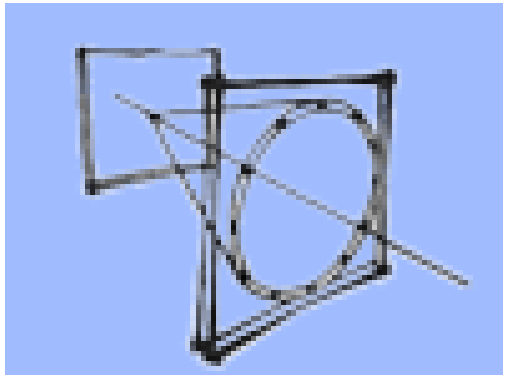
Gas RICH at forward rapidities: status/progress

Also updated with the outcomes of the recent
9th International Workshop on Ring Imaging Cherenkov Counters - RICH2016 (http://rich2016.ijs.si/)
Bled, Slovenia on September 5-9, 2016



OUTLINE

- RICH FACTS, A QUICK REMINDER
- HIGH_MOMENTUM RICHes
- GASEOUS PHOTON DETECTORS, AN R&D
- PERSPECTIVES

RICHes: WHAT FOR ?

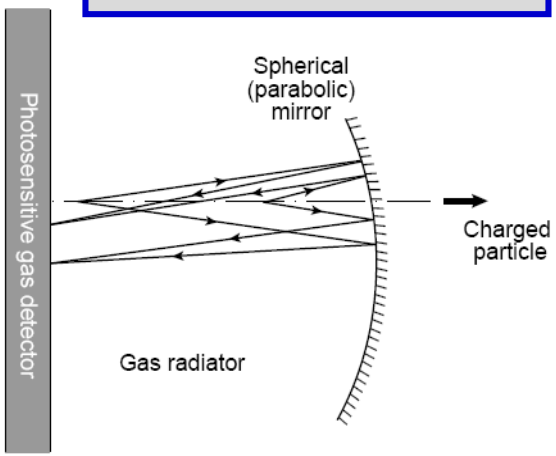
- The most classical and widely used application:
  - h PID in a wide phase space, in events with multiple particle in the final state
  - <u>Our focus !</u>
- e/h discrimination in a wide momentum range
  - HADES, CBM
- μ/π discrimination in a wide momentum range at high momenta
  - NA62
- Discriminate among relativistic (heavy) ions
  - CAPRICE, HIRICH, AMS2

THE FAMILY OF RICH COUNTERS & THE MOMENTUM DOMAINS

HIGH MOMENTA

With focalization

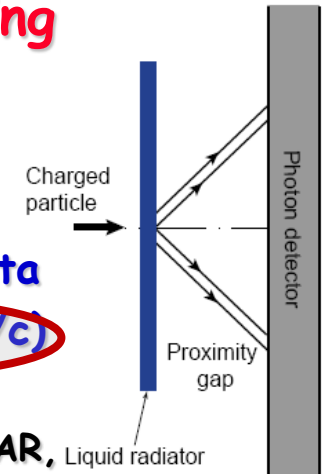
- Extended radiator (gas)
- the only approach at high momenta (p > 1- 4 GeV/c)



- EXAMPLES: SELEX, OMEGA, DELPHI, SLD-CRID, HeraB, HERMES, COMPASS, LHCb, NA62

Proximity focusing

- thin radiator (liquid, solid)
- Effective at low momenta (p < 5-6 GeV/c)

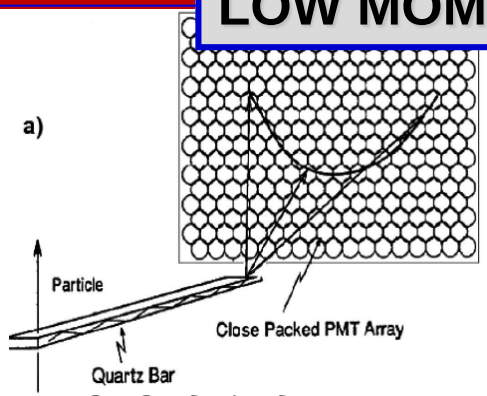


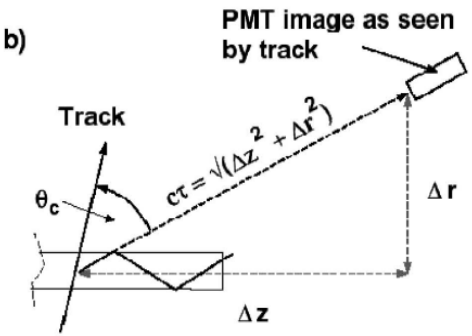
- EXAMPLES: STAR, ALICE HMPID, HERMES, CLEO III

LOW MOMENTA

DIRC

- Quartz as radiator and as light guide
- Effective at low momenta (p < 5-6 GeV/c)





- The only existing DIRC operated in an experiment: BABAR DIRC
- NEW: DIRC-derived architectures in BELLE II (TOP), Panda (focusing DIRC), LHCb (TORCH)

A FEW WORDS ABOUT SINGLE PHOTON DETECTORS

3 families (grouping by technologies)

Vacuum based PDs

- **PMTS (SELEX, Hermes, BaBar DIRC, NA62)**
- **MAPMTs (HeraB, COMPASS RICH-1 forward region, LHCb upgrade, GlueX, CLASS12, Panda forward-RICH)**
- **Hybride PMTs (LHCb)**
- **HAPD (BELLE II aerogel-RICH)**
- **MCP-PMT (BELLE II barrel: TOP detector)**

Gaseous PDs

- **Organic vapours - in practice only TMAE and TEA (Delphi, OMEGA, SLD CRID, CLEO III, …)**
- **CsI and open geometry (HADES, COMPASS, ALICE, STAR, JLAB-HALL A)**
- **CsI and closed geometries (PHENIX HBD, no imaging, NEW: COMPASS RICH-1 2016 upgrade)**

Si PDs

- **Silicon PMs (not used or foreseen in any experiment)**

A FEW WORDS ABOUT SINGLE PHOTON DETECTORS cont.

Time resolution (σ)

- PMTs, MAPMTs >/~ 0.3 ns
- MCP-PMT <50 ps

- MWPCs >/~ 400 ns
- MPGDs ~ 7-10 ns

Effective QE range

- Vacuum-based devices:
  λ > 300, 250, 200 nm
  [also solar-blind]

- Gaseous devices (CsI):
  λ < 210 nm

Operation in magnetic field

- PMTs, MAPMTs, HPMTs NO

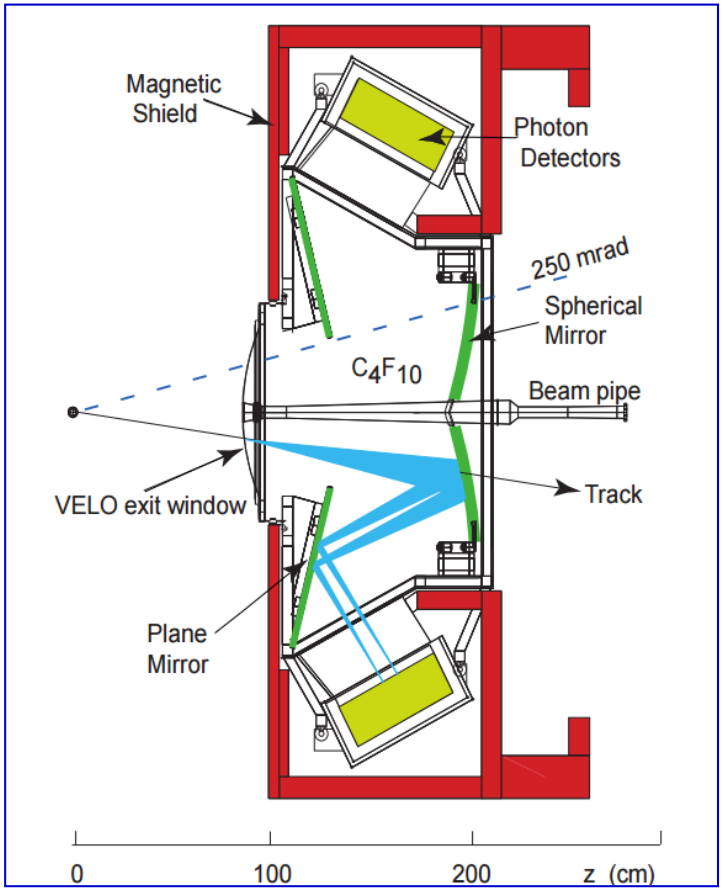
- MCP-PMT, MWPCs, MPGDs YES

COSTS

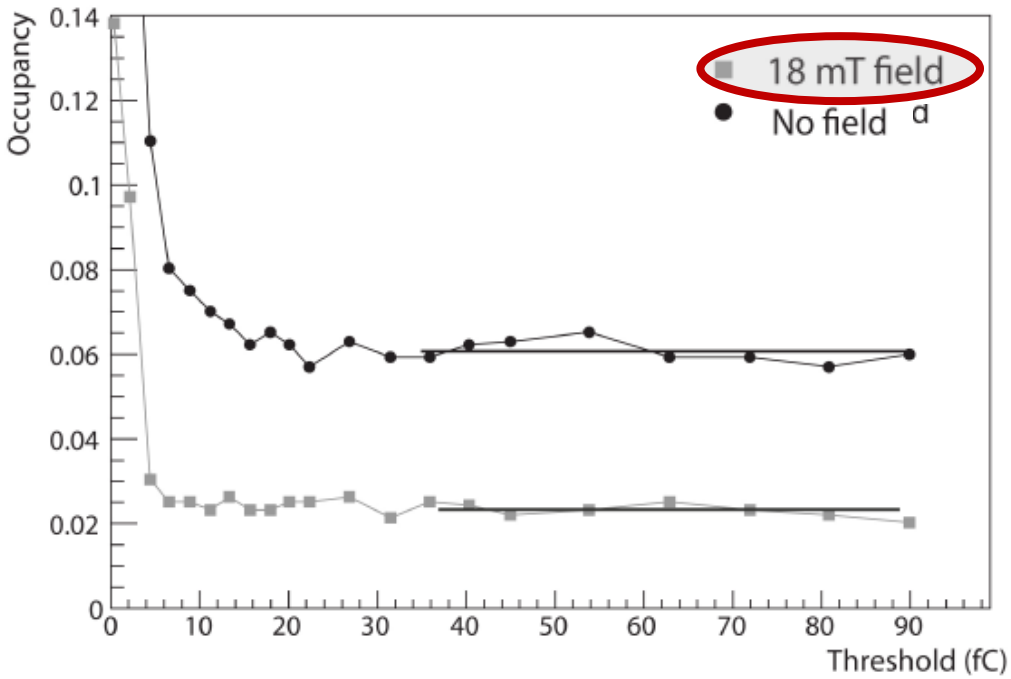
- Gaseous - $ (0.1-0.2 M / m^2)
- MAPMTs - $$ (0.5-1 M / m^2)
- MCP-PMT - $$$ (???)

