of the physics program



- Excellent PID capabilities by combining different techniques over a large momentum range



ALICE: P.P.R., vol. I", J.Phys.G30:1517-1763,2004

Physics motivation

- The Very High Momentum PID (VHMPID) RICH has been proposed as additional detector to extend charged hadron *track-by-track* PID capability up to 25 GeV/c and complement the existing measurements based on statistical methods (dE/dx), addressing specifically the study of jets properties

- The latest proposal foresees the combined integration of an EMCAL and a RICH in the same acceptance to achieve direct reconstruction of the full jet and its energy, thus significantly improving the track-by-track physics and correlation measurements (jet-hadron, di-hadron)

- Such an integrated detector system will provide major contribution in the determination of particle identified fragmentation functions both in pp and in heavy ion physics

Design specifications and R&D issues I.

First VHMPID proposal in 2006, various layouts studied; after first LHC results at the end of 2011, new specifications requiring further R&D:

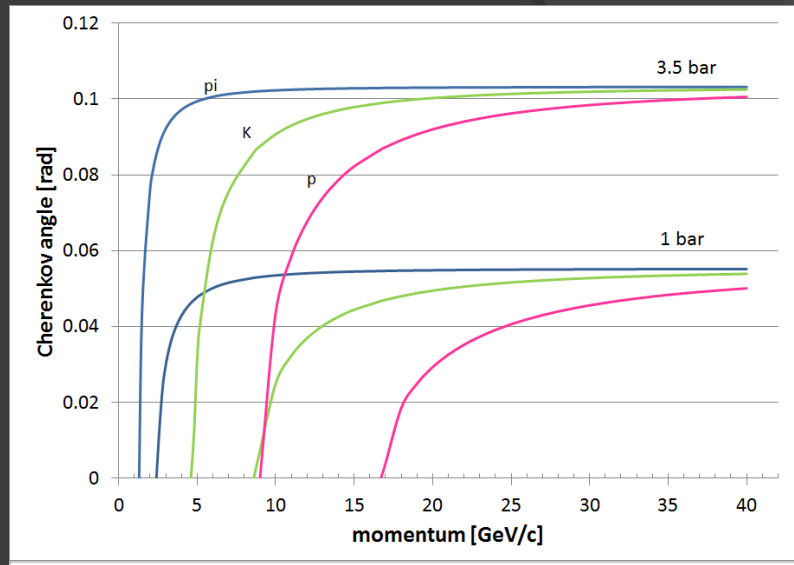
- Charged hadrons (π, K, p) identification in 5 -25 GeV/c and combined integration with EMCAL extension (DCAL) -> Cherenkov radiator
  - K identification starting at 5 GeV/c not possible with any gaseous radiator at atmospheric pressure: increase radiator gas pressure to lower Cherenkov threshold
  - After discontinuing of production by 3M, poor UV transparency and larger cost of C_4F_{10} available on the market: new radiator gas C_4F_8O, tested for BTeV RICH in the visible, first use in UV. 2nd option: C_5F_{12}.
  - Max detector depth ~70 cm (limited "free" space) pushes for a compact detector

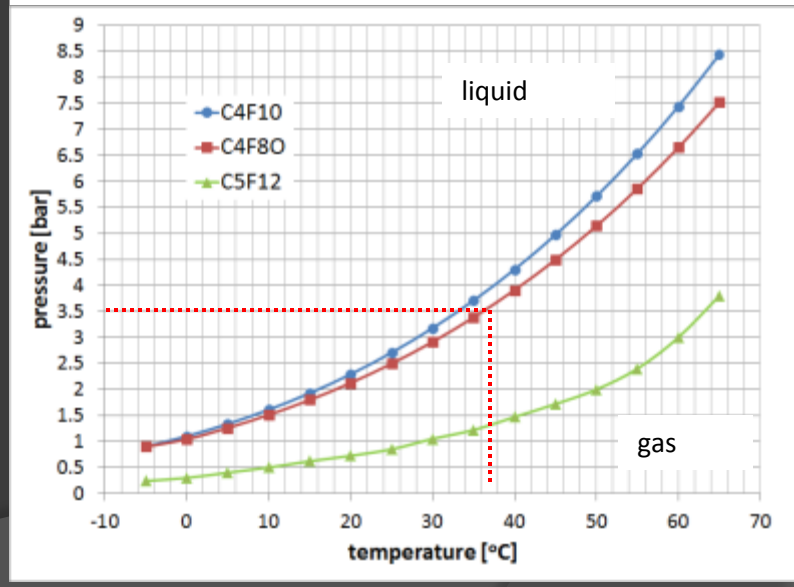
→ Focusing RICH with <u>pressurized</u> C_4F_8O gaseous radiator

Cherenkov radiator gas pressurization

- Refractive index optimization

P [bar]	Refr. ind.@ 175 nm	Momentum threshold [GeV/c]			N_{ph} cm^{-1} eV^{-1} at saturation
		π	K	p	
1	1.00153	2.5	9	17	1.1
1.5	1.002295	2.1	7.3	13.5	1.7
2	1.00306	1.8	6.4	12	2.2
2.5	1.00383	1.6	5.6	10.7	2.9
3	1.0046	1.5	5.1	9.8	3.4
3.5	1.00535	1.3	4.8	9.1	3.9



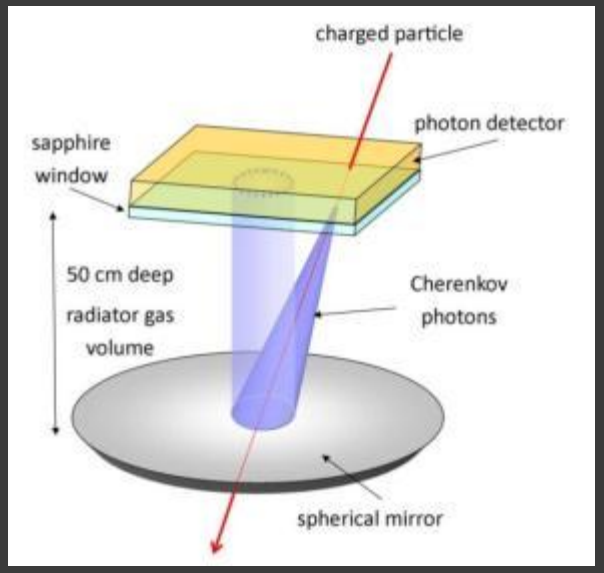


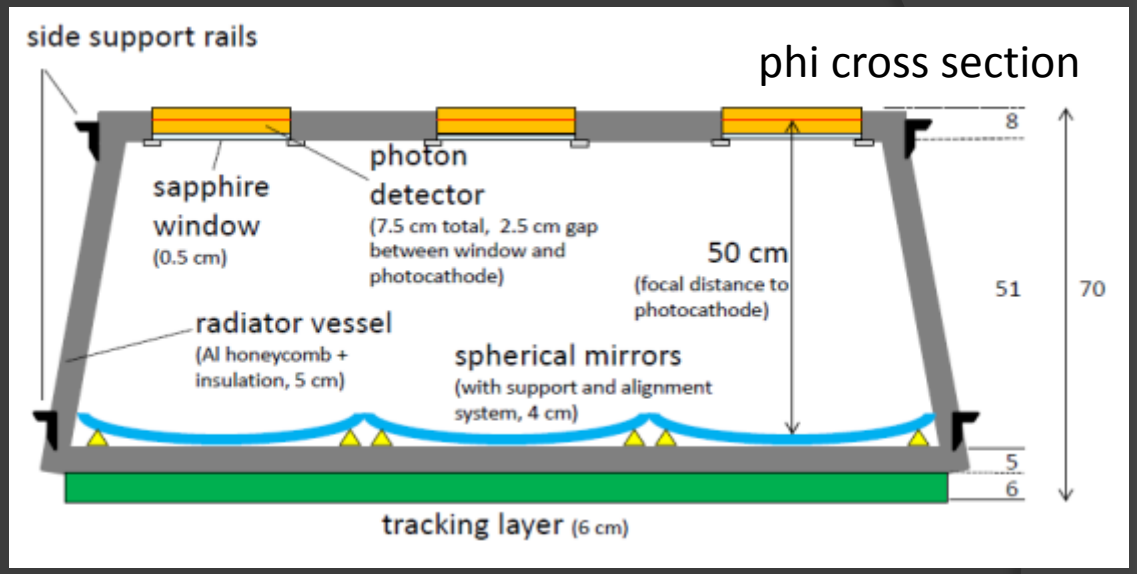
- @ 3.5 bar and L= 50 cm: excellent photon yield and ring radius (5 cm) suitable for pattern recognition
- PID range can be extended by lowering P
- @ 3.5 bar C_4F_8O needs heating at ~ 40 °C to prevent condensation
- Using C_5F_{12} : P ~ 2.8 bar, T~ 60 °C

Design specifications and R&D issues II.

- Large acceptance (up to 60 m^2, ~ 30% of the barrel) and large photosensitive area (up to 8 m^2) + B=0.5 T -> photon detector
  - ALICE HMPID (11 m^2 of CsI-MWPC) know-how, CsI-based photo-detector is the most cost effective solution
  - Modified MWPC with reduced CsI PC pad size and anode-cathode gap: improved spatial resolution + smaller induction spread (5 cm ring radius wrt 12 cm in HMPID)
  - CsI-based TGEM photon detector
  - Photonis Planacon XP85012Q with bialkali PC to work in the visible
- High luminosity ALICE upgrade (pp: up to 2 MHz, Pb-Pb: 50 KHz)
  - Front-end and readout electronics
- Other topics
  - Radiator vessel and mirror system engineering studies
  - Radiator gas cleaning and UV transparency measurement systems
  - Tracking detector based on CCC (Close-Cathode Chamber)

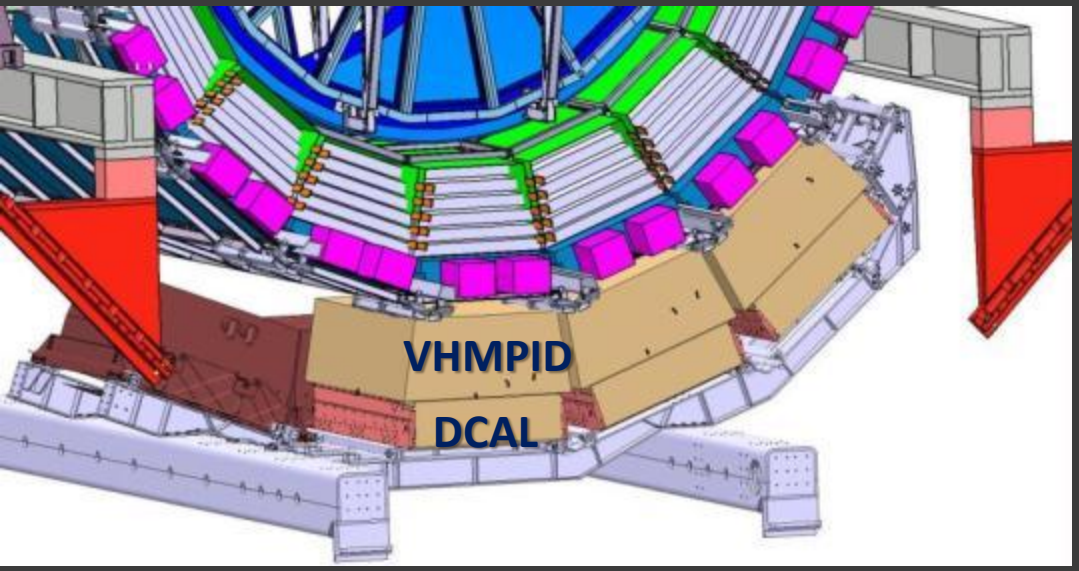
Baseline detector principle scheme

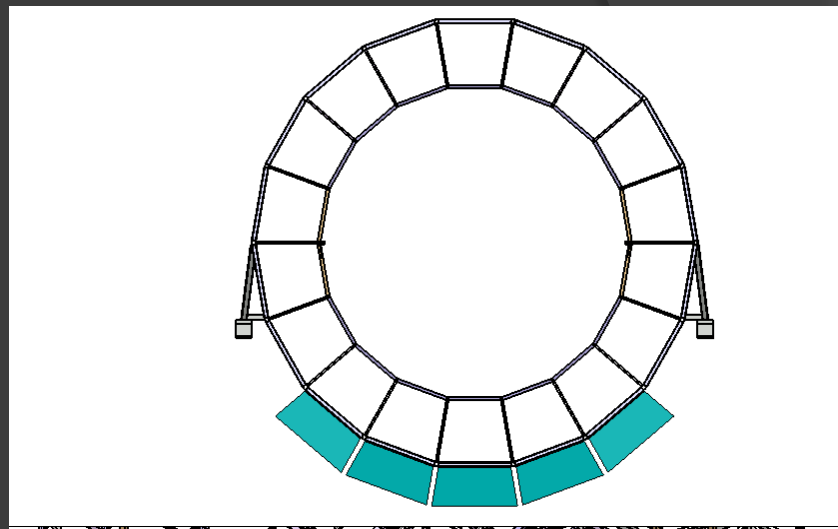


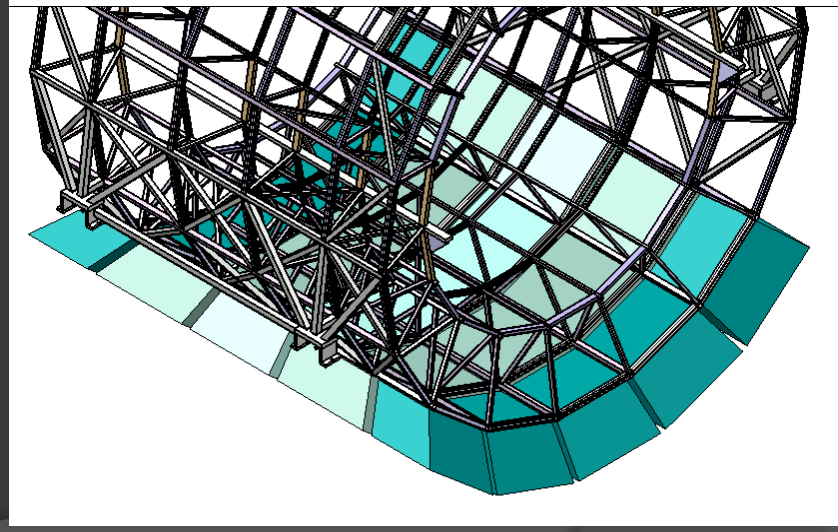


- Focusing RICH, C_4F_8O gaseous radiator L~ 50 cm, operated at 1-3.5 bar
- Al honeycomb radiator vessel, 4 mm sapphire window with A/R coating
- HMPID-like photon detector: MWPC with CsI pad segmented photocathode, operated with CH_4 ; pad size 4x8 mm^2 , 20 μm anode wires, 0.8 mm gap, 4 mm pitch
- 50x50 cm^2 spherical mirror, light C-fiber substrate, Al/MgF_2 coating
- CCC tracking layers with strip chambers
- FEE with analogue readout for centroid measurement, three options:
  - HMPID Gassiplex chip with T/H, modified version from COMPASS RICH (max 500 KHz trigger rate)
  - APV25 with continuous sampling at 40 MHz, as used in COMPASS RICH and HADES RICH upgrades
  - new common FEE developments for ALICE high-lumi upgrade

Detector layout and integration in ALICE

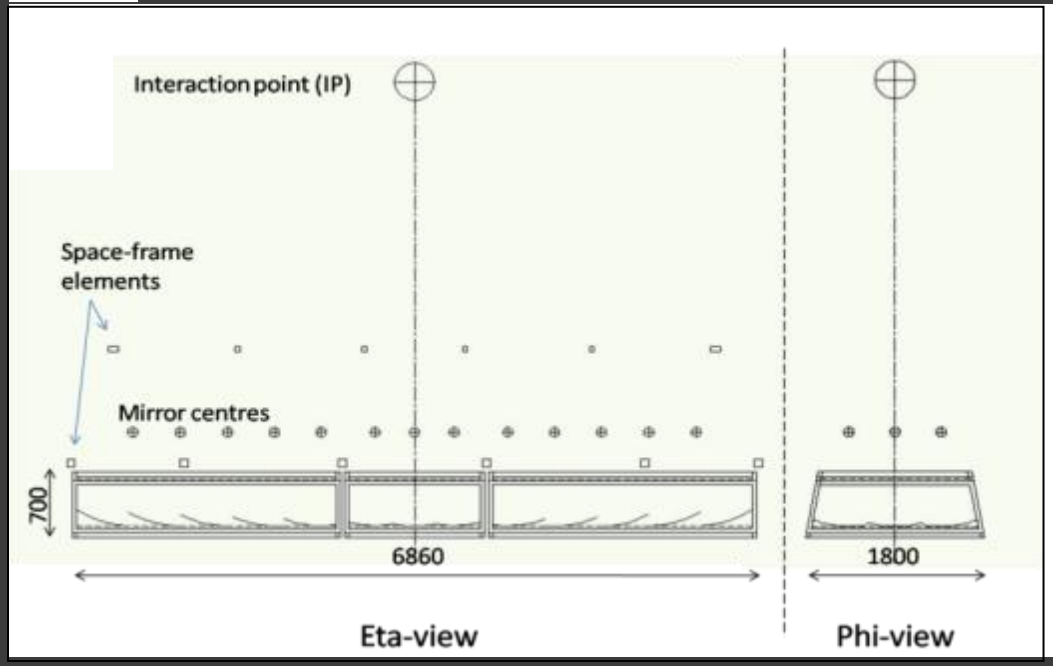


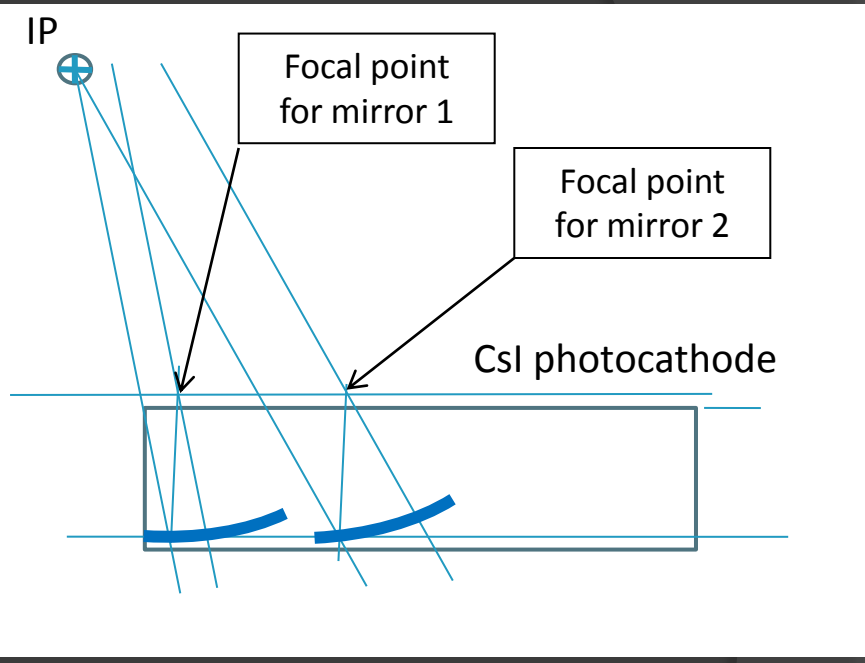


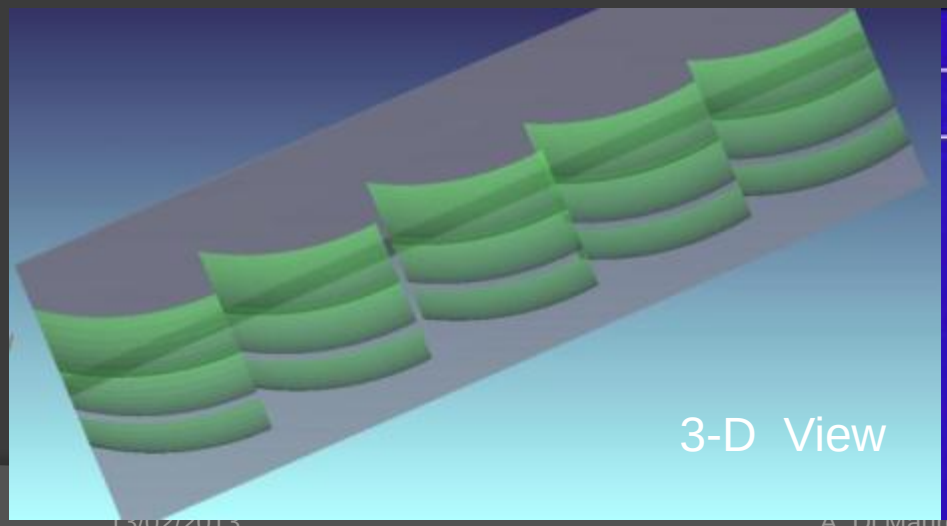


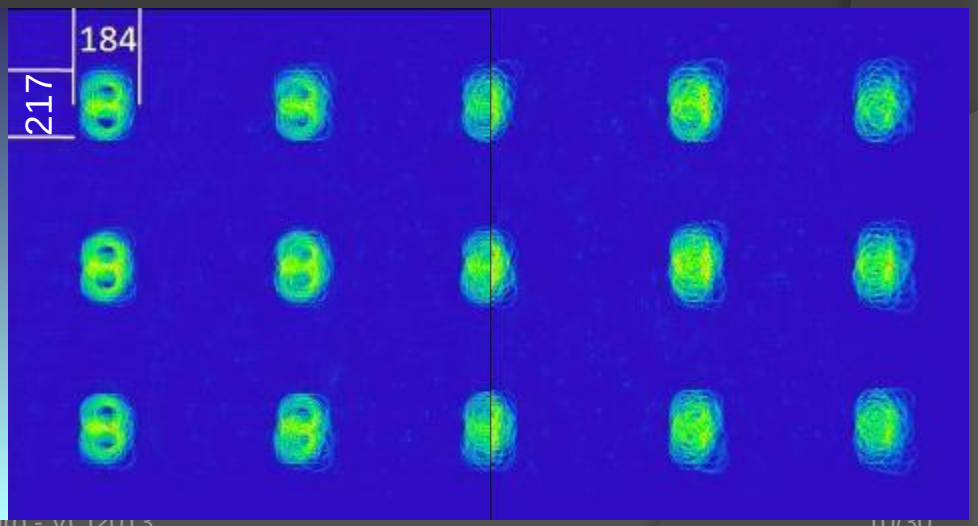
- Module arrangement under study
- 5 Central modules, size ~ 1.4x1.7x0.7 m^3
- 10 Side modules, size: ~ 2.7x1.7x0.7 m^3