PDs & MAGNETIC FIELD

Iron shielding of LHCb RICH 1 HPMTs

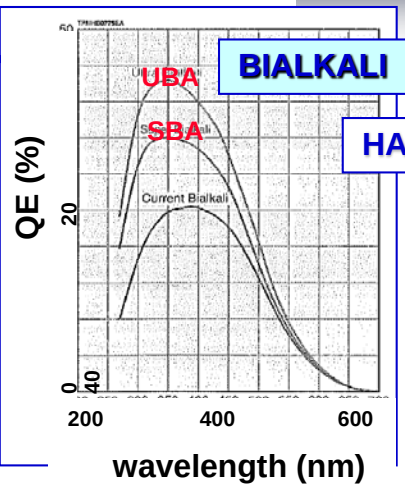


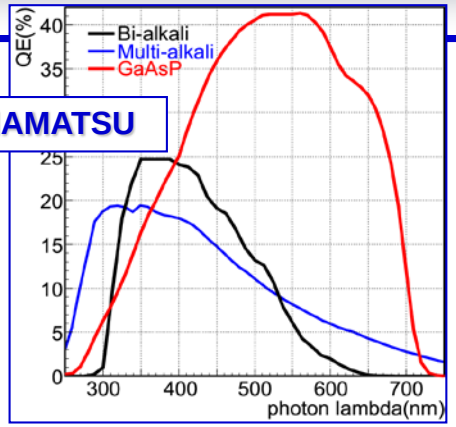
the effect of a moderate B field



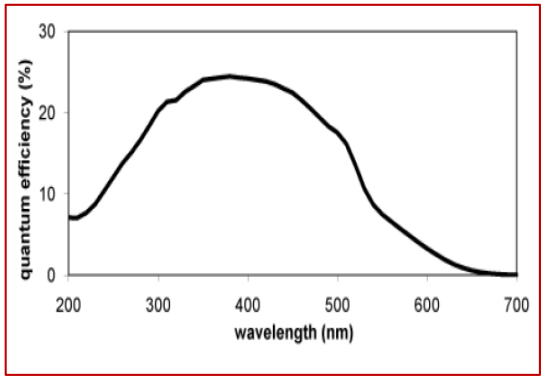
MAPMT type R7600-03-M16 by Hamamatsu

PDs and range of effective QE

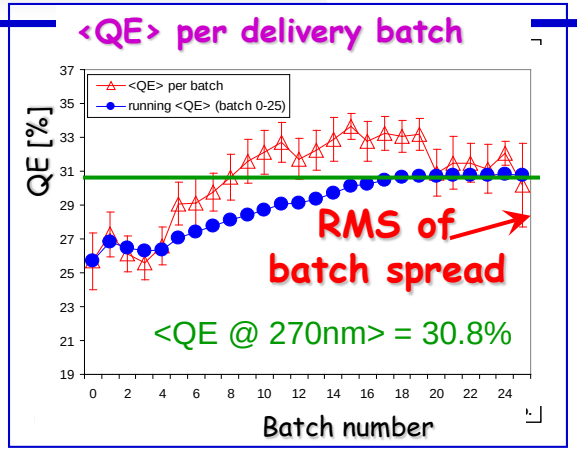




UV extended glass window

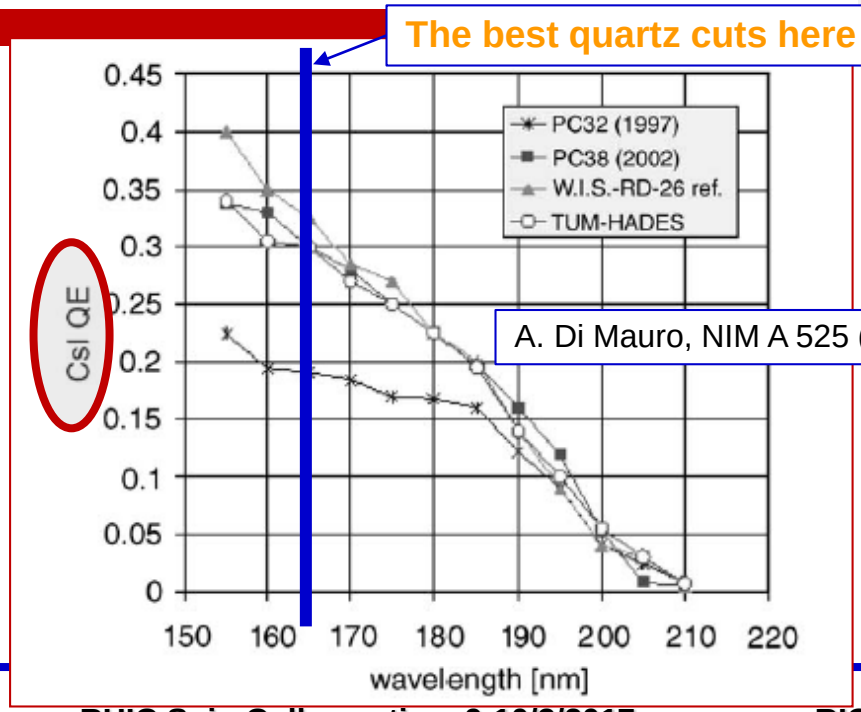


LHCb HPD production by DEP



VACUM-BASED ↑

GASEOUS ↓



A. Di Mauro, NIM A 525 (2004) 173.

R&D to use visible photo-converters in gas are being performed …

- **far from converging**
- **usage in RICHes questionable**
- **the best so far (by Hamamatsu) has this size:**

WHY GASEOUS PDs ?

- the most effective solution for what concerns the cost of large detector area application (a cheap approach)
- operation in magnetic field (low sensitivity to B)
- minimum material budget when the photon detectors have to seat in the experiment acceptance (advantages for experiment architectures)

TRENDS, PERSPECTIVES AND MOMENTUM DOMAIN

Low p (< 6 GeV/c)

- Wide dedicated activity in the last years resulting in important progress
- All this related to the needs of numerous new projects:
  - Belle-II barrel
  - Belle-II forward
  - CLAS12
  - GlueX
  - Panda barrel
  - Panda end-caps
  - Panda forward
  - LHCb-Torch

(from RICH2016)

High p (> 1 - 4 GeV/c)

- Presently only 3 running high-p RICHes:
  - COMPASS
  - LHCb (2-counter system)
  - NA62
- Limited number of new projects:
  - CBM (e-PID < 8 GeV/c)
  - COMPASS novel gaseous PDs (MPGDs)
- Further future projects:
  - Only EIC
  - It would be desired also for circular e+e- collider, but … (Y. Gao @ Hong Kong HEP conference, Jan 2017)

TRENDS, PERSPECTIVES AND MOMENTUM DOMAIN

Low p (< 6 GeV/c)

- Can this threshold be raised (up 10 GeV/c) ? ? ?

- **Options**
  - Proximity focusing using
    - C_6F_{14} (or analogous)
    - aerogel
  - DIRC-derived detectors
    - Focusing DIRC (FDIRC)
    - TOP counter
    - TORCH
  - Alternative approaches
    - New TOF perspectives
    - Improved dE/dx in gas by cluster counting [also for high p?]

t resolution required: ~O(10ps)

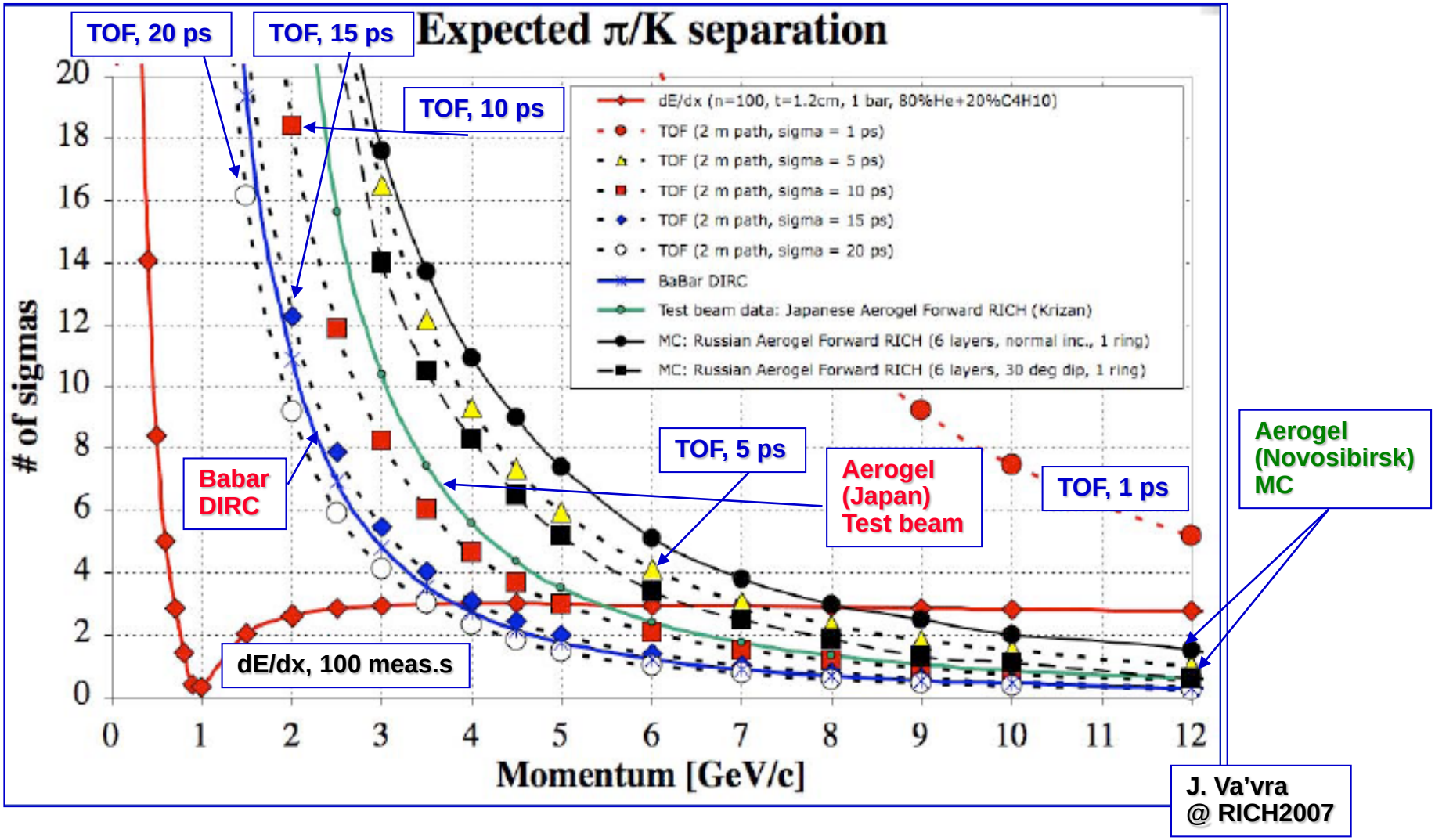
High p (> 1 - 4 GeV/c)

- Can the radiator be "thinner" (to avoid gigantic sizes: advantages for colliders, also for fixed target)?

namely more detected photons per unit radiator length

- **Options proposed so far**
  - For thinner radiators:
    - P > 1 atm
      - Proposal for ALICE HMPID upgrade, than abandoned
    - Exploit the VUV region,
      - testbeam @ Fermilab
    - Use vacuum-based (visible light) photon detectors

TOF vs CHERENKOV IMAGING



J. Va'vra @ RICH2007

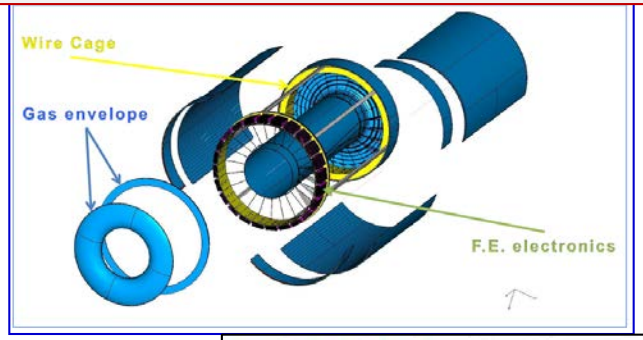
improved dE/dx from cluster counting in gas

DRIFT CHAMBER, 3 m long, gas: 90% He - 10% iC4H10

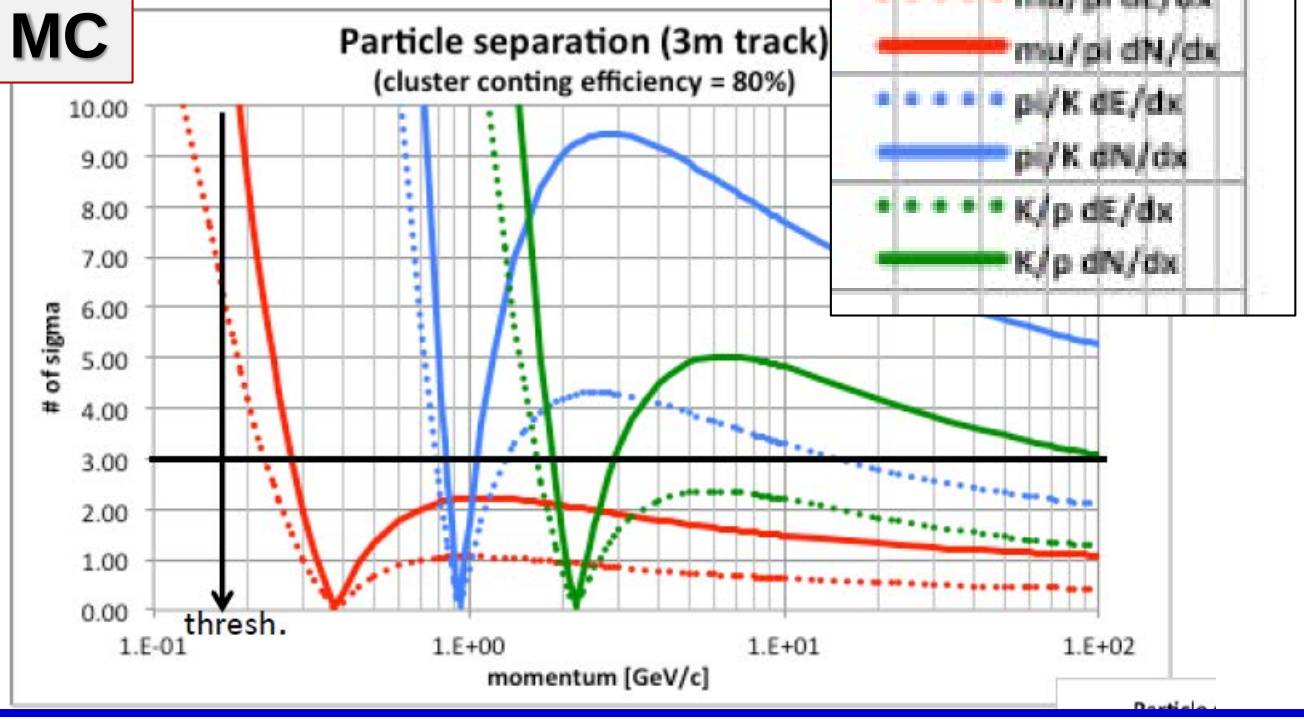
An ultra-light drift chamber with particle identification capabilities

F. Grancagnolo
INFN – Lecce, ITALY

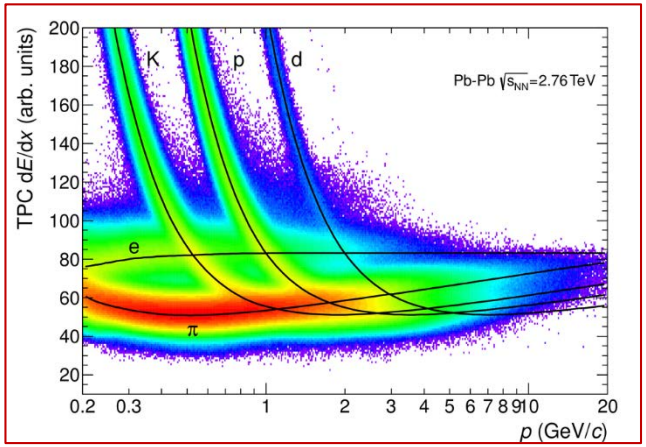
WG11 Detector Design Meeting
CERN
17 October 2016