Mirror layout studies with ZEMAX

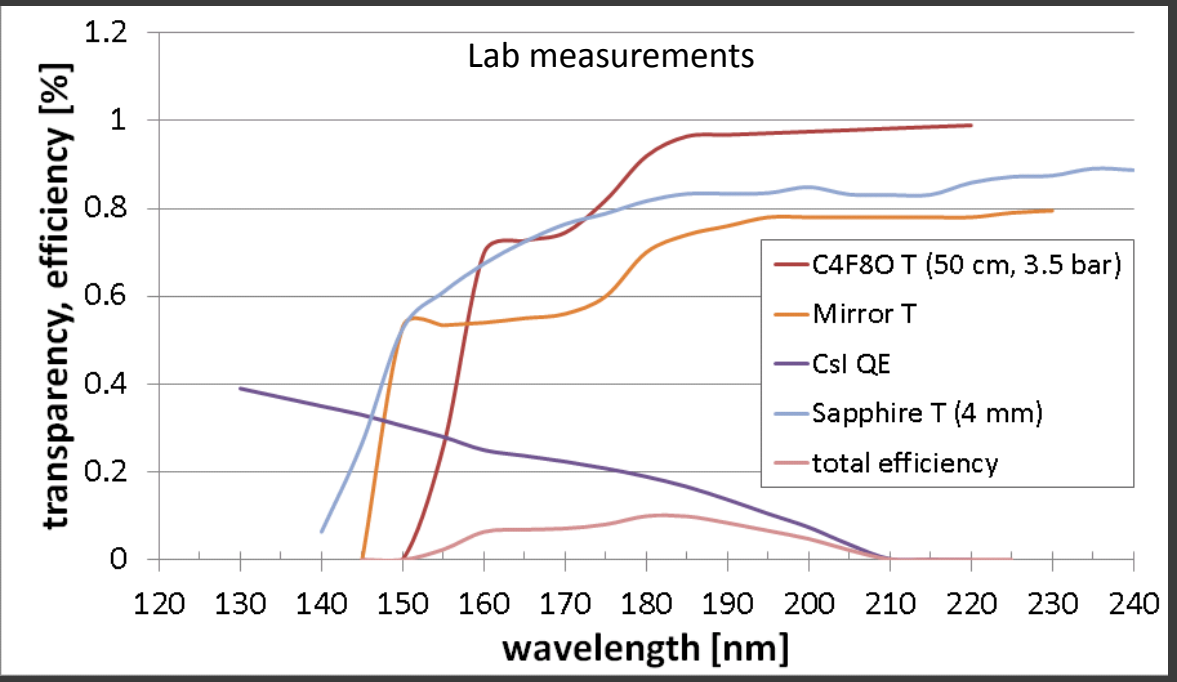








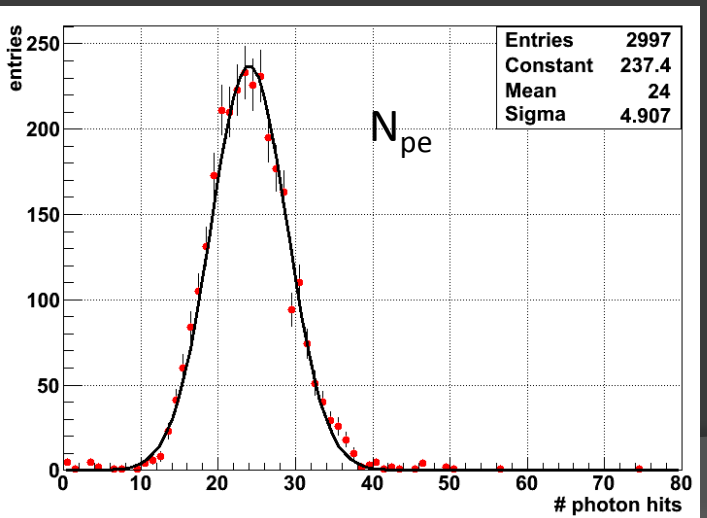
Detector figure of merit N_0



$$N_0 = 370 \int \varepsilon \cdot QE \cdot T \cdot RdE$$

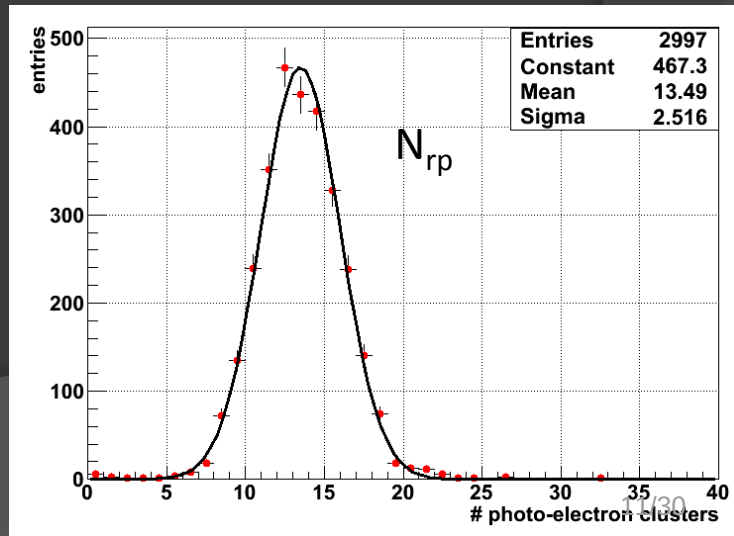
$$N_{pe} = N_0 L \sin^2 \vartheta_c$$

	UV	Visible
N_0 [cm^{-1}]	60	130
N_{pe}	24	45



MC simulation: 15 GeV/c π, C_4F_8O @ 3.5 bar

Single photoelectrons overlap within a pad cluster: number of reconstructed photons $N_{rp} < N_{pe}$.

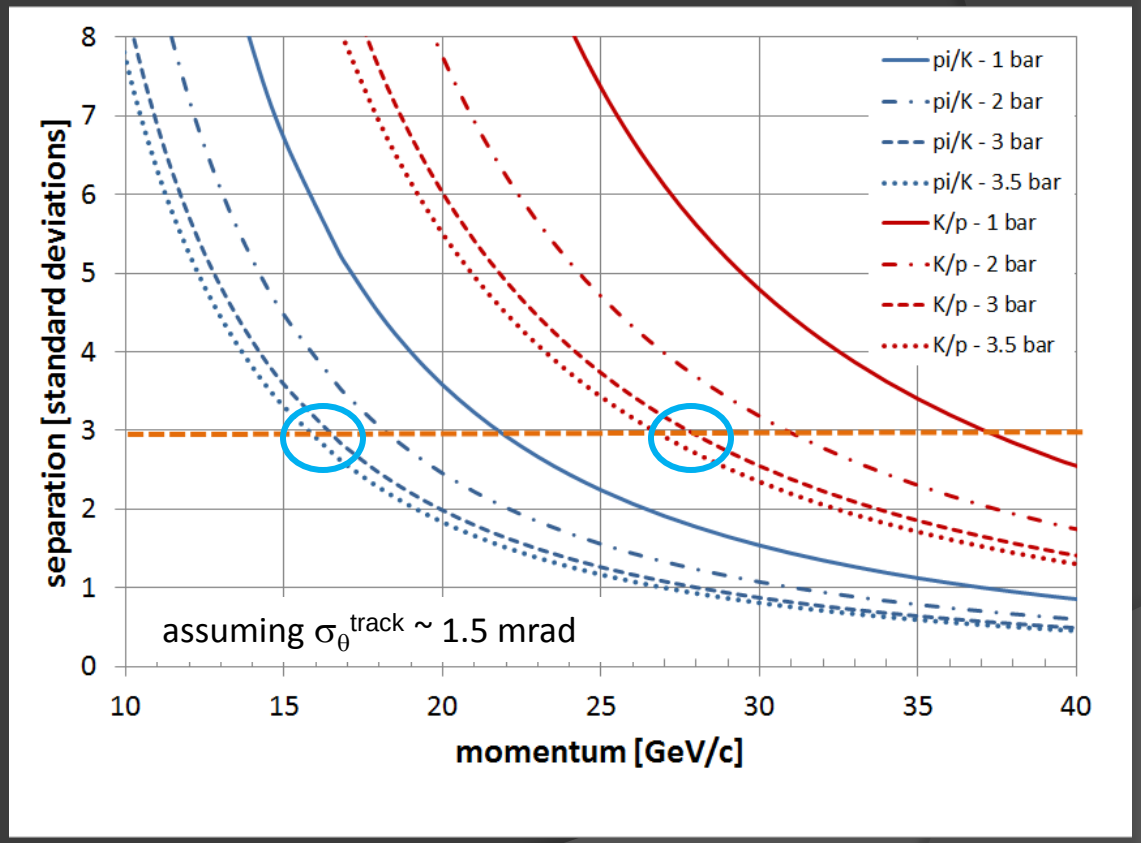


Angular resolution and particle separation

Theoretical estimation
C_4F_8O @ 3.5 bar

$$\frac{\sigma_\theta}{\sqrt{N_{rp}}} = \frac{m_2^{\,2} - m_1^{\,2}}{2 n_\sigma p^2 \tan \vartheta_c}$$

	UV	Visible
σ_θ chromatic	2.7 mrad	5.3 mrad (!)
σ_θ emission	0.5 mrad	0.5 mrad
σ_θ granularity	1.7 mrad	1.7 mrad
σ_θ tracking	1.6 mrad	1.6 mrad
σ_θ total	3.6 mrad	5.8 mrad
N_{rp}	~ 13	~ 30
σ_θ track	~ 1 mrad	~ 1.1 mrad

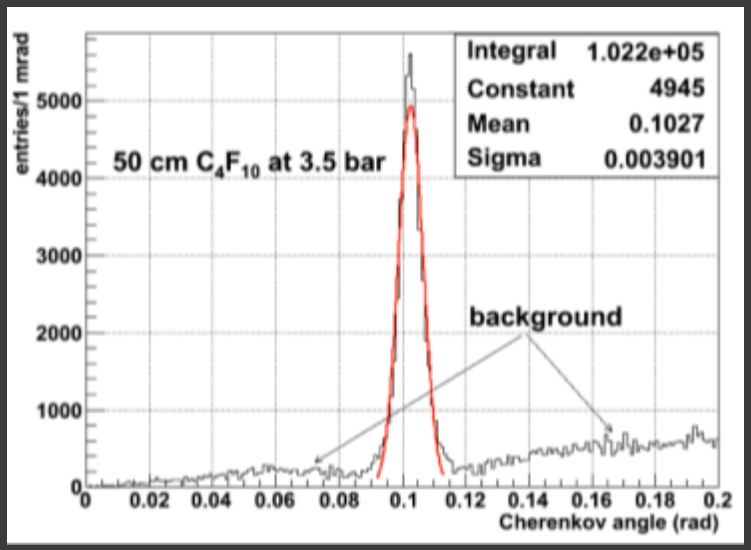


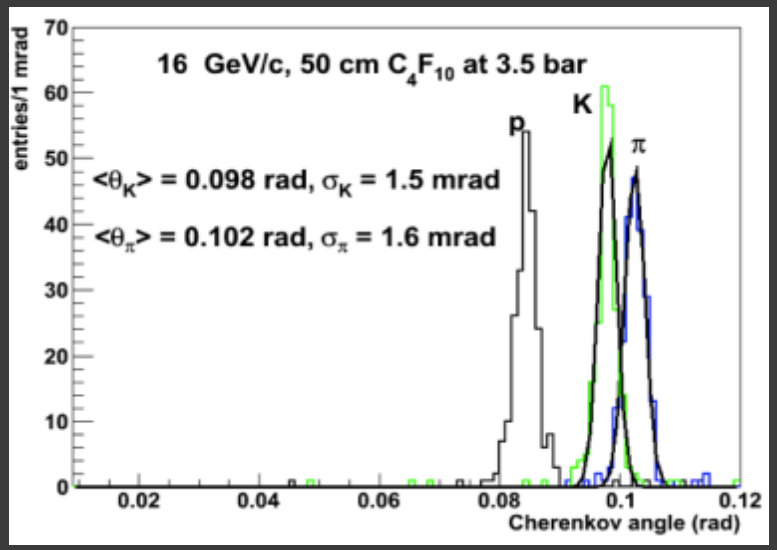
	Signal (GeV/c)	Absence of signal (GeV/c)
π	2-16	
K	5-16	
p	10-25	5-10

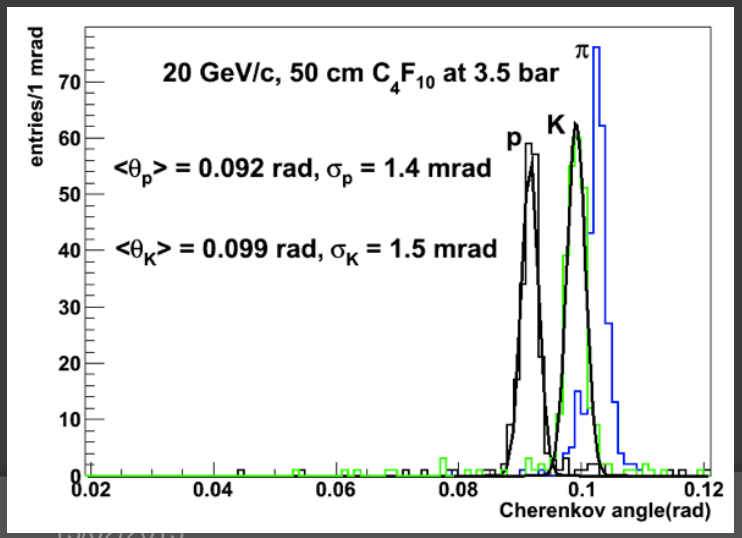
PID ranges
- Lower limit: cut N_{rp} >2
- Upper limit: 3σ separation

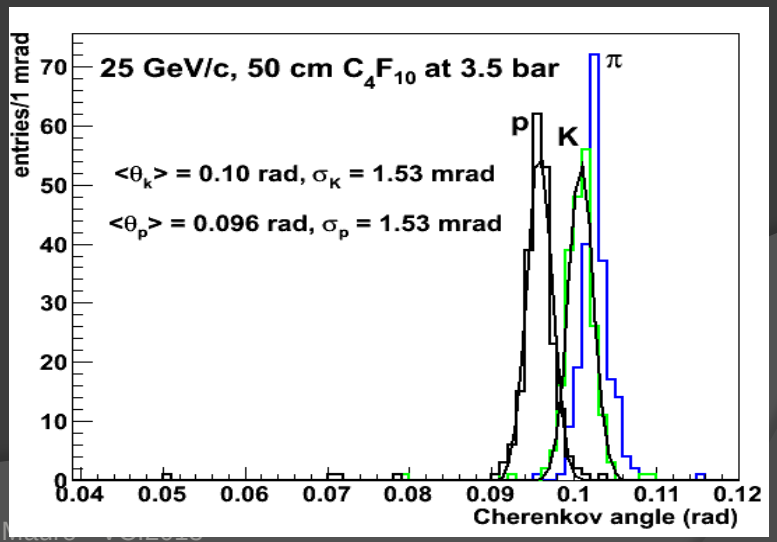
MC studies of PID performance

Events from single particles gun embedded in HIJING generated background (ALIROOT framework)





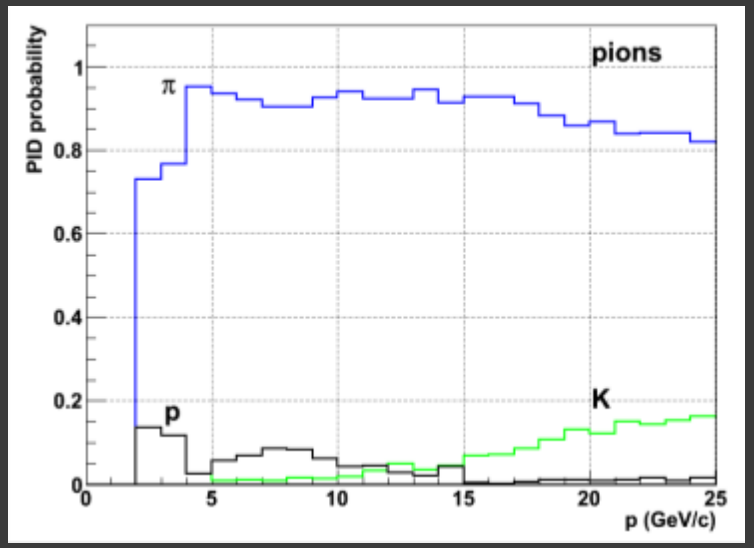


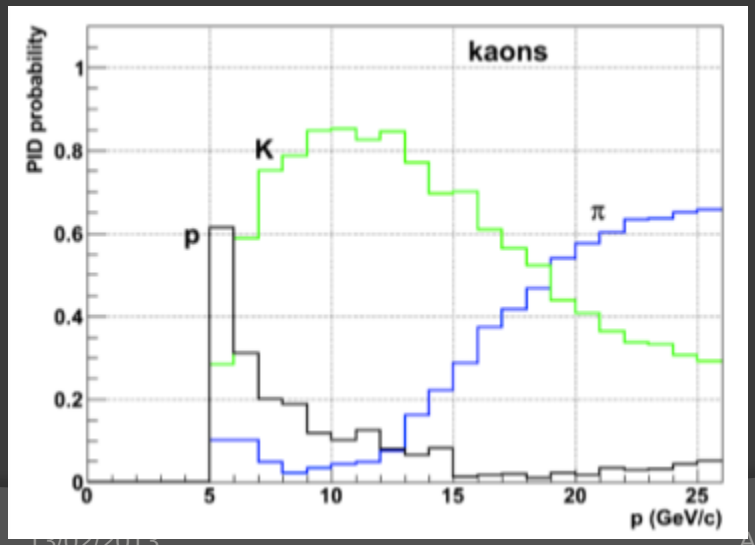


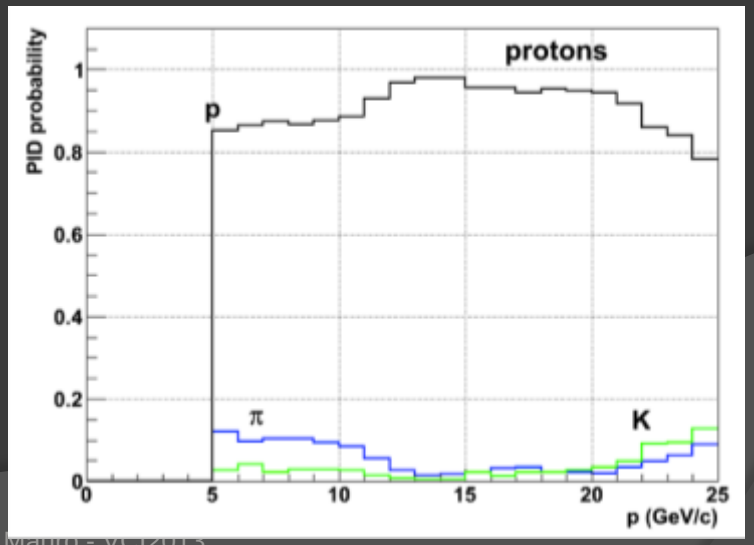
MC studies of PID performance

Events from single particles gun embedded in HIJING generated background (ALIROOT framework)

- Probability of identification for π, K, p
- PID algorithm based on HMPID pattern recognition (Hough transform)
- Further tuning/optimization in progress for VHMPID ring patterns



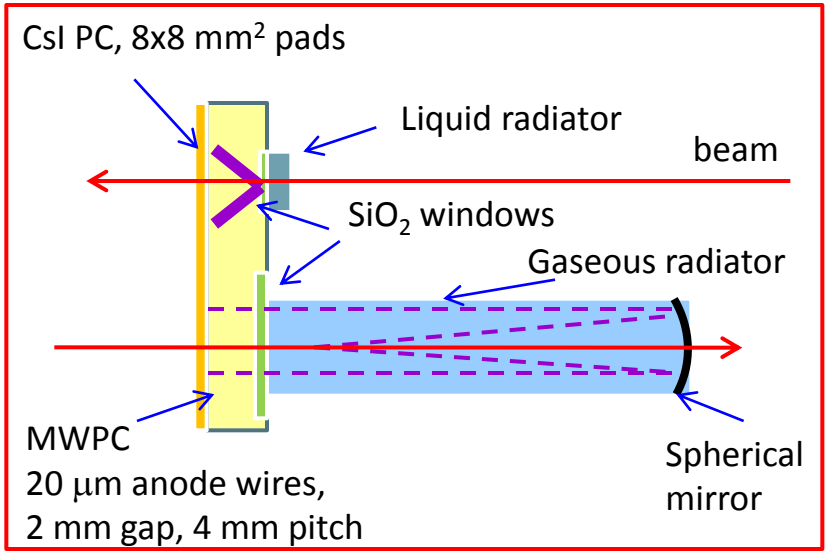


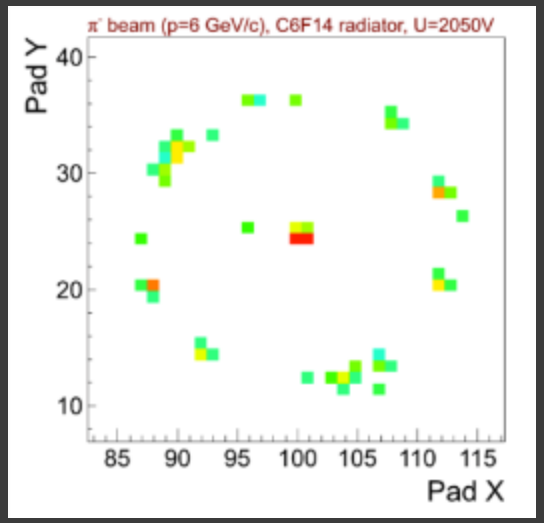


Testbeam studies at CERN PS/T10

- Prototypes using liquid C_6F_{14} radiator (in proximity focusing, HMPID-like), and C_4F_{10} or C_4F_8O at atmospheric pressure with mirror focusing
- MWPC prototype with adjustable anode-cathode gap (0.8-2 mm), smaller pad
- Prototype with C_4F_8O radiator pressurization and heating
- CsI-TGEM and -RETGEM as photon-detector in RICH prototype with C_6F_{14} radiator (see V. Peskov's talk)

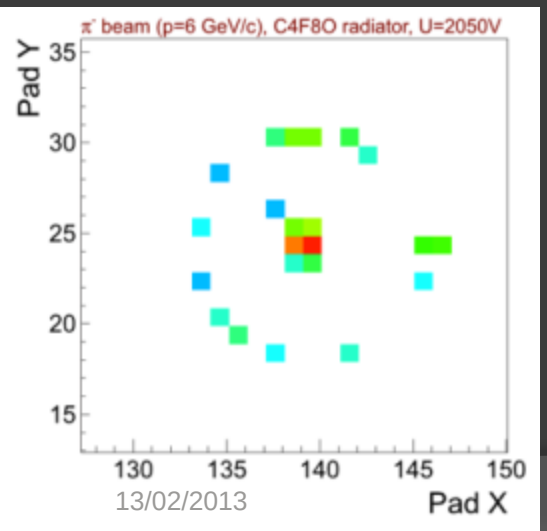
Prototype with two Cherenkov radiators (Nov 2011)



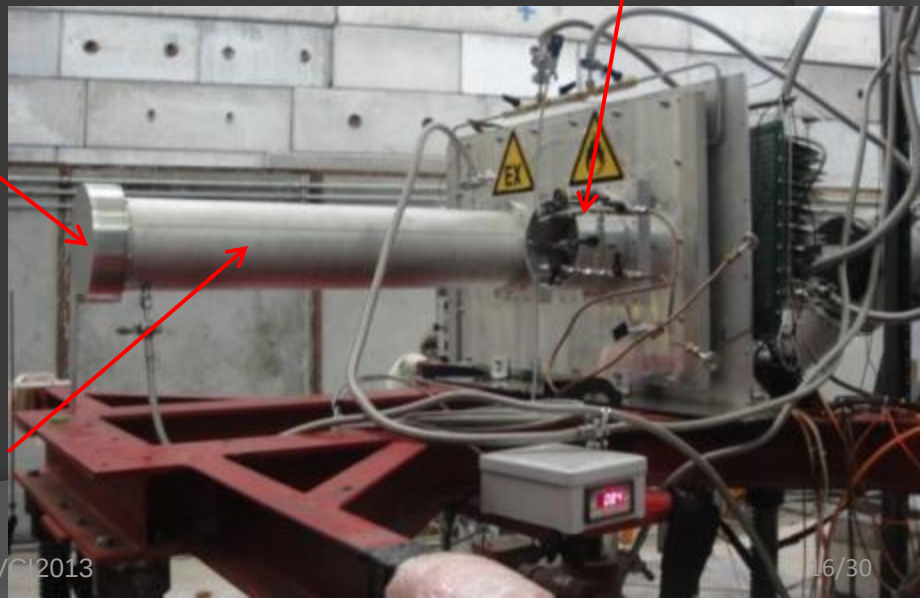


Achieved HMPID benchmark performance

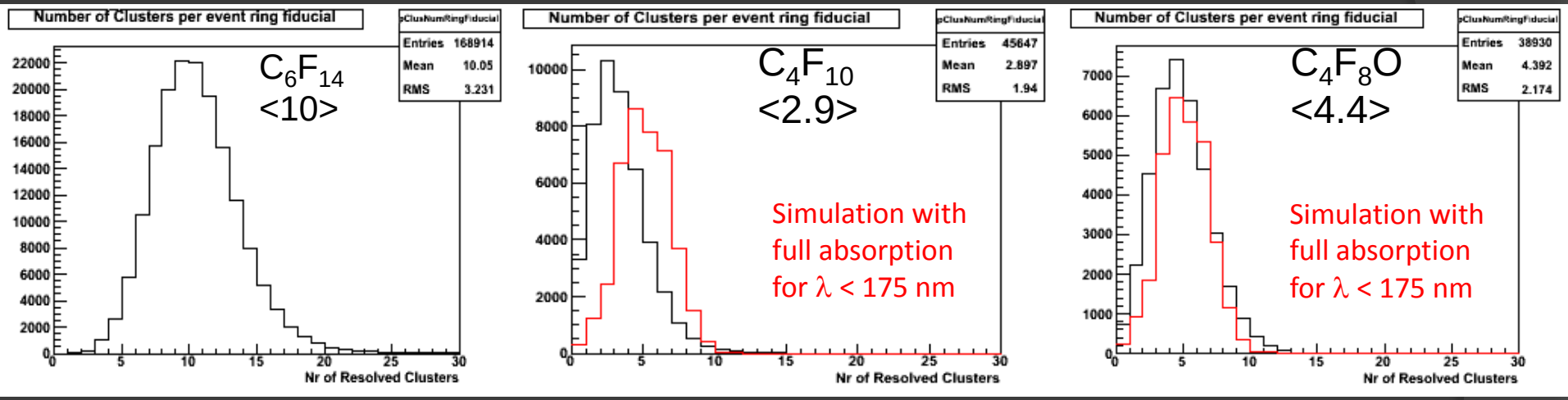
C_6F_{14} liquid radiator



C_4F_{10} or C_4F_8O radiator gas at atmospheric pressure (L = 100 cm)