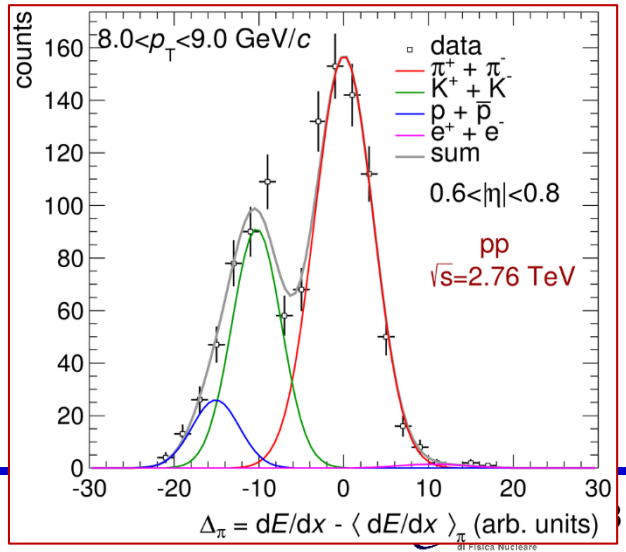


MC



ALICE TPC, for comparison





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A FOCUSING RICH: COMPASS RICH-1

is a large gaseous RICH

with two kind of photon detectors

providing:

hadron PID from 3 to 60 GeV/c

acceptance: H: 500 mrad V: 400 mrad

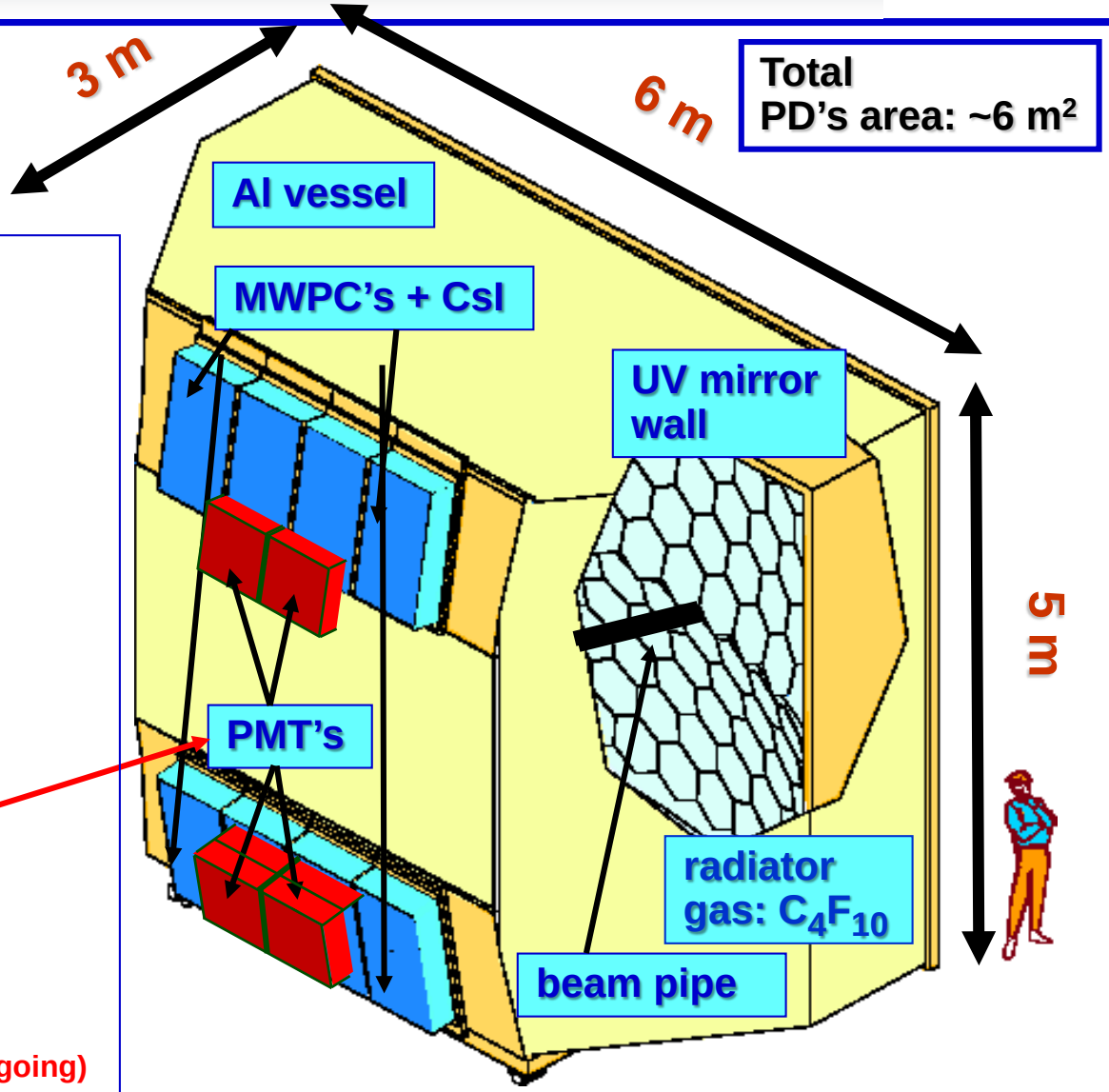
trigger rates: up to ~50 KHz
beam rates up to ~10^8 Hz

material in the beam region: 1.2% Xo
material in the acceptance: 22% Xo

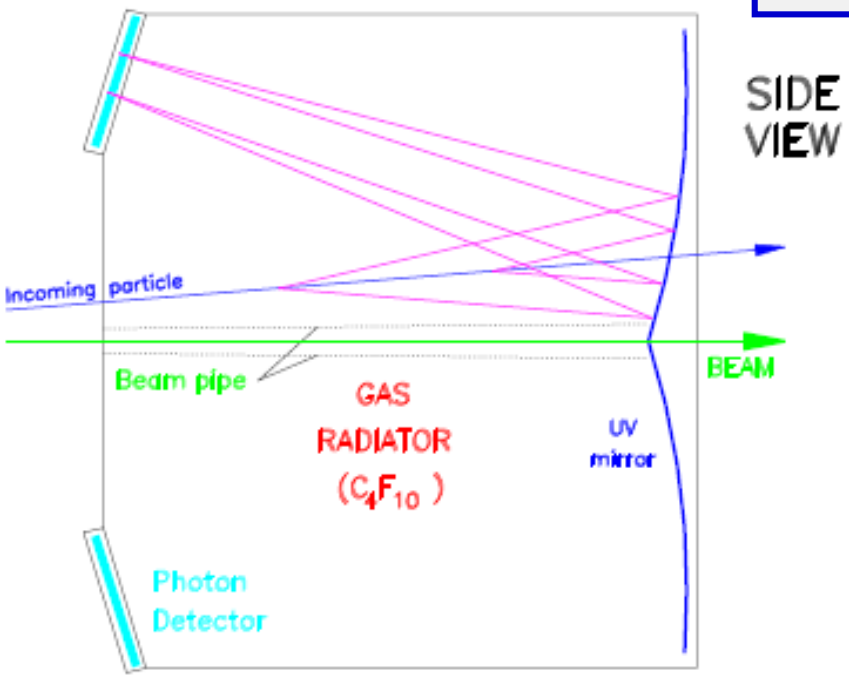
detector designed in 1996
in operation since 2002
upgraded in 2006

total investment: ~ 4 M €

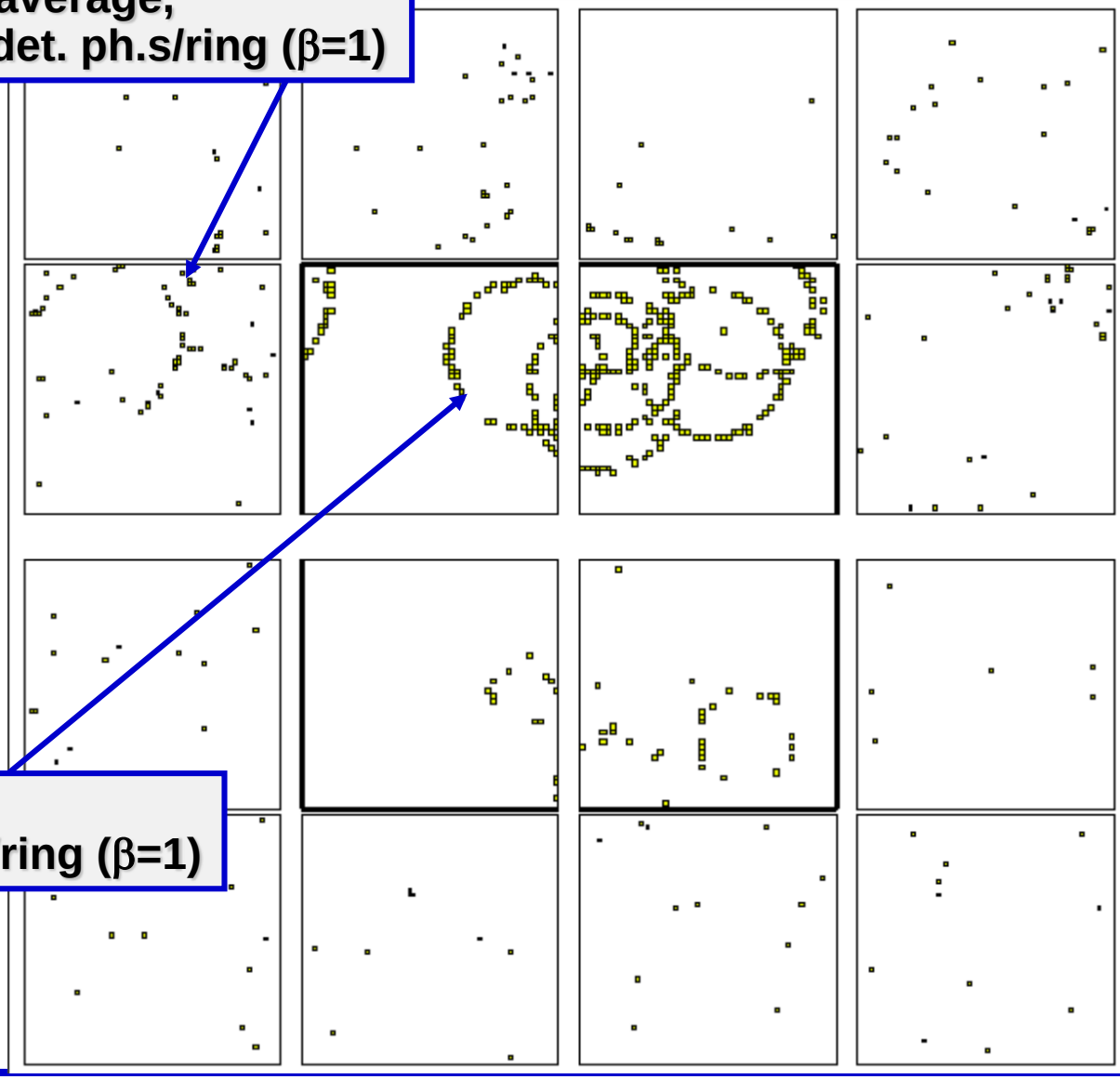
a new upgrade in 2016 for higher rates (on going)



A FOCUSING RICH: COMPASS RICH-1

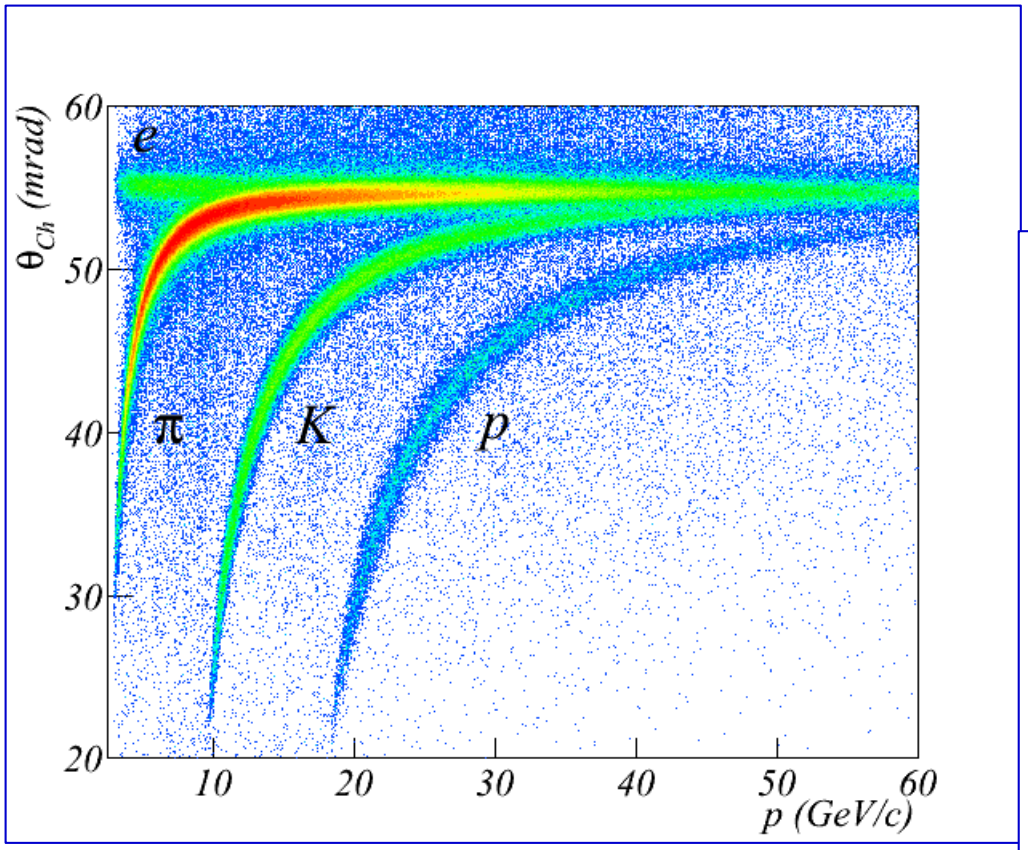


on average, 14 det. ph.s/ring (β=1)

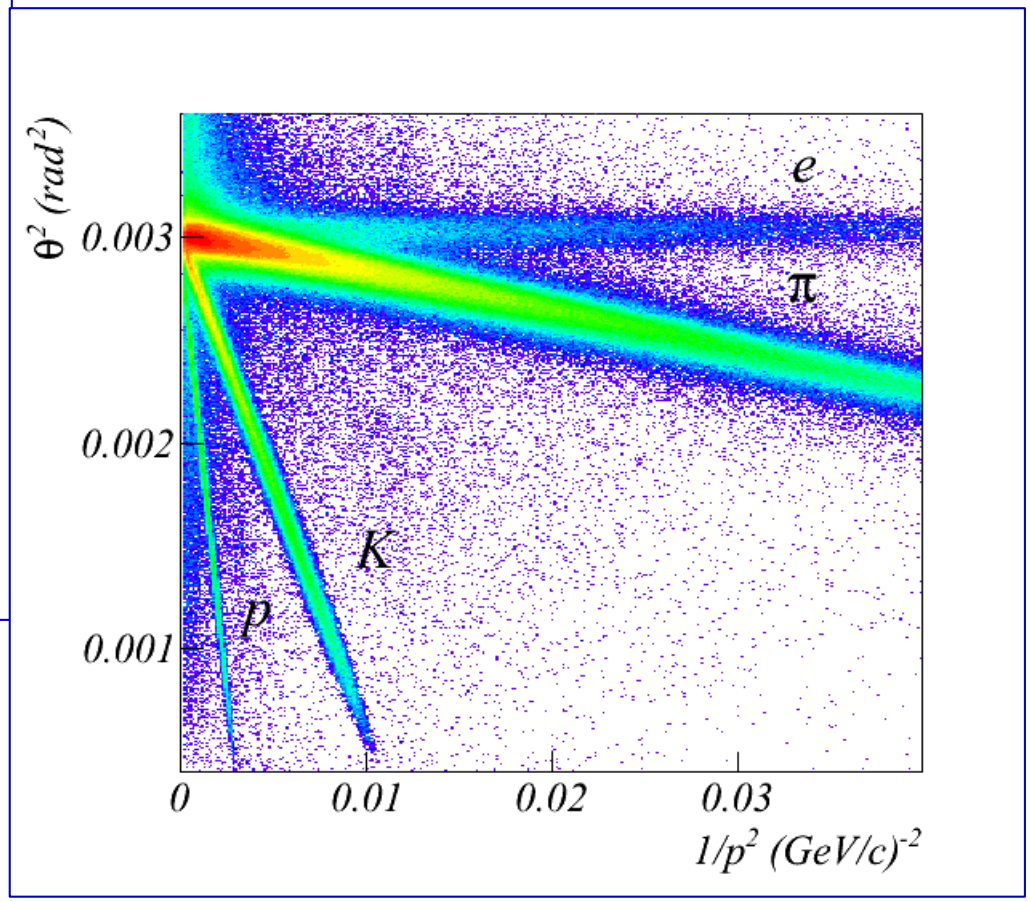


on average, 58 det. ph.s/ring (β=1)

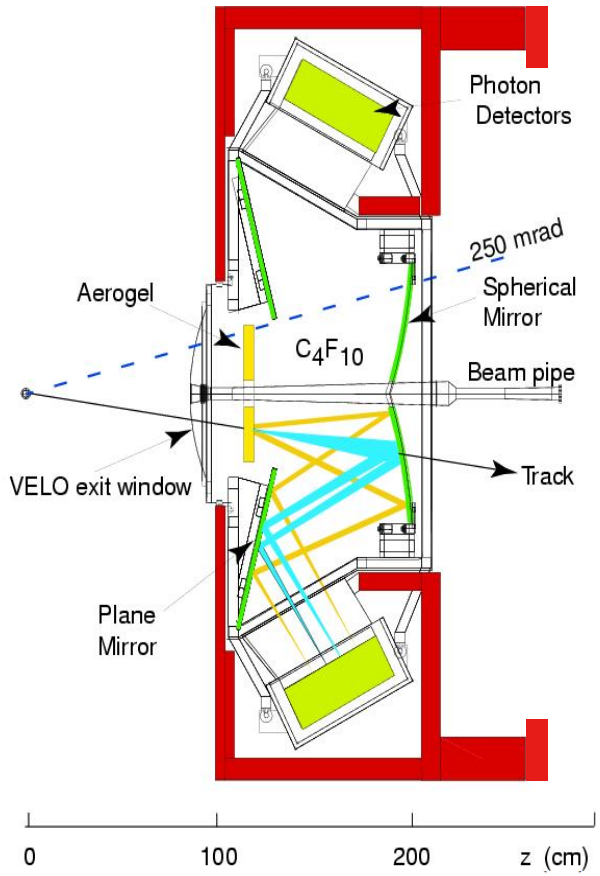
A FOCUSING RICH: COMPASS RICH-1



π-K separation, CL > 95% up to 45 GeV/c
π-K separation, CL > 90% up to 60 GeV/c

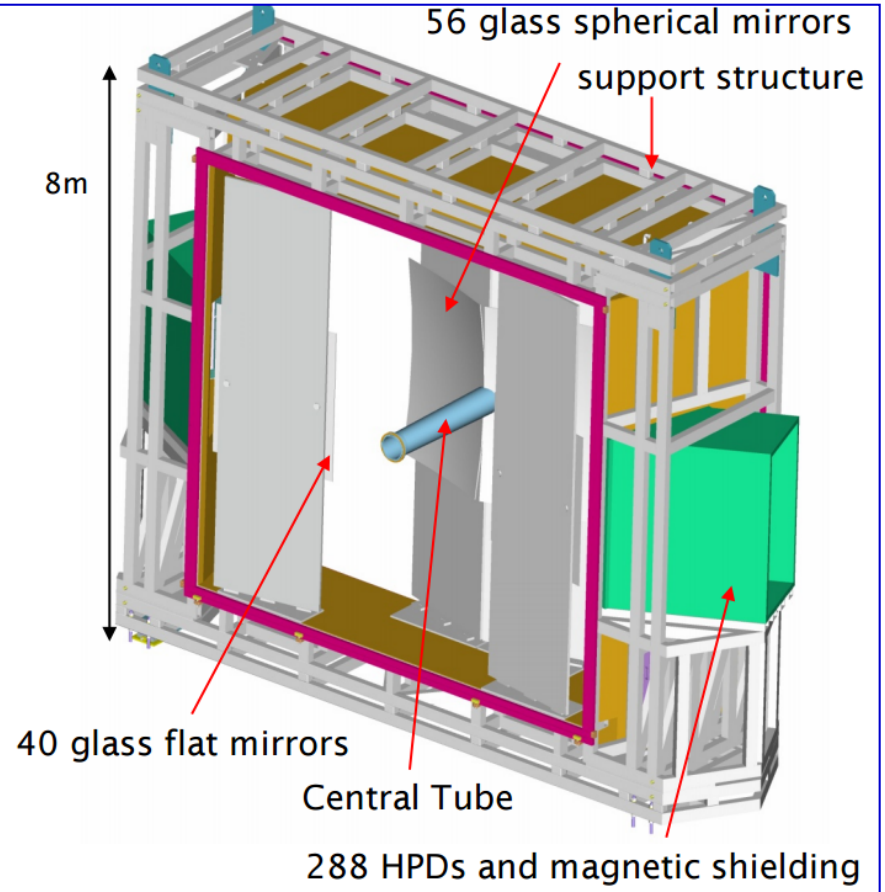


LHCb RICHes, a MULTI-RADIATOR SYSTEM



RICH-1 (25-300 mrad)

4 m^3 C_4F_{10} n = 1.0014, up to 60 GeV



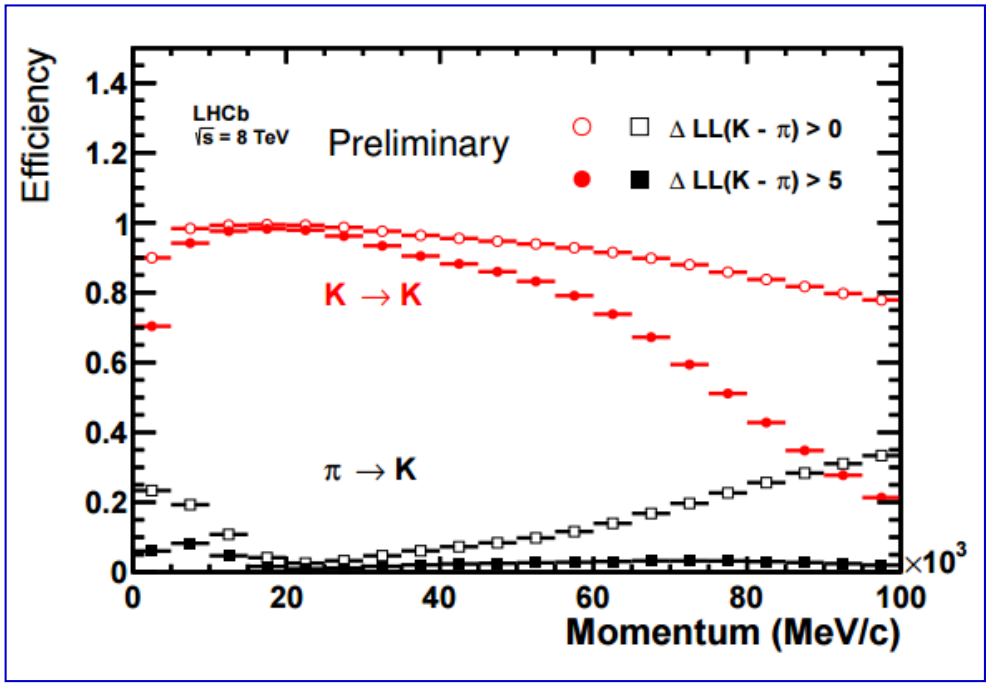
RICH-2 (15-120 mrad)