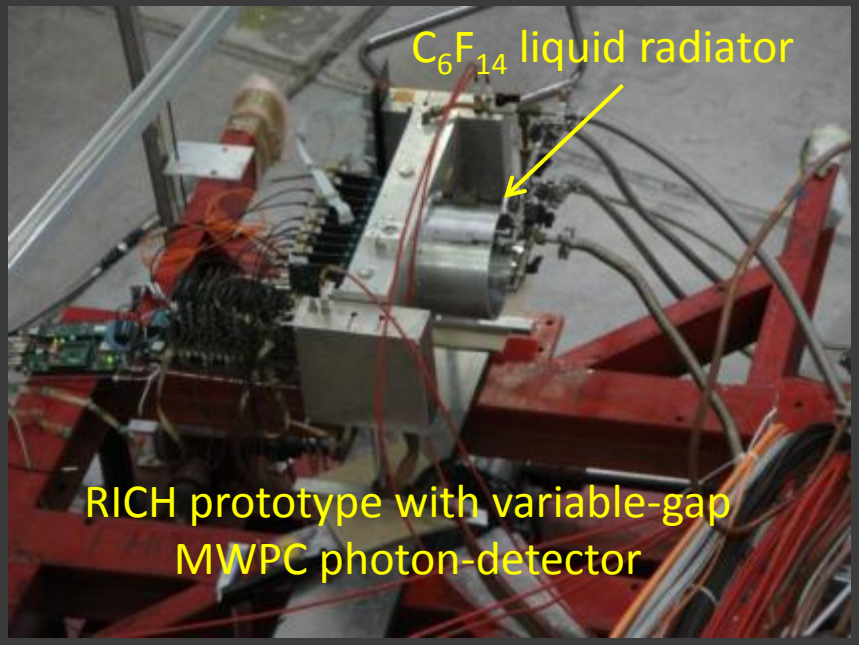


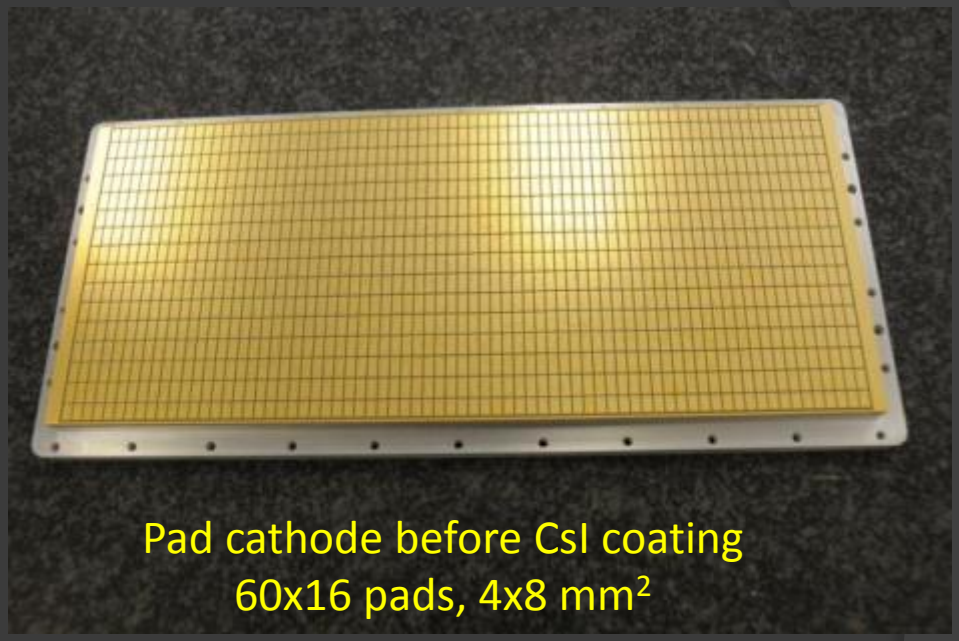
Comparison C_6F_{14} /C_4F_{10} /C_4F_8O



- C_6F_{14} thickness : 6 mm, to obtain same photon yield as 100 cm gaseous radiator
- First tests with radiator gas, C_4F_{10} and C_4F_8O used w/o cleaning or filtering

Variable-gap chamber tests (June 2012)

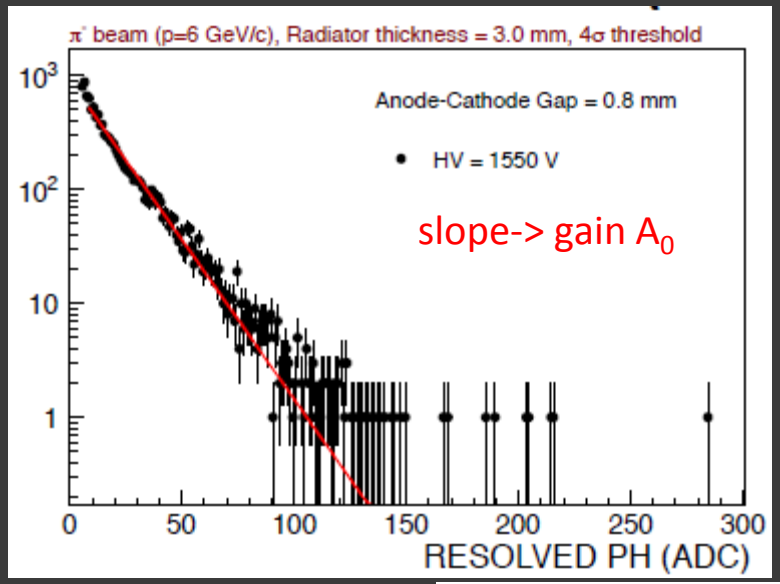




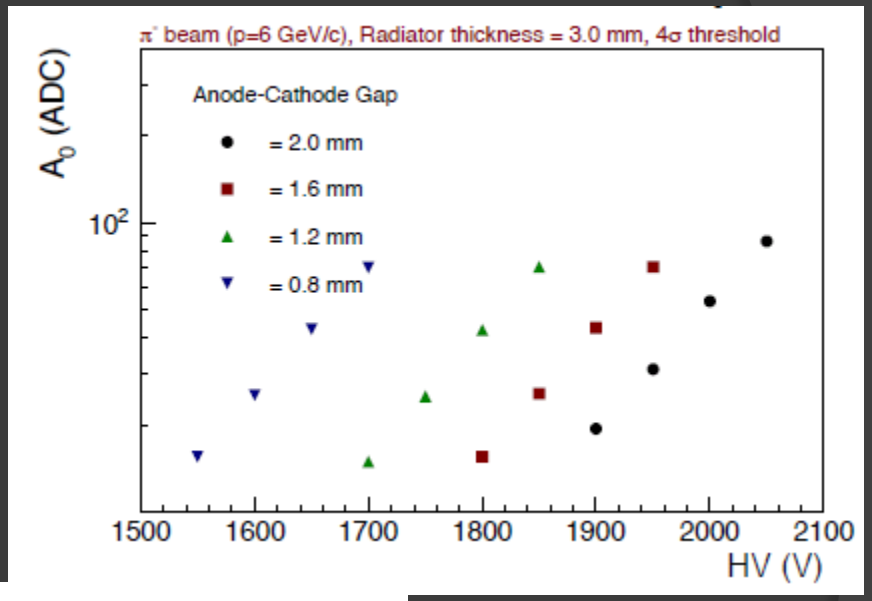
- Refurbished old prototype (F. Piuz, RD26), anode-pad cathode gap adjustable in 0.8-2 mm (100 μm steps), anode -wire cathode 2 mm, 20 μm anode wires, pitch 4 mm
- Basic performance studies using liquid C_6F_{14} radiator, 3 mm thick: HV scan, gap scan

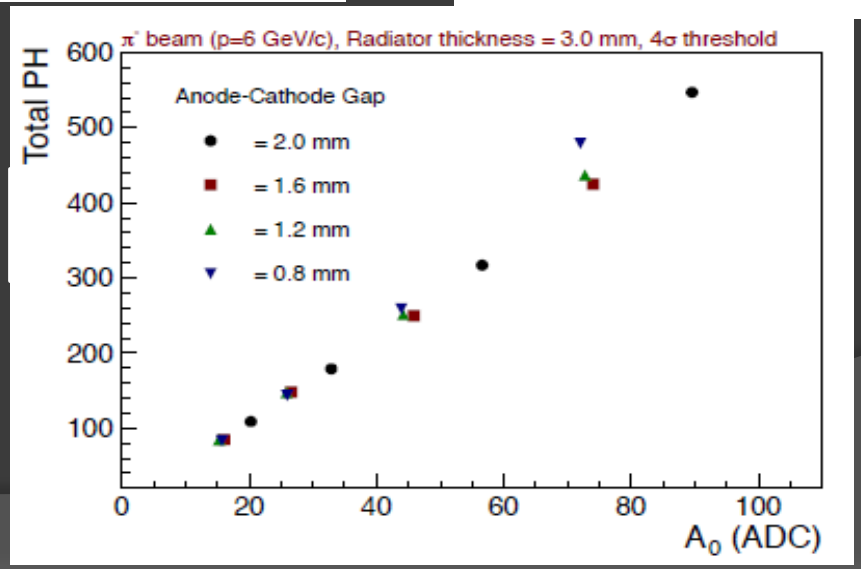
Variable-gap chamber tests (June 2012)

Single e- PH spectrum



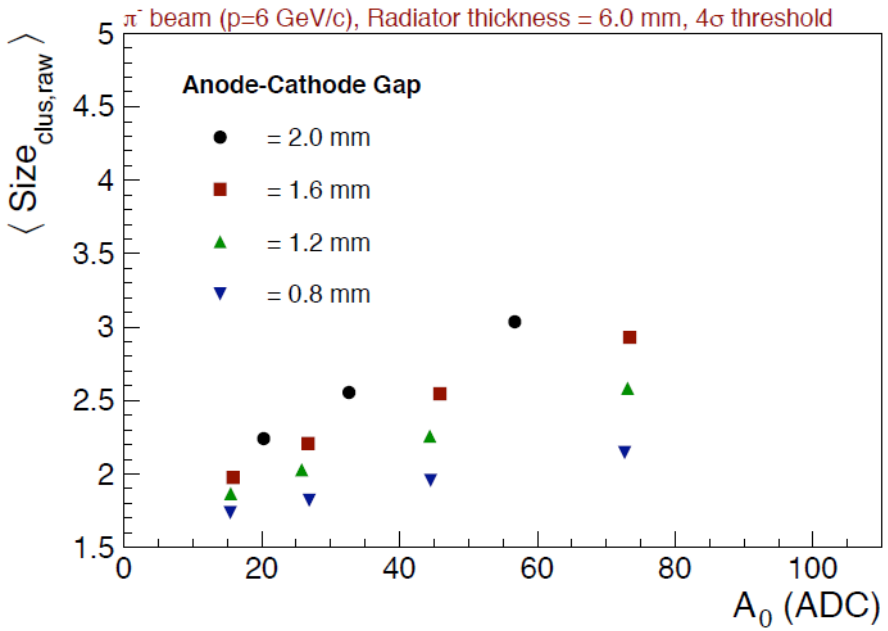
Gain vs HV at various gaps





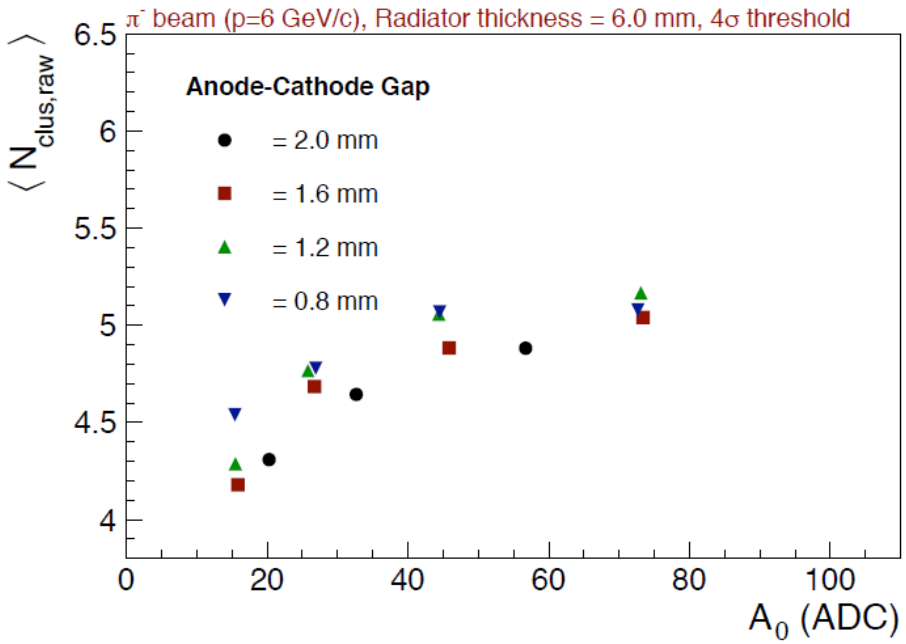
Equal amount of photons seen @ various gaps