100 m^3 CF_4 n = 1.0005, up to ~100 GeV

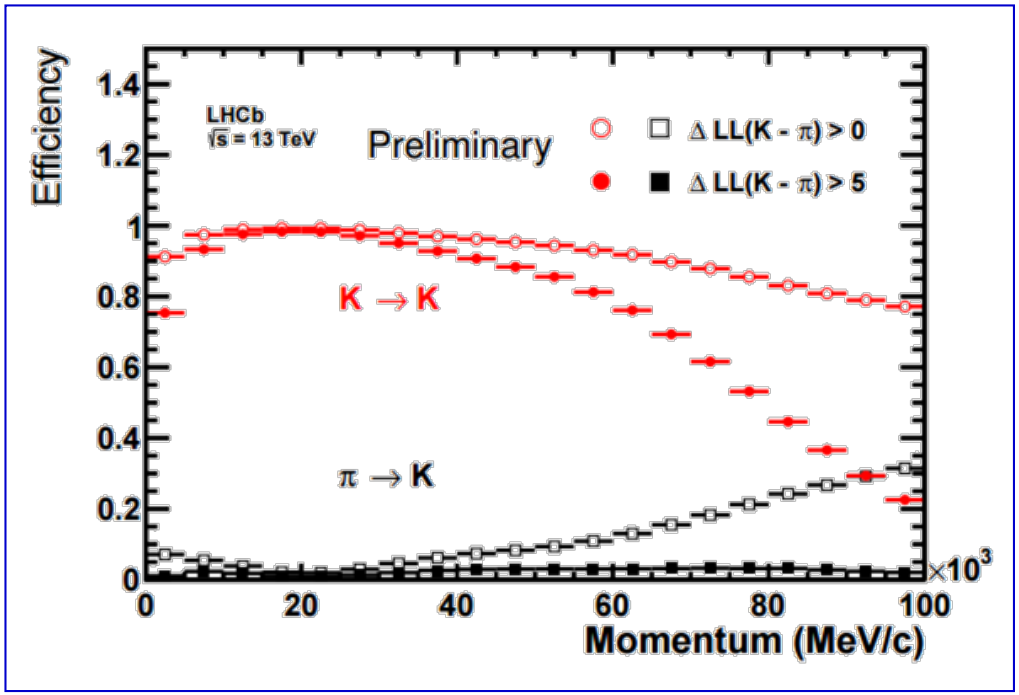
LHCb RICHes, a MULTI-RADIATOR SYSTEM

A. Papanestis at RICH2016

Run I with aerogel



Run II (2015) w/o aerogel

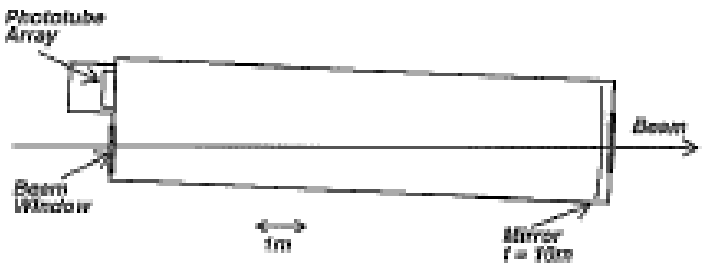


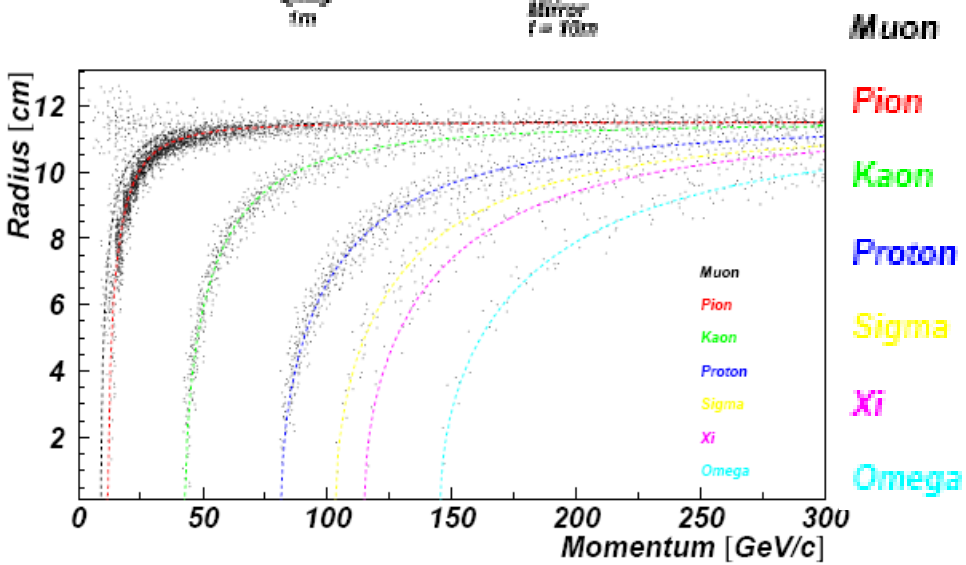
The use of dual RICHes with aerogel questionable ….

Extreme performance with RICHes

SELEX (E 781) @ Fermilab

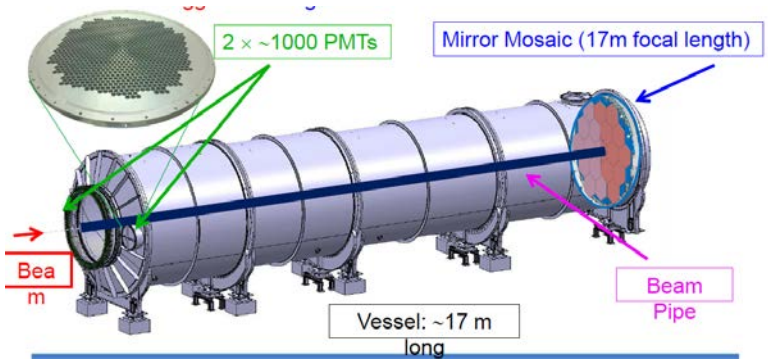
- 10 m He
- n_ph (β=1) : 13.6

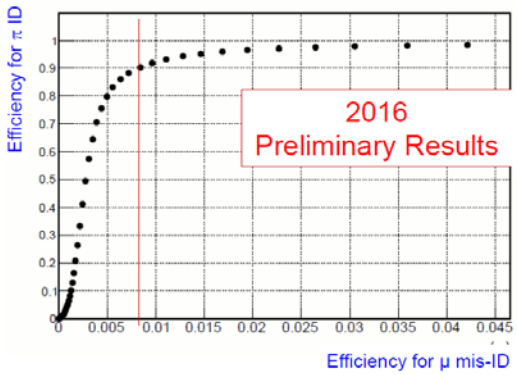




NA62 @ CERN SPS

- 17 m Ne
- n_ph (β=1) :





For 90% π ID efficiency a 0.8% μ mis-ID efficiency is

Extreme performance with RICH

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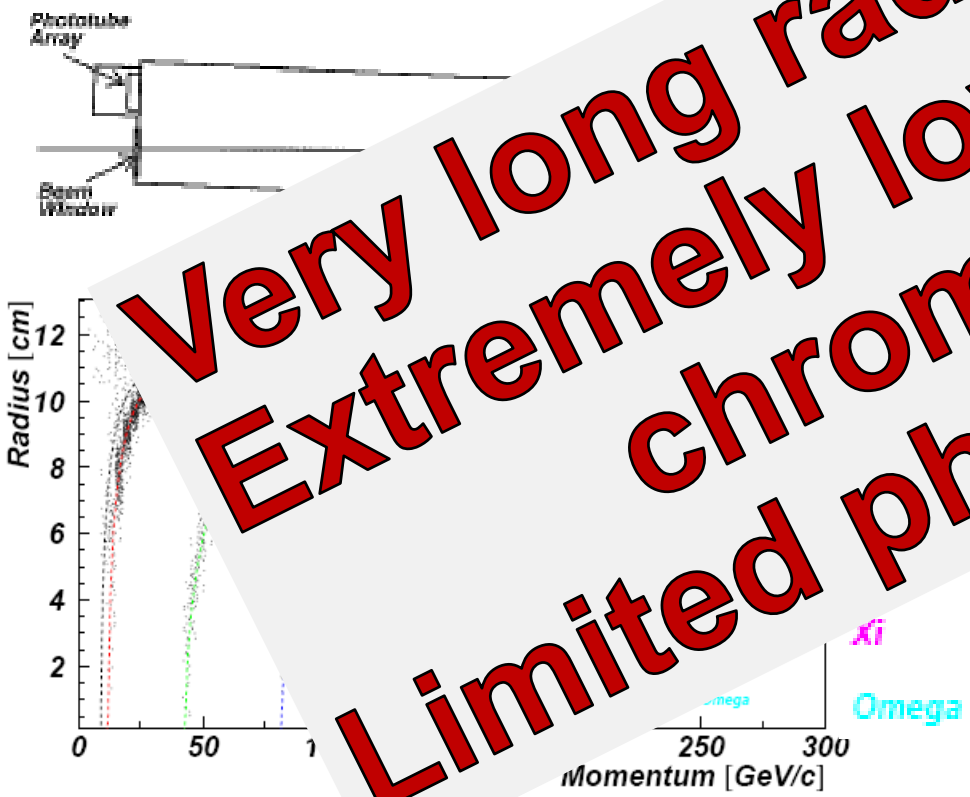
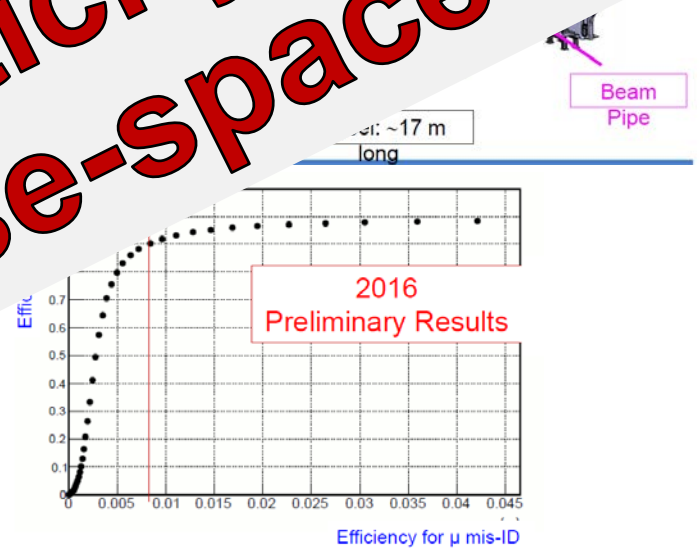


NA62



For 90% π ID efficiency a 0.8% μ mis-ID efficiency is

Very long radiators
Extremely low chromaticity gases
Limited phase-space

- **SHORTER RADIOTOR PERSPECTIVES**

COMPACT RICHes via HIGH PRESSURE GAS

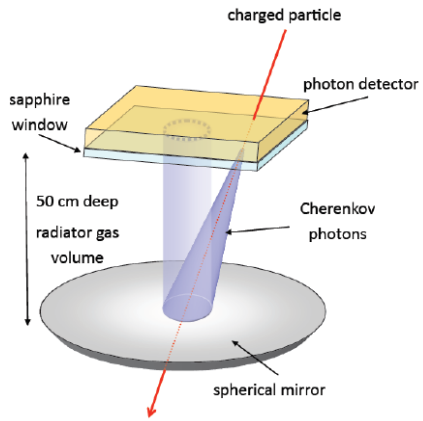
M. Weber at RICH2013

An option for ALICE HMPID upgrade (later abandoned)

Goals:

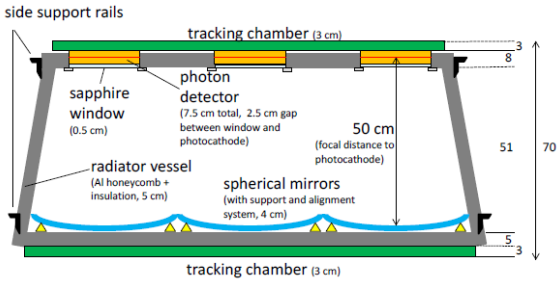
- 1.5 mrad resolution
- p/k 3 s sep. up to 25 GeV/c
- π/k sep. from 5 GeV/c

A. Agocs et al. NIM A 732 (2013), 361-365

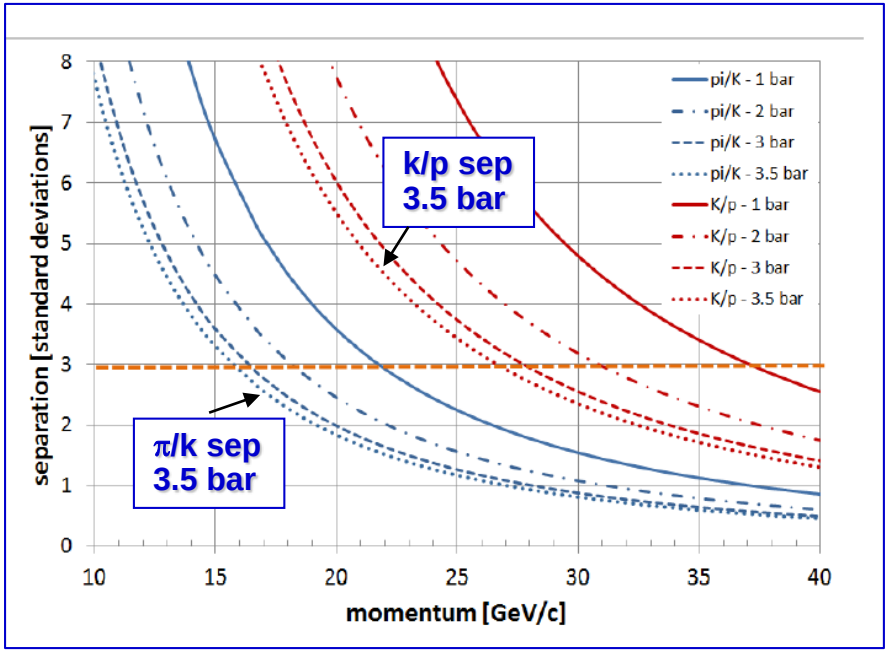


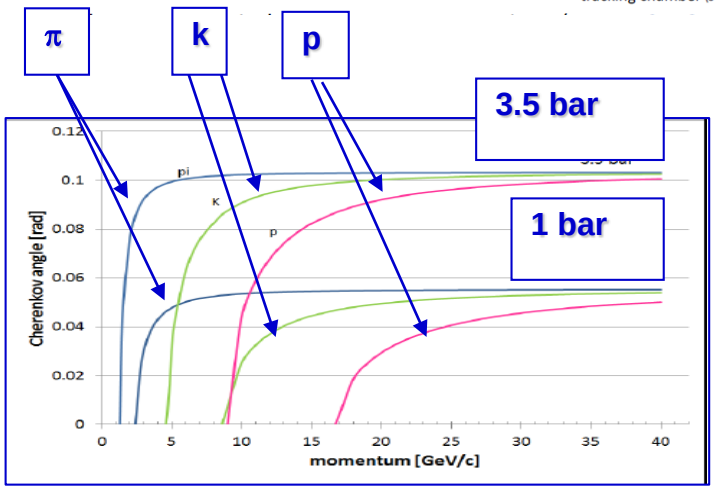
Details:

- Focusing RICH
- Radiator: 3.5 bar C_4F_8O (50 cm)
- Photon detector: CsI-MWPC (CH_4)
- Window: Sapphire
- Mirrors: 3x3



Expected (simulations):





COMPACT RICHes via HIGH PRESSURE GAS

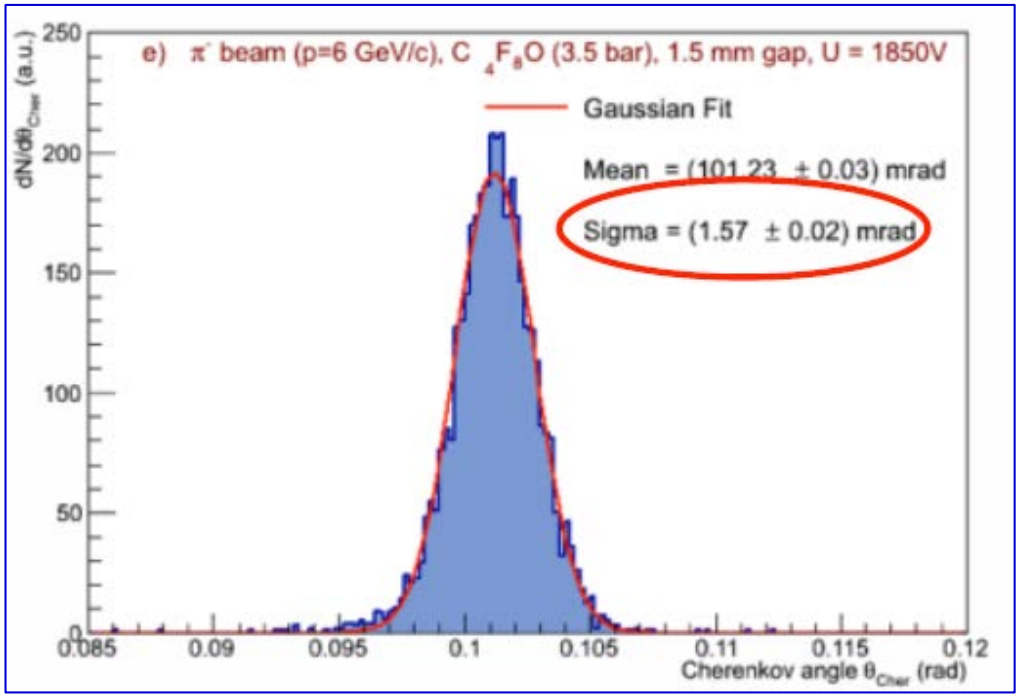
An option for ALICE HMPID upgrade (later abandoned)

Goals:

- 1.5 mrad resolution
- p/k 3 s sep. up to 25 GeV/c
- p/k sep. from 5 GeV/c

Expected resolution confirmed in test beam: promising !

(lower background …)

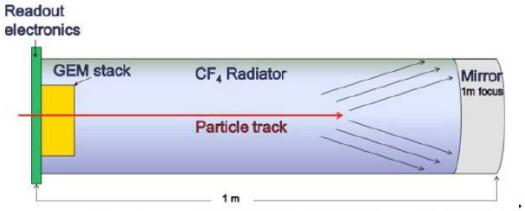


The window-less way

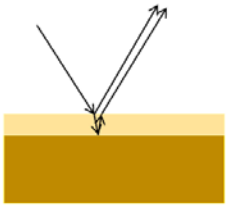
T. Hemmick at RICH2016

AN OPTION FOR EIC EXPERIMENTS

- Test beam of a window-less RICH
- Far UV mirrors
- Read-out: 5-layer GEM detectors

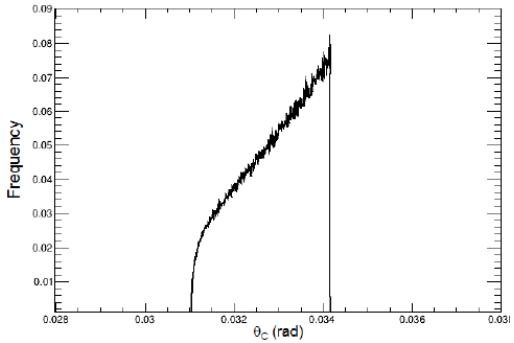


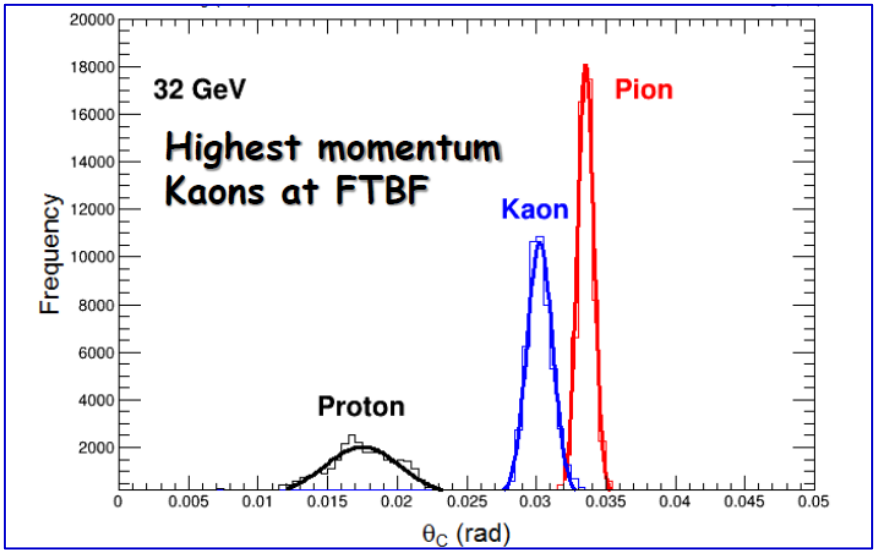
- Thin Film Interference!
  - Tuned for peak at 120 nm.
  - Retrieves (most of) the lost light.



Thin Film Interference

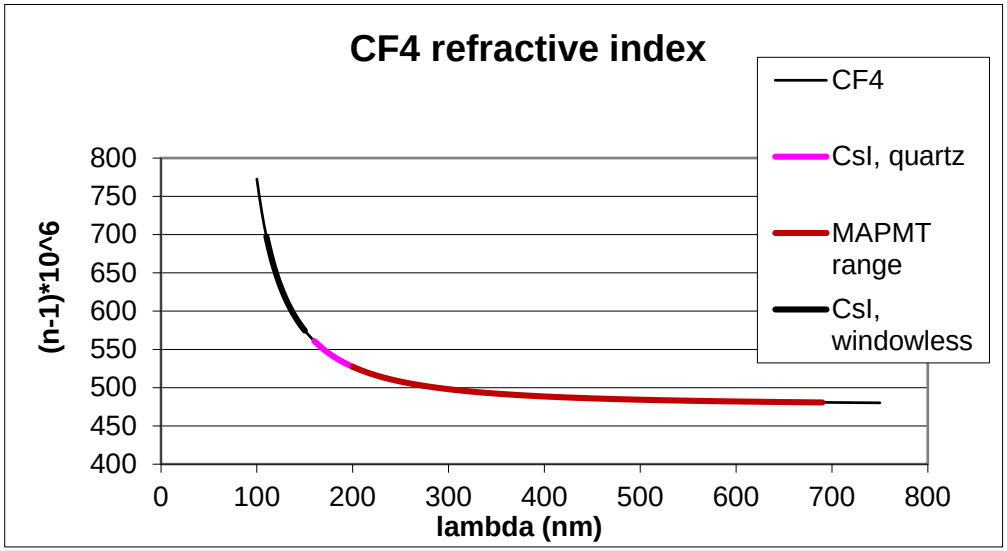
- Dispersion is significant.
- Mitigated by:
  - Limited Bandwidth
  - $\frac{1}{\lambda^2}$ photon yield
  - QE(λ) falling linearly with λ

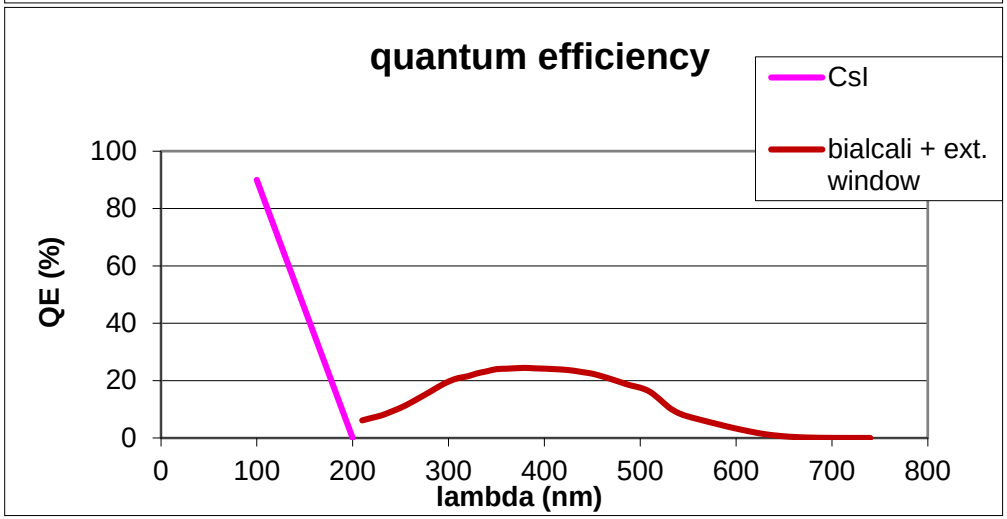




GASEOUS PDs with CsI vs PMTs

a trivial exercise for comparison





Neglect photon losses due to transparency, reflectivity, …

Nphotons

CsI-quartz/PMT	**17%**
CsI-Window-less/PMT	**114%**

IMPROVING GASOUS PHOTON DETECTORS IS A SERIOUS OPTION FOR HIGH-p RICHes

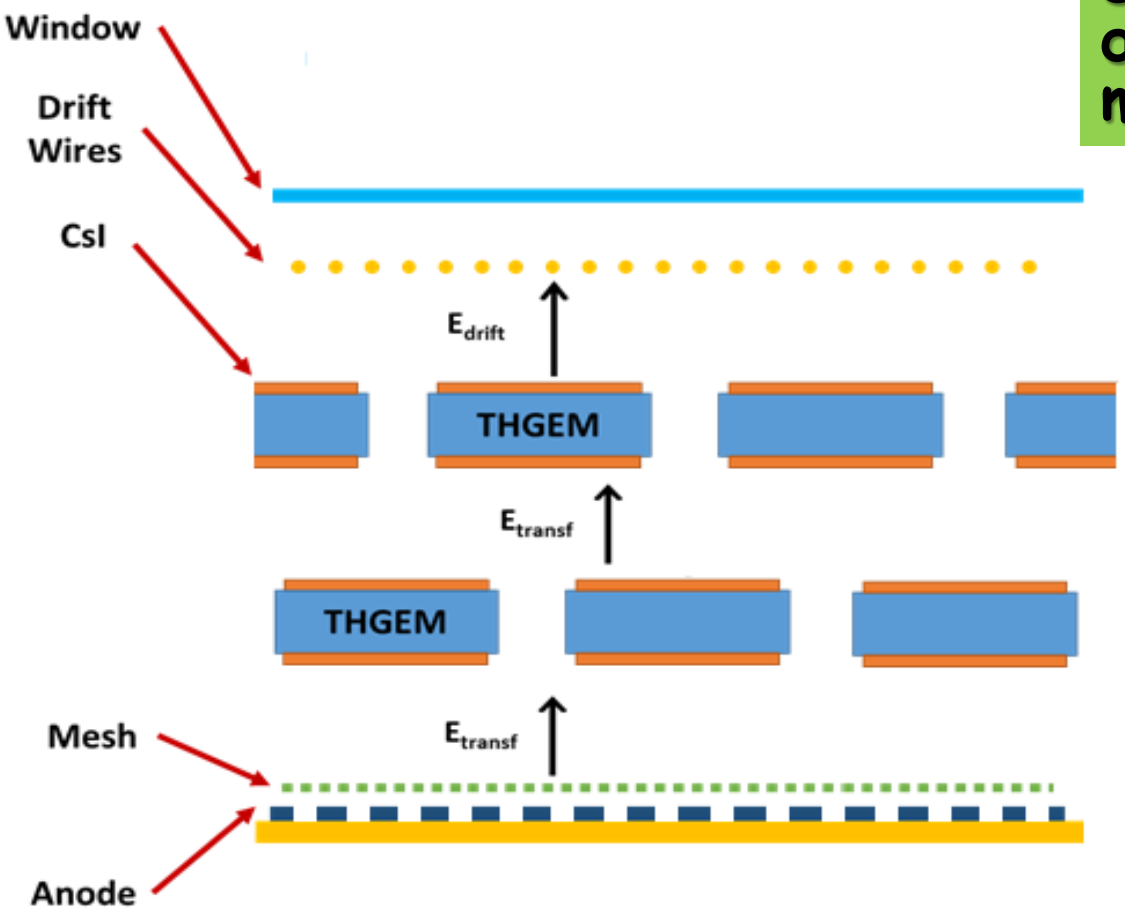
OUTLINE

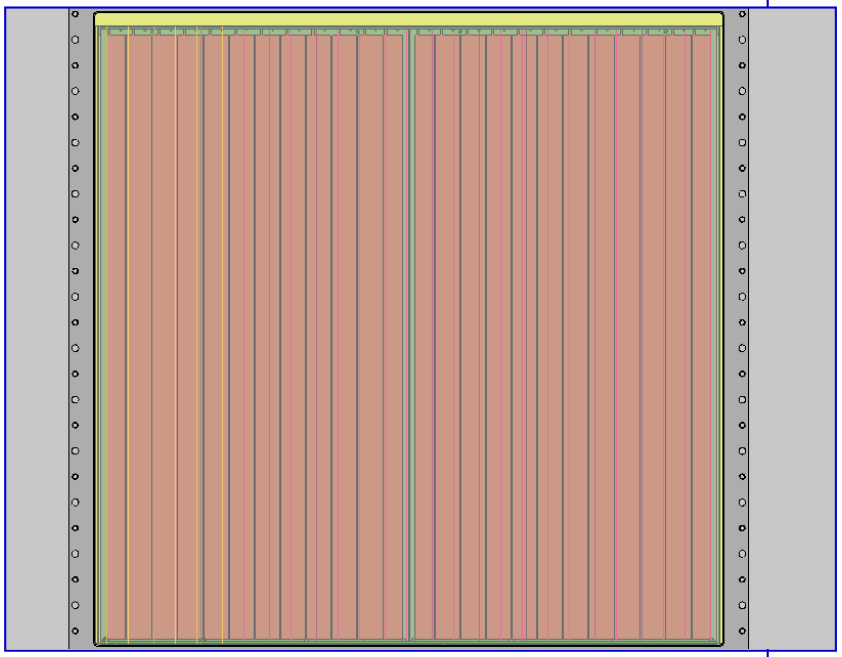
- RICH FACTS, A QUICK REMINDER
- HIGH_MOMENTUM RICHes
- **GASEOUS PHOTON DETECTORS, AN R&D**
- PERSPECTIVES