Variable-gap chamber tests (June 2012)



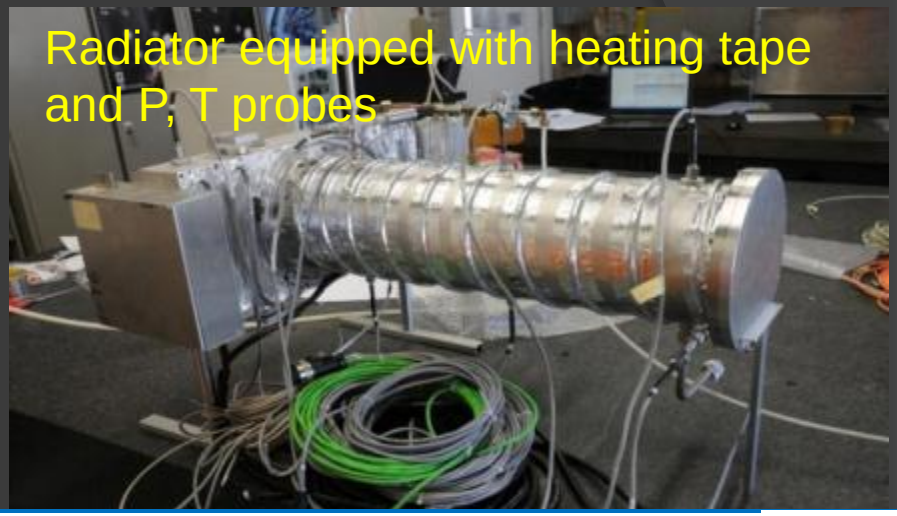
Cluster size proportional to gap

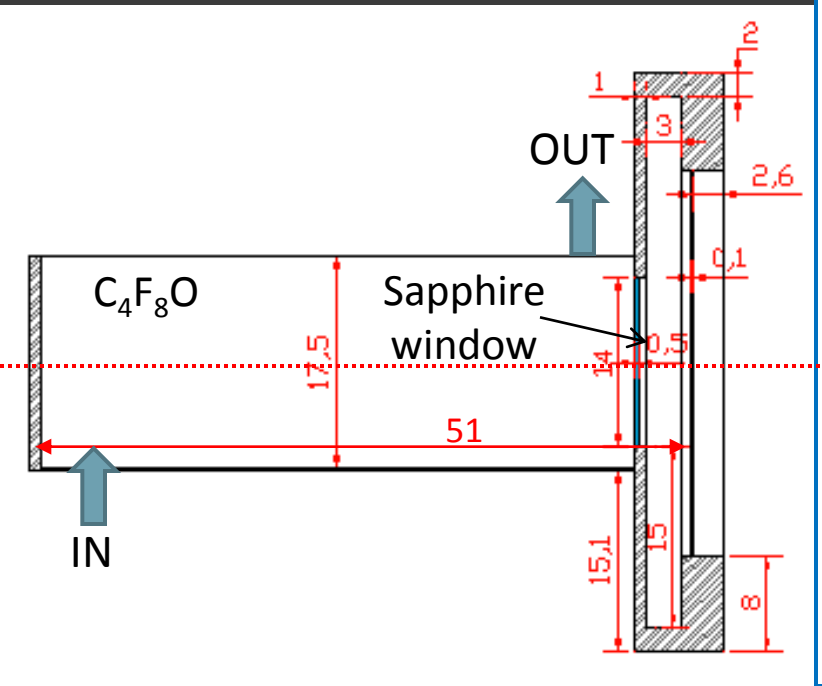
No. of raw clusters increases by reducing the gap

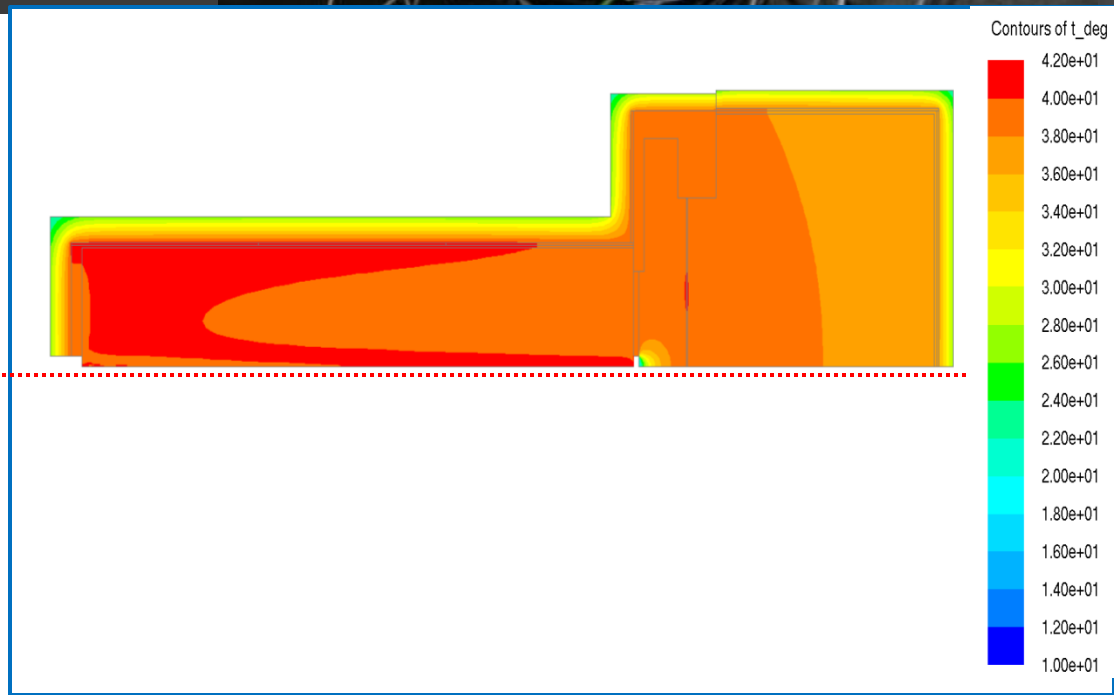


Testbeam with pressurized C_4F_8O radiator (Oct 2012)

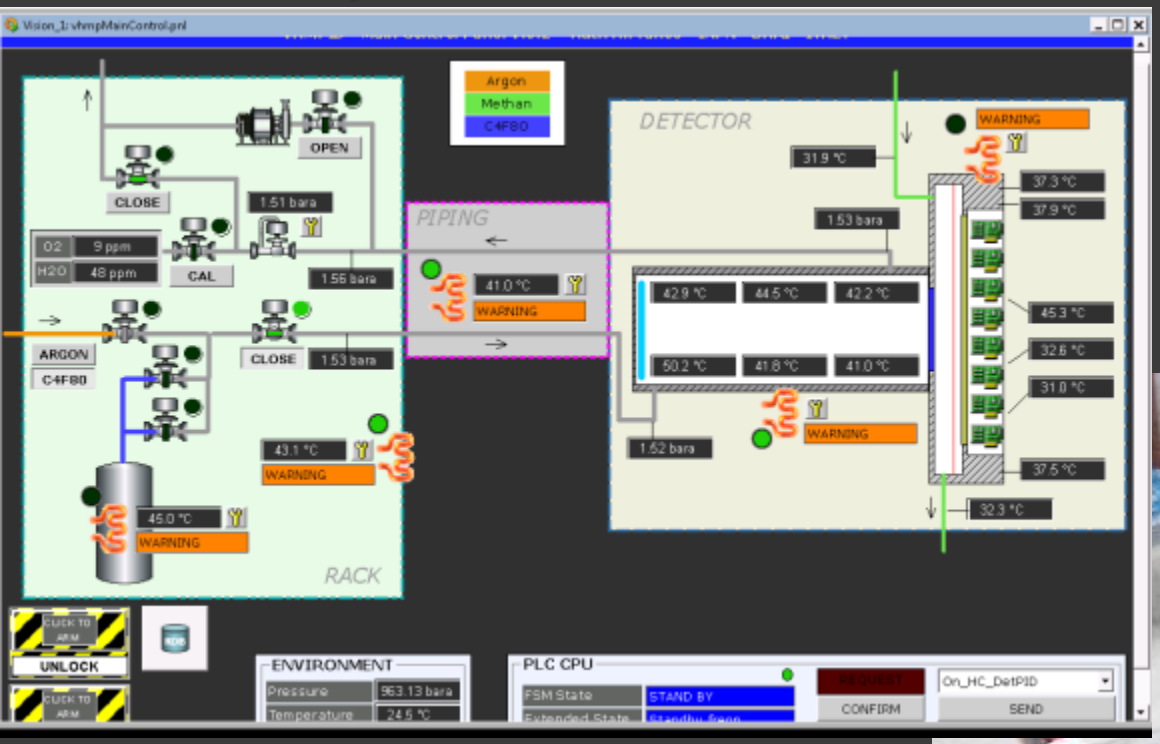
- Safety pressure test (@ 5 bar for 5 h)
- Heating studies with Fluent 6.0 to optimize insulation and ensure radiator temperature uniformity



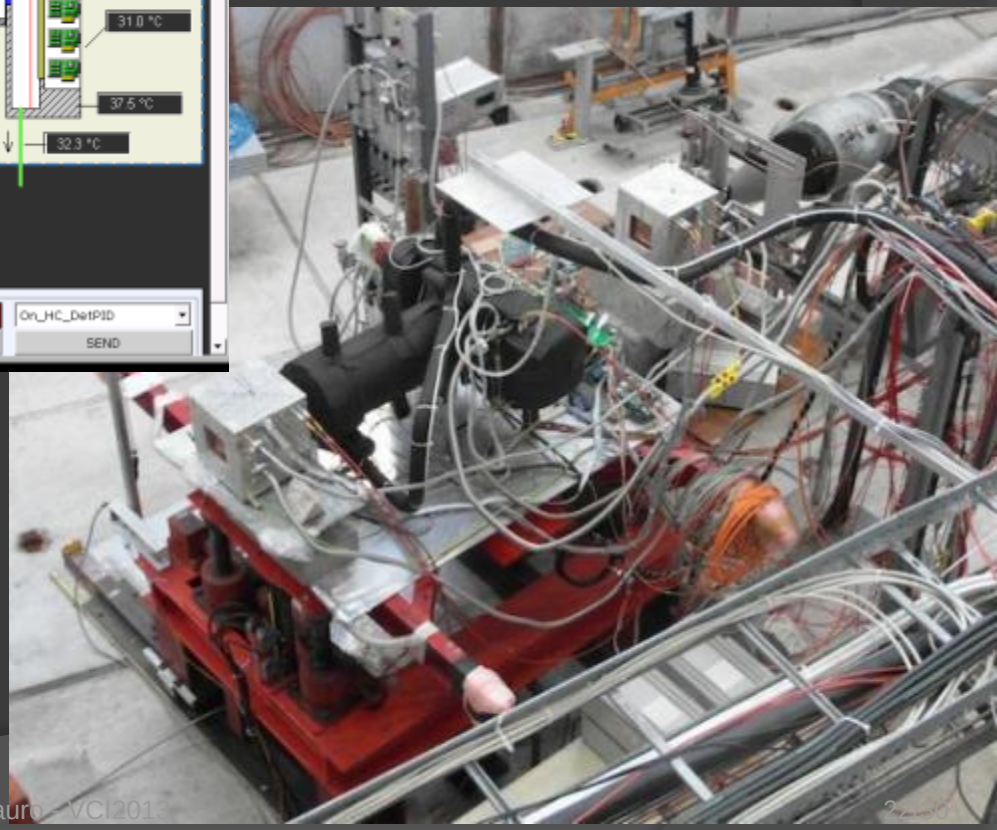




Testbeam with pressurized C_4F_8O radiator (Oct 2012)