STARTING POINT: THE PDs FOR RICH UPGRADE

The detector architecture

each 600 x 600 mm^2 detector consists of two modules having 600 x 300 mm^2

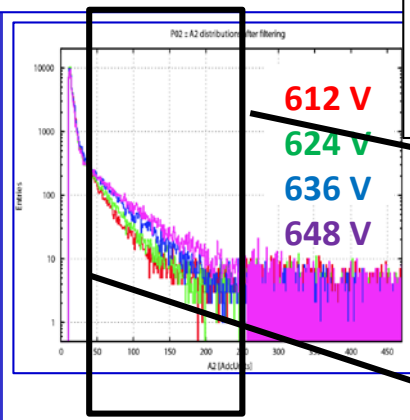


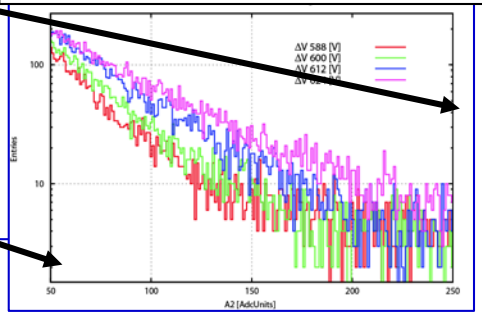


THE COMMISIONING COMPASS MPGD-PDs

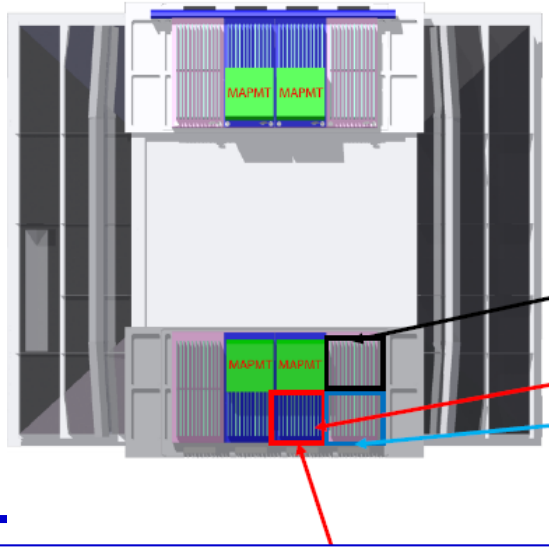
60 x 60 cm^2 single photon detectors for the upgrade of COMPASS RICH-1

- **Construction completed in 2016, commissioning during the 2016 run**
- **Characterization on-going**

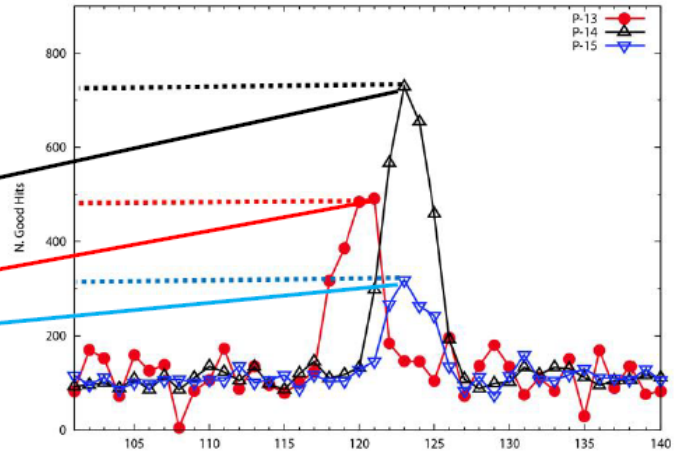




Effective gain values up to 25 k



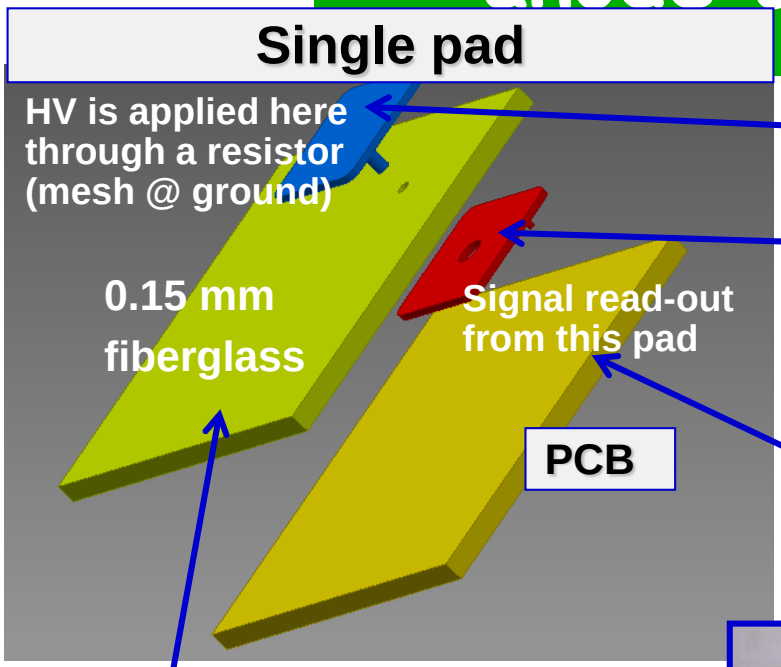
Comparing the number of detected photons in the present status:

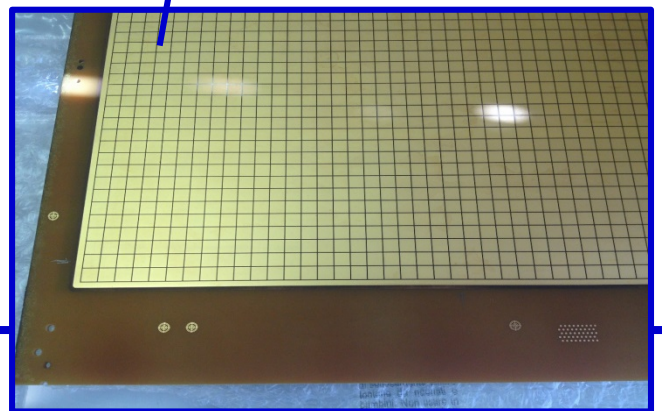


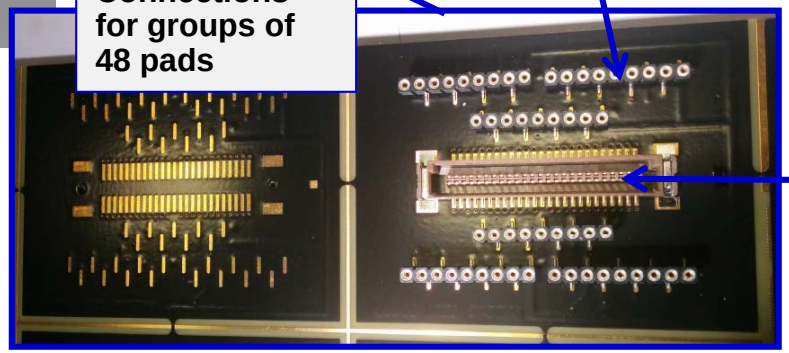
Number of photons according to expectations

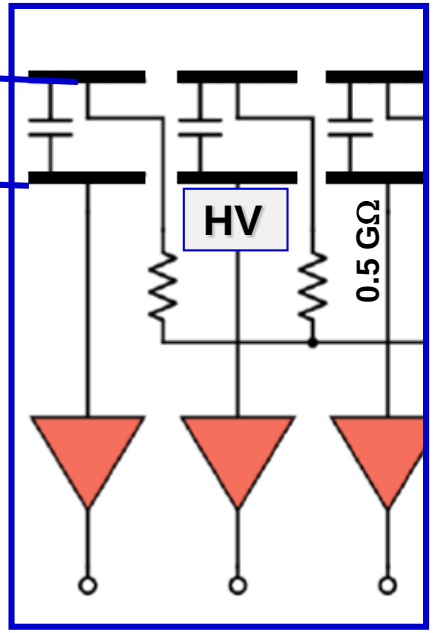
STARTING POINT: THE PDs FOR RICH UPGRADE

The bulk MICROMEGAS with resistive anode and capacitive coupling R-O







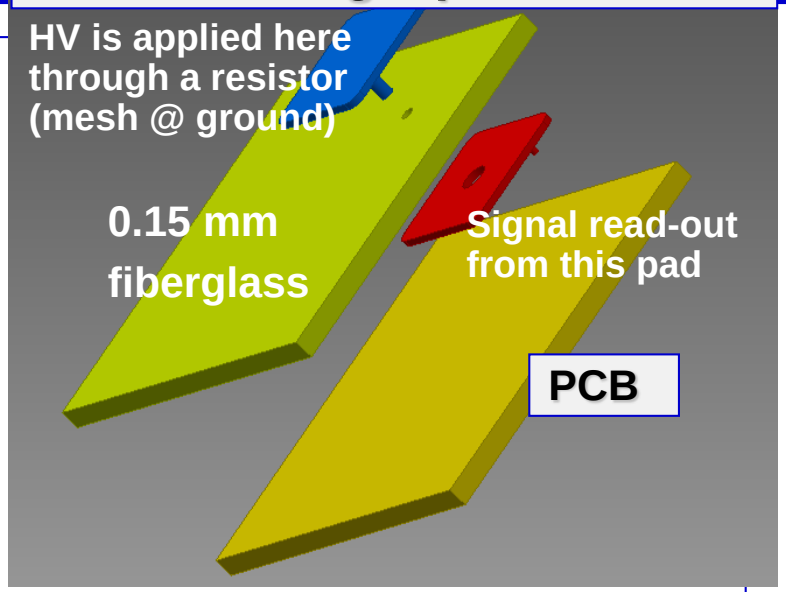


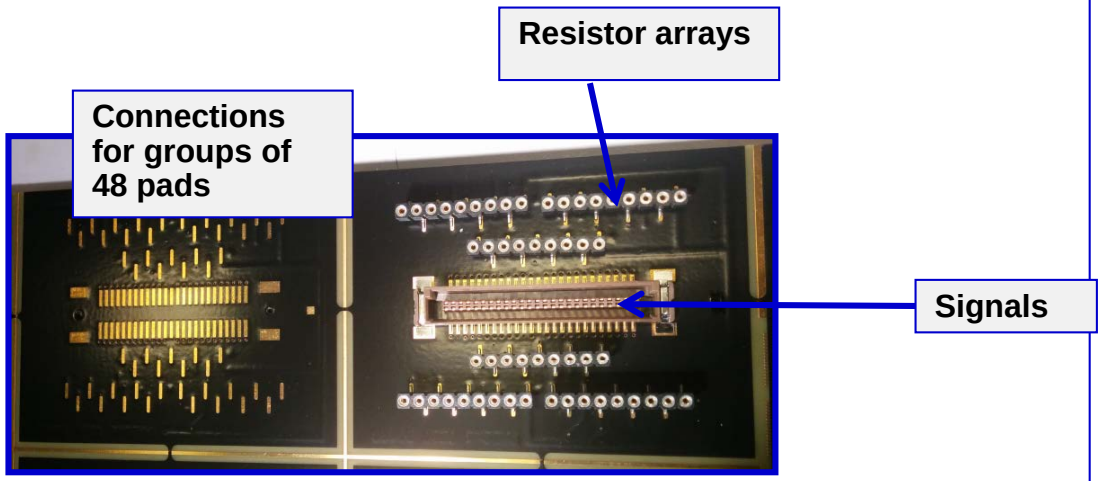
R&D PROGRAM - 1

In the COMPASS RICH-1 photon detectors the pad size is 8 x 8 mm².

A first R&D item is passing to smaller pad size of the order of 3 x 3 or 4 x 4 mm².

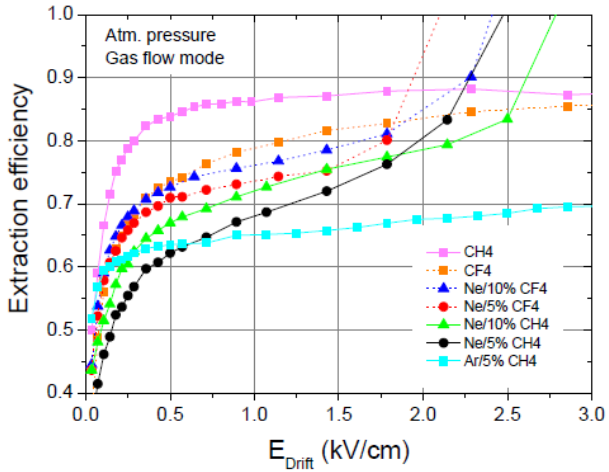
Single pad





R&D PROGRAM - 2

The performance of the hybrid photon detectors operated in fluorocarbon-rich atmospheres, as it is the case for windowless RICHes, is a second item.