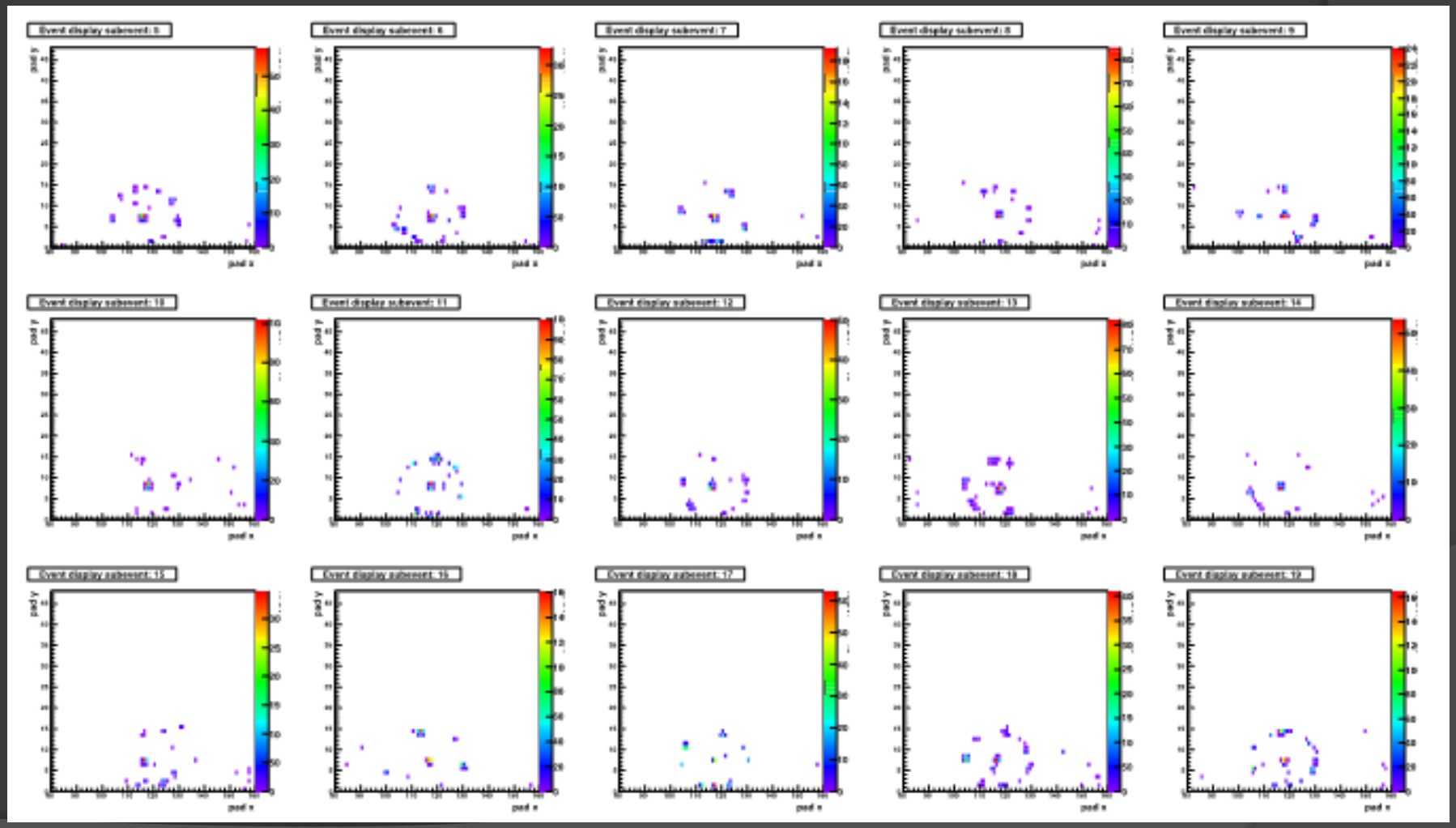
P, T monitoring and control panel



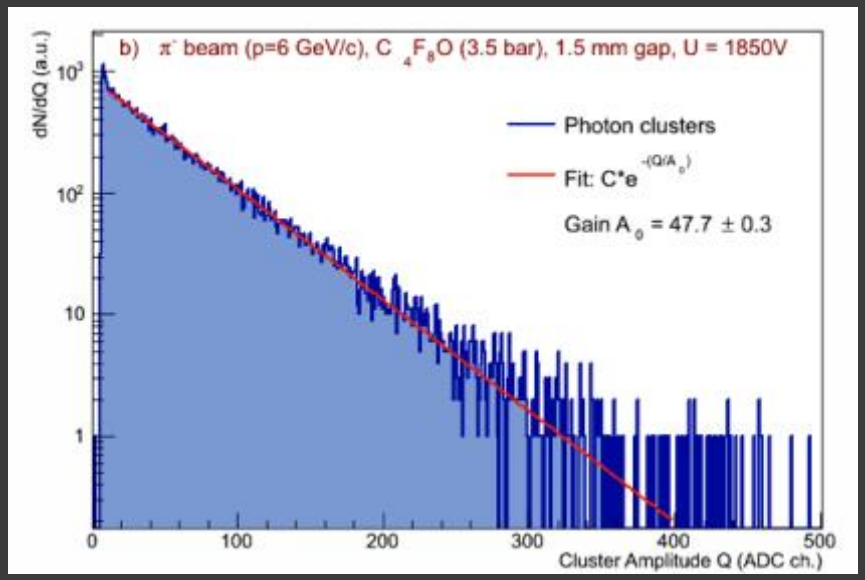
Gas system, piping and detector heated and insulated

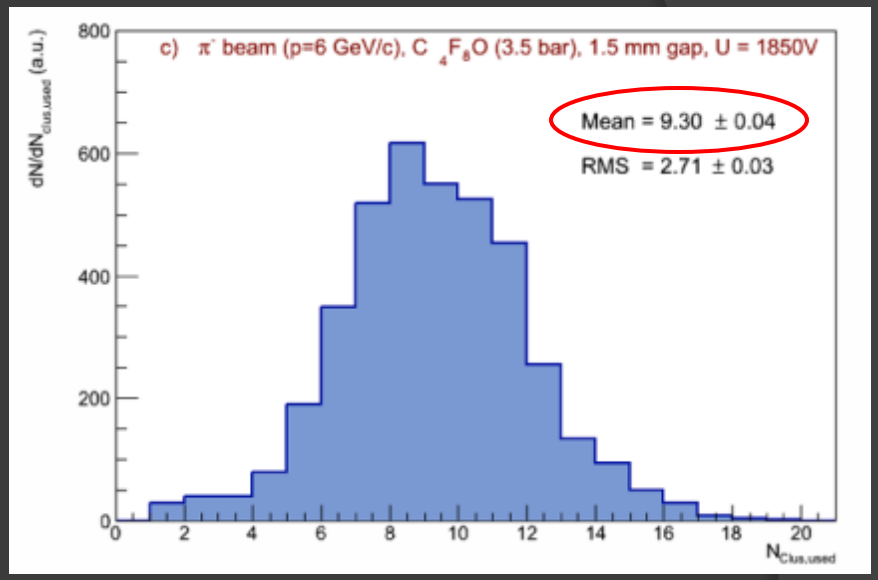
Testbeam with pressurized C_4F_8O radiator (Oct 2012)

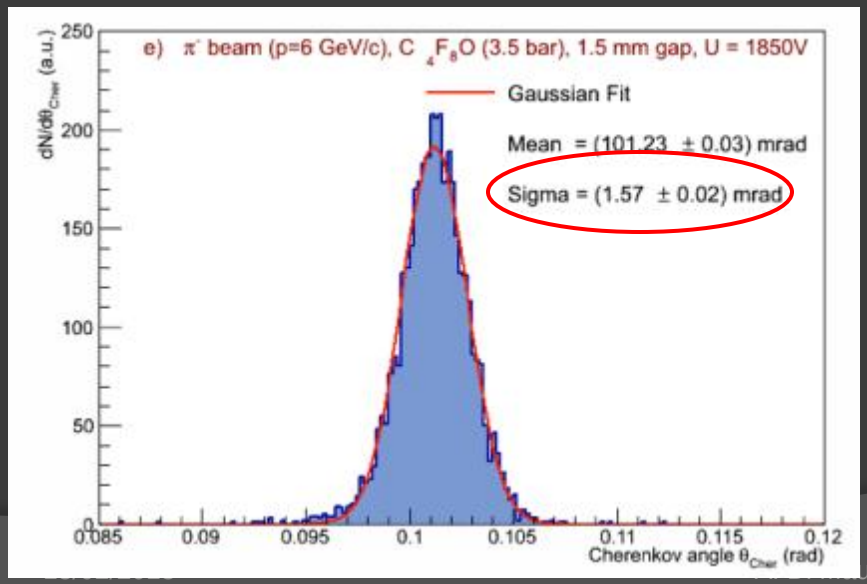
The first 15 events for C_4F_8O at 3.5 bara with 6 GeV/c π^- beam

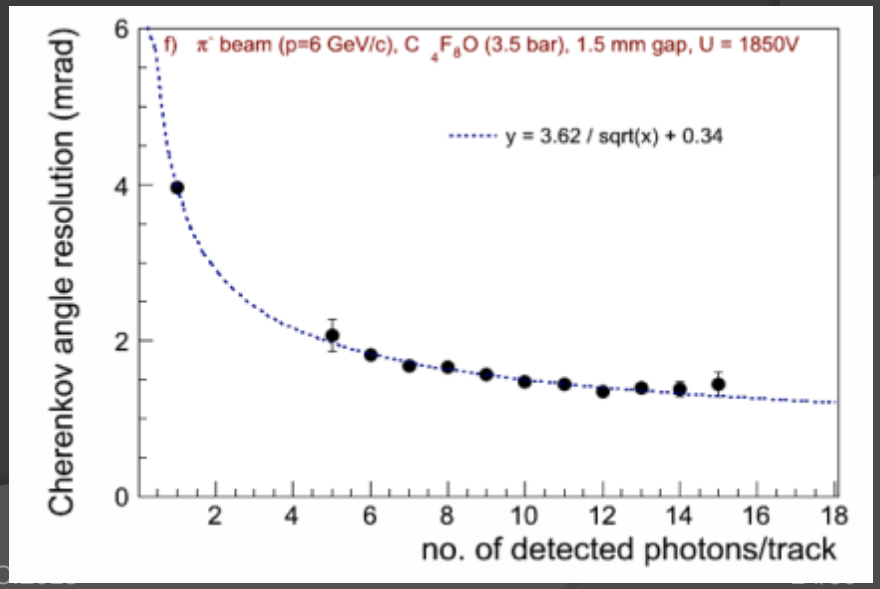


Testbeam with pressurized C_4F_8O radiator (Oct 2012)

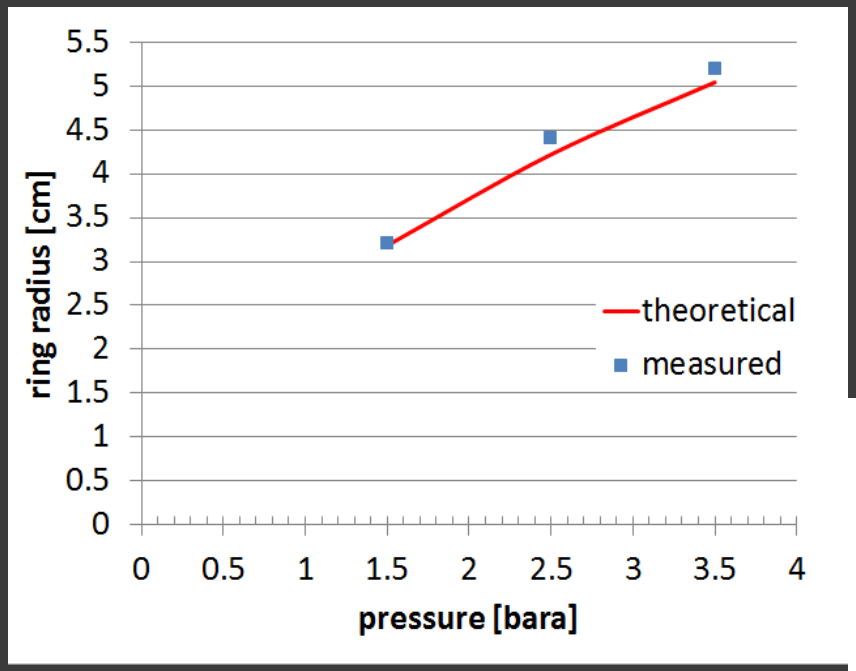




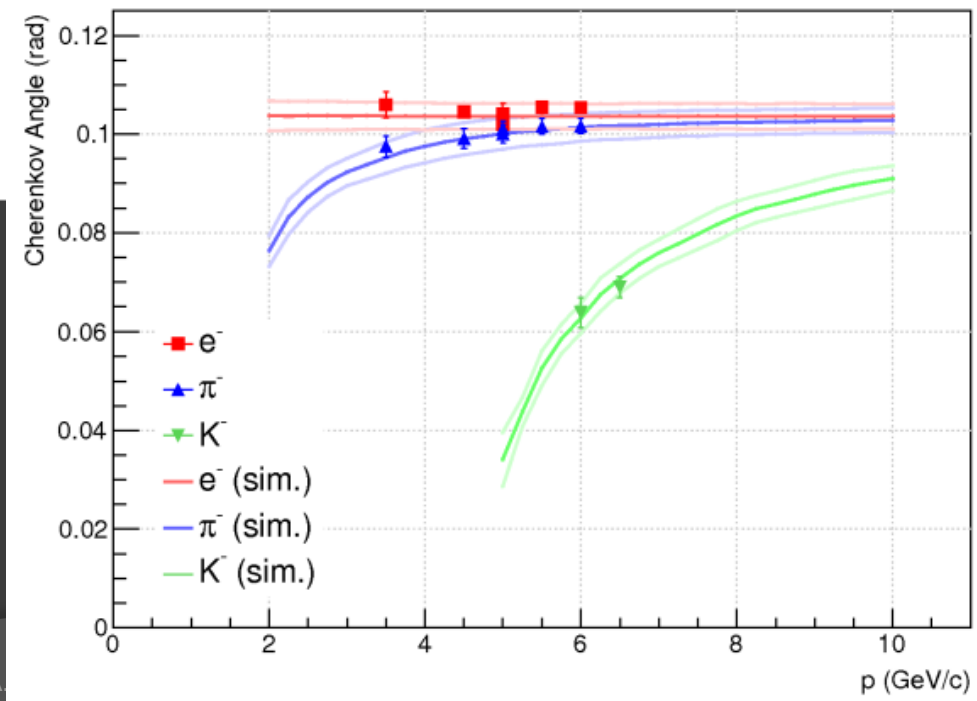




Testbeam with pressurized C_4F_8O radiator (Oct 2012)

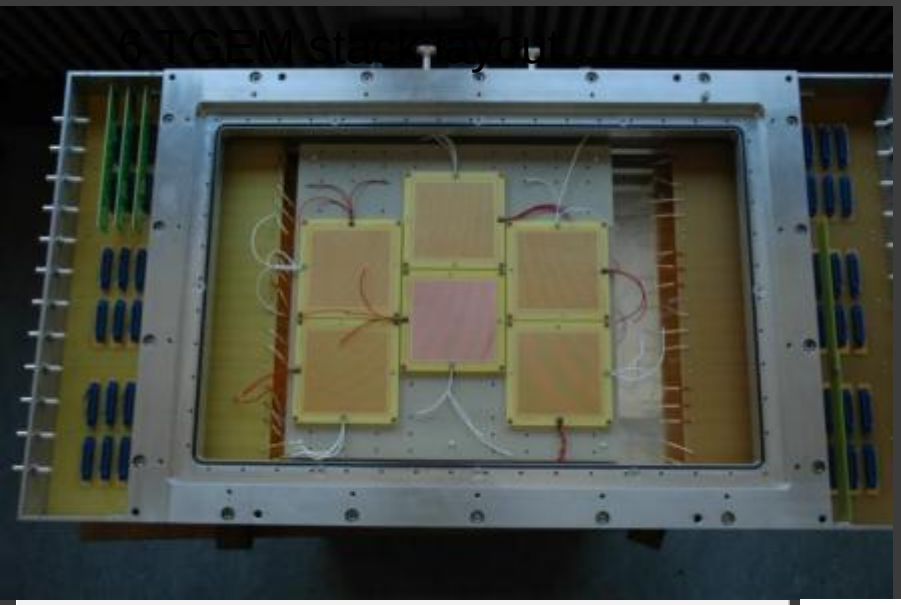


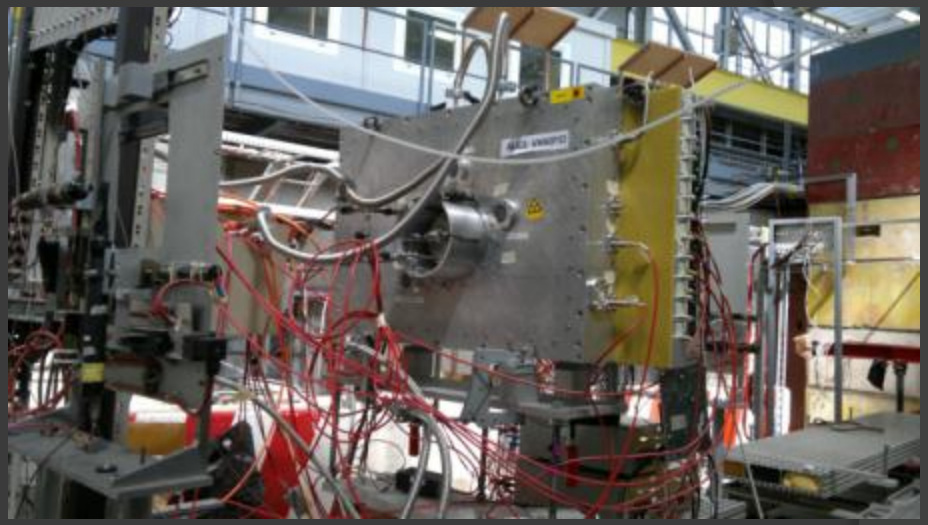
C_4F_8O refractive index in UV ~ C_4F_{10} , simulation are in progress to deduce exact parameterization

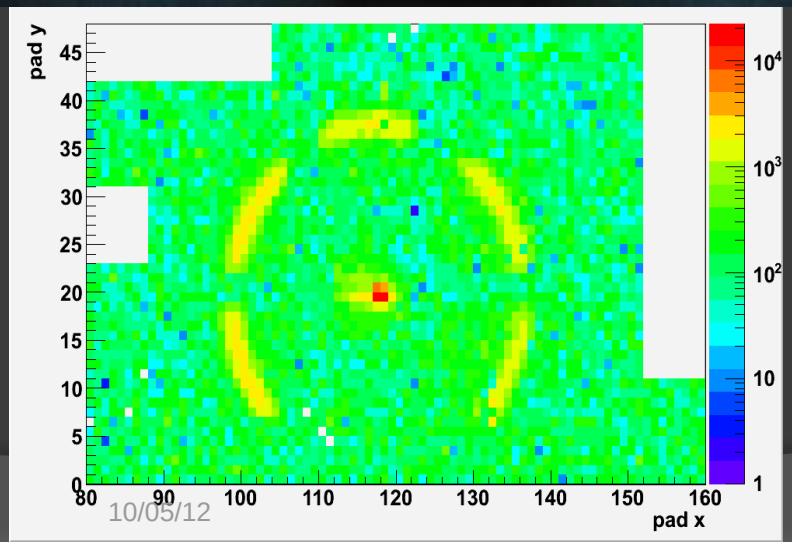


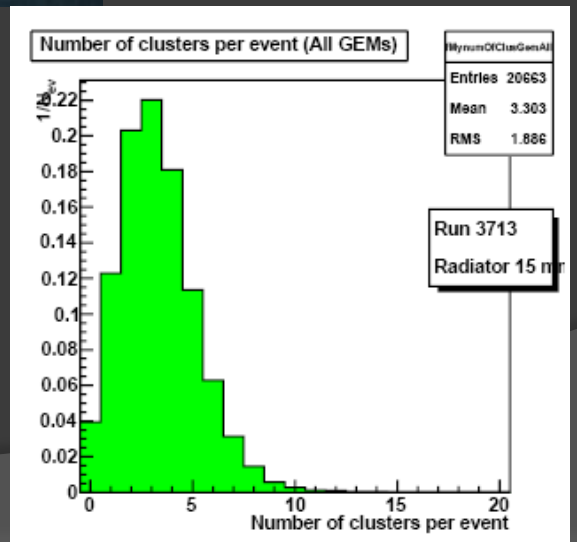
Few % K's contamination: detected and identified

Testbeam of CsI-TGEM photon detector with C_6F_{14} liquid radiator (2011)







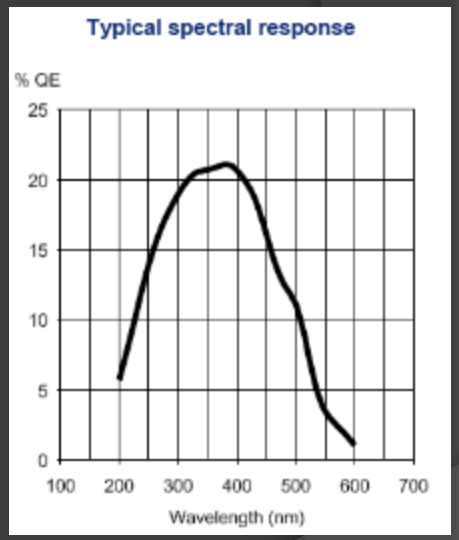


- Observed detection efficiency ~ 60% of HMPID, Gassiplex not optimized for TGEM
- First tests performed with APV25 and in progress
- New tests planned with larger TGEM

Photonis Planacon XP85012

Description	
Window material Photocathode Multiplier structure	UV-Glass, Schott 8337B or equivalent Bialkali MCP chevron (2), 25 μm pore, 40:1 L:D ratio
Anode structure	8×8 array, 5.9 / 6.5 mm (size / pitch)
Active area	53×53 mm
Package open-area-ratio	80%

- Due to delay on electronics production, it could not be tested before the end of testbeam at CERN/PS in 2012
- Planned lab tests with LED source



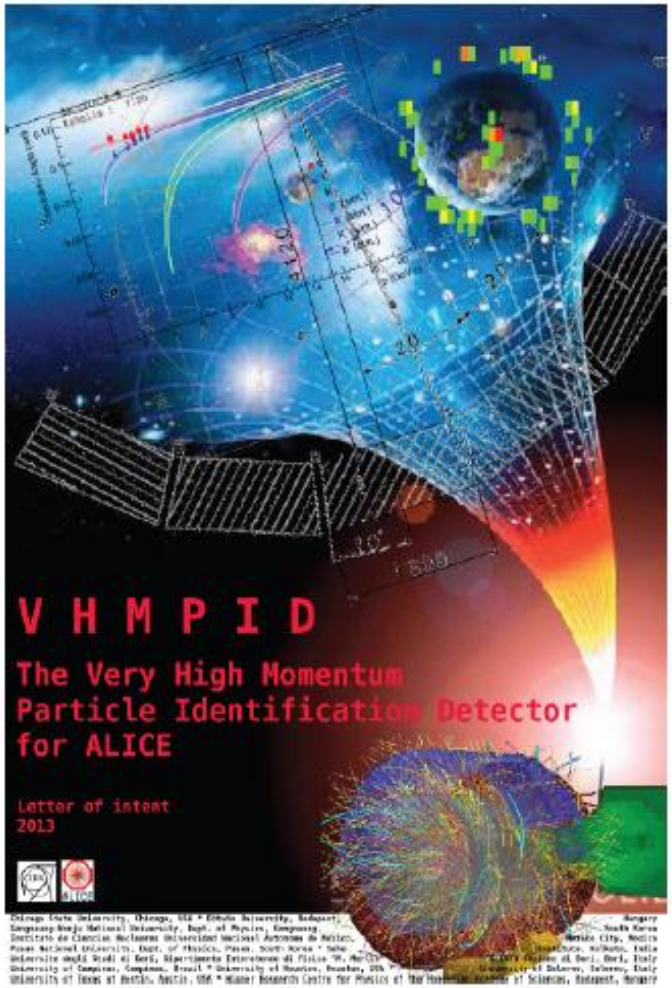
Pro's	Con's
Larger photon yield (larger bandwidth in visible), intrinsically faster	Cost (~ 8.8 K$ /piece) and timescale for full production
No issues from radiator gas transparency (purity, O_2 and H_2O contamination), less demanding systems	Chromatic error due to larger bandwidth, (compensated by photon yield, final performance similar to UV)
Can be mounted inside radiator vessel, sapphire windows not needed	Detection efficiency losses due to 80% packing factor
Commercial device, savings on work for photon detector, no CH_4 gas system	

LAPPD ALD-MCP (A. Elagin's talk) could be a further option depending on R&D timescale

Summary and outlook

- Intense R&D campaign has been performed in 2011/12 to meet new design requirements
- Successful tests of C_4F_8O as Cherenkov radiator in UV, proven preliminary design concepts for pressurization/heating
- Baseline solution for photon-detector: CsI-MWPC with thin gap; new prototype with final layout successfully tested in Dec '12
- Further activities
  - continue tests on CsI-TGEM and Planacon, for "faster" detector option
  - FEE and readout electronics development
  - engineering studies on vessel structure and mirror system
- LoI submitted this week to the ALICE Collaboration, final decision in March

Letter of Intent



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plus former contributions from CERN & Yale
plus future contributions from LLNL

BACK-UP SLIDES

Material budget

Detector component	X/X_0
Bottom+top radiator vessel sandwich panel	7%
Photon detector + tracking layers	3%
C-fiber mirror substrate	2%
Radiator gas at 3.5 bar	4%
Sapphire window	6%
total	22%

For comparison:
- ITS + TPC ~ 15% X0
- TRD ~ 26% X0
- TOF ~ 20% X0

Radiator refractive index and QE curves