C. D. R. Azevedo et al., 2010 *JINST* 5 P01002

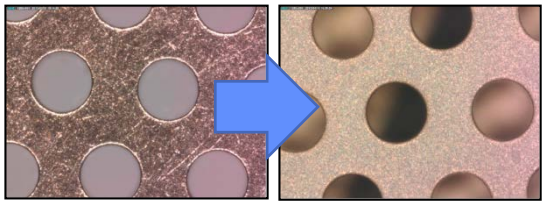
R&D PROGRAM - 3

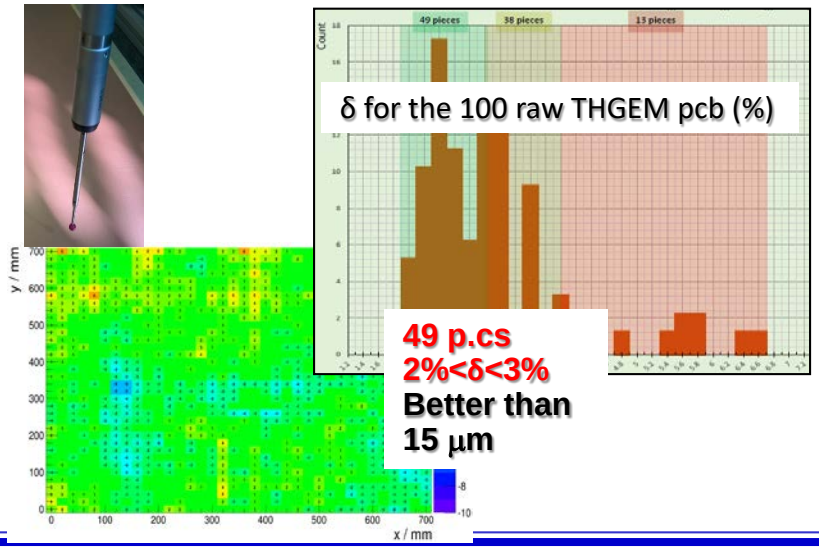
- the present hybrid photon detectors have an Ion BackFlow (IBF) rate ~ 5%
- ultimate figure? → enhancing the control of IBF is a third R&D item

R&D PROGRAM - 4

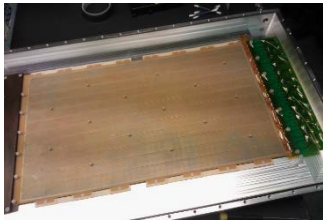
The reduced production yield of large surface THGEMs suggests to investigate different substrate materials: this is a fourth item of the R&D program.

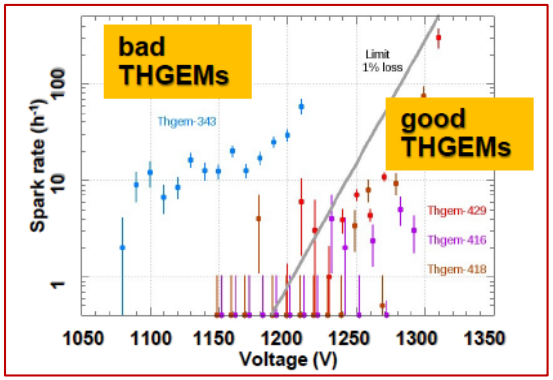
In Trieste a specific cleaning procedure is applied : polish with fine grain pumice powder, pressure water cleaning, ultrasonic Bath with Sonica PCB solution (PH11), distilled water rinsing and oven @ 160 ºC

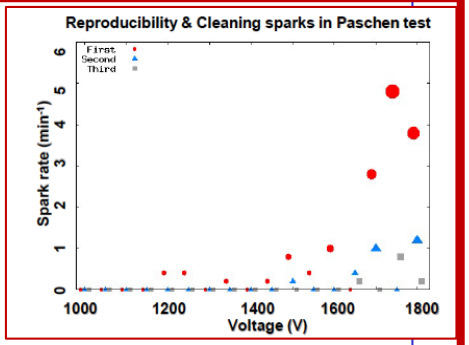




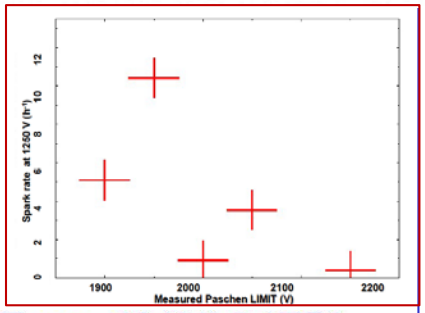
DISCHARGE RATES in single layer THGEM







Paschen measurements in N_2

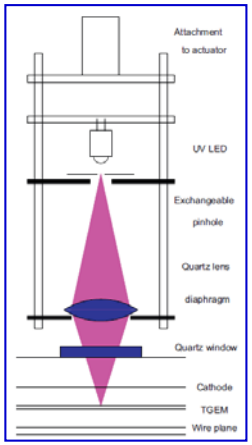


Correlation of PASCHEN LIMIT vs SPARK RATES

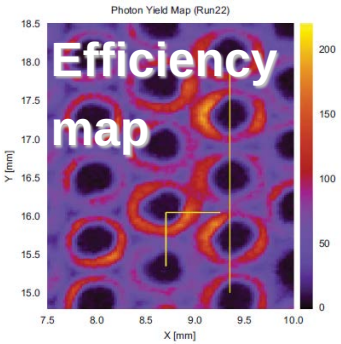
R&D PROGRAM - 5

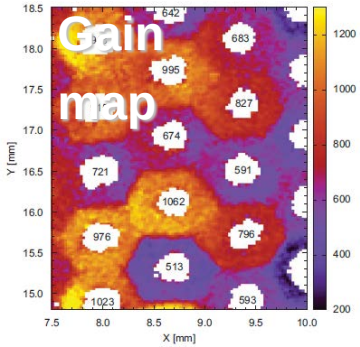
Dilemma: GEMs or THGEMs is a (hybrid) MPGD photon detector for RICHes?

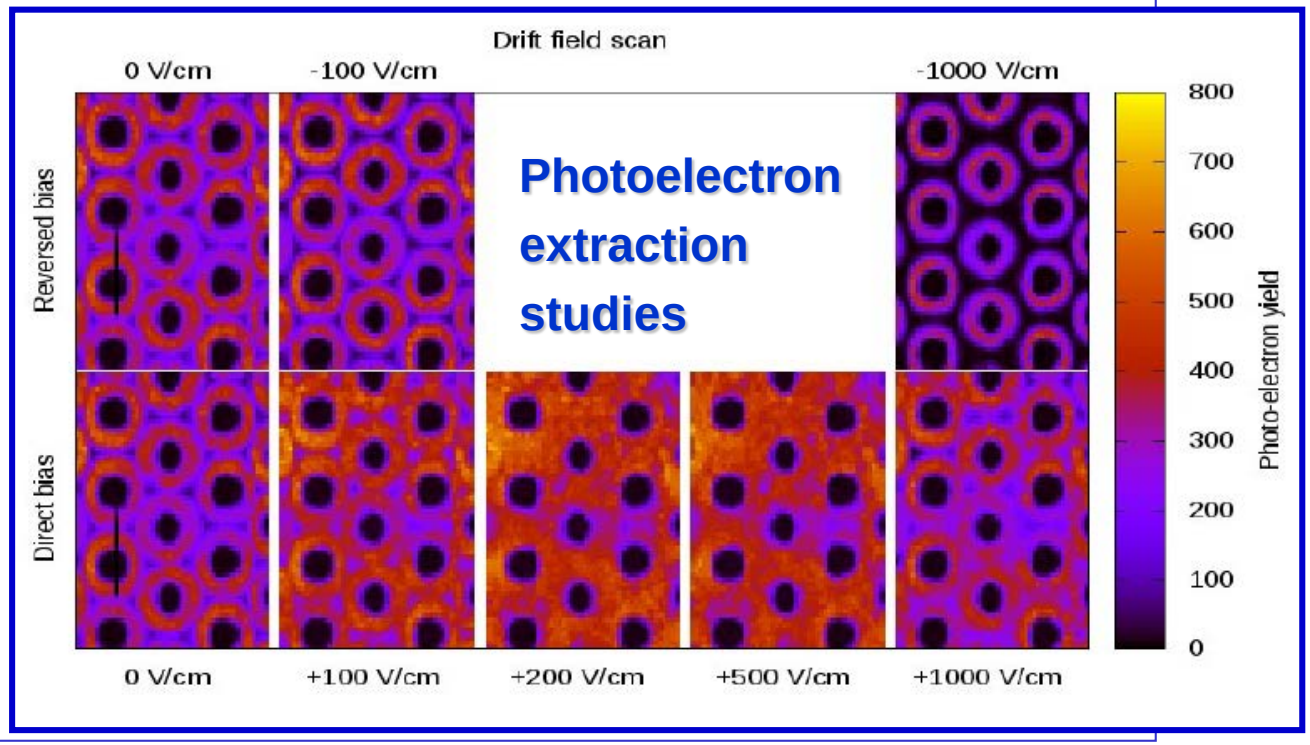
- **the comparative study of the photoelectron extraction in gas atmosphere is the fifth R&D item by the LEOPARD**



G.Hamar and D. Varga, NIMA 694(2012)16







PHOTOCATHODES: something new and exciting?

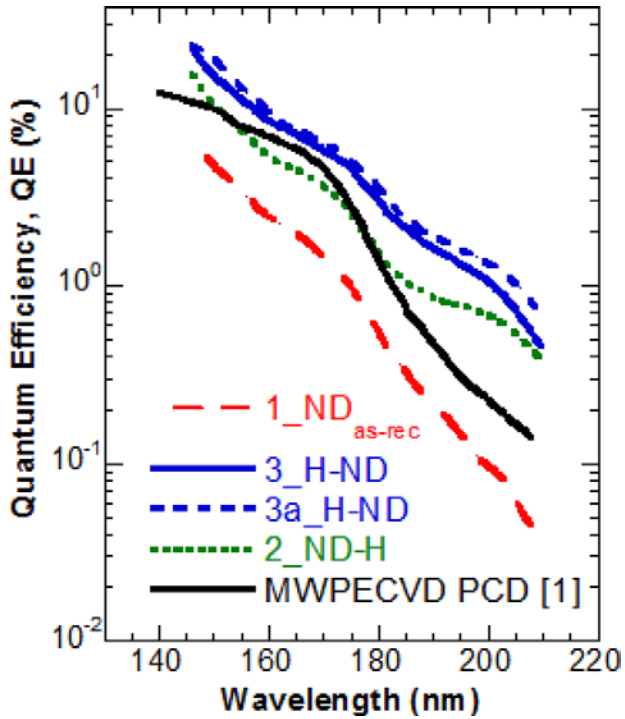
Antonio Valentini – Sezione INFN di Bari (2016)

Italian patent application n. 102015000053374

Photocatodes: diamon film obtained with Spray* Technique making use of *NC powder

Spray technique: T ~ 120° (instead of 800° as in standard techniques)

PHOTOCATHODES: something new and exciting?



QE= 22% at 146 nm

CsI (for comparison)

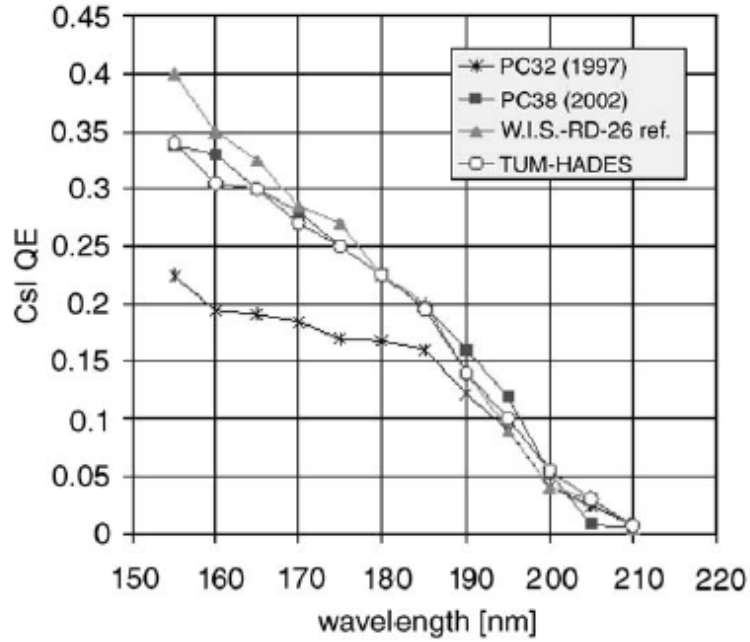


Fig. 1. The QE of CsI PCs produced at CERN for ALICE and at TUM for HADES, compared to that measured at the W.I.S. on small samples (reference for RD-26). PC32 is one of the four PCs equipping the ALICE-RICH prototype used in STAR at BNL.

A. Di Mauro, NIM A 525 (2004) 173.

- **Higher QE recently obtained, submitted for publication**

OUTLINE

- RICH FACTS, A QUICK REMINDER
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- GASEOUS PHOTON DETECTORS, AN R&D
- **PERSPECTIVES**

PERSPECTIVES

- Solid bricks needed to design a detector as complex as a RICH for EIC forward rapidities
- We are at work to further consolidate gaseous PDs, tentatively one of the bricks
- The detector design can only come later
- No realistic RICH prototype can be envisaged till
  - the money flow does not increase (this dependents on the overall progress of the EIC approval)
  - A collaboration large enough to attack the various RICH items is not formed:
    - PDs, gas system, mirrors, mechanics, r-o electronics, MC support for the design
- Being optimistic: we can dream of a prototype around 2024