Particle ID R&D programs

Focus on with h-PID

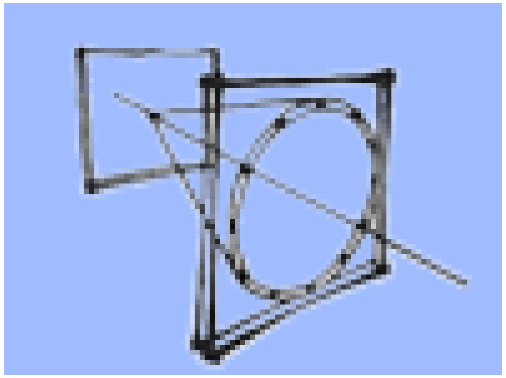
with reference to EIC needs

Thank you to

all the colleagues who kindly provided information

all the colleagues whose material (paper, slides) I used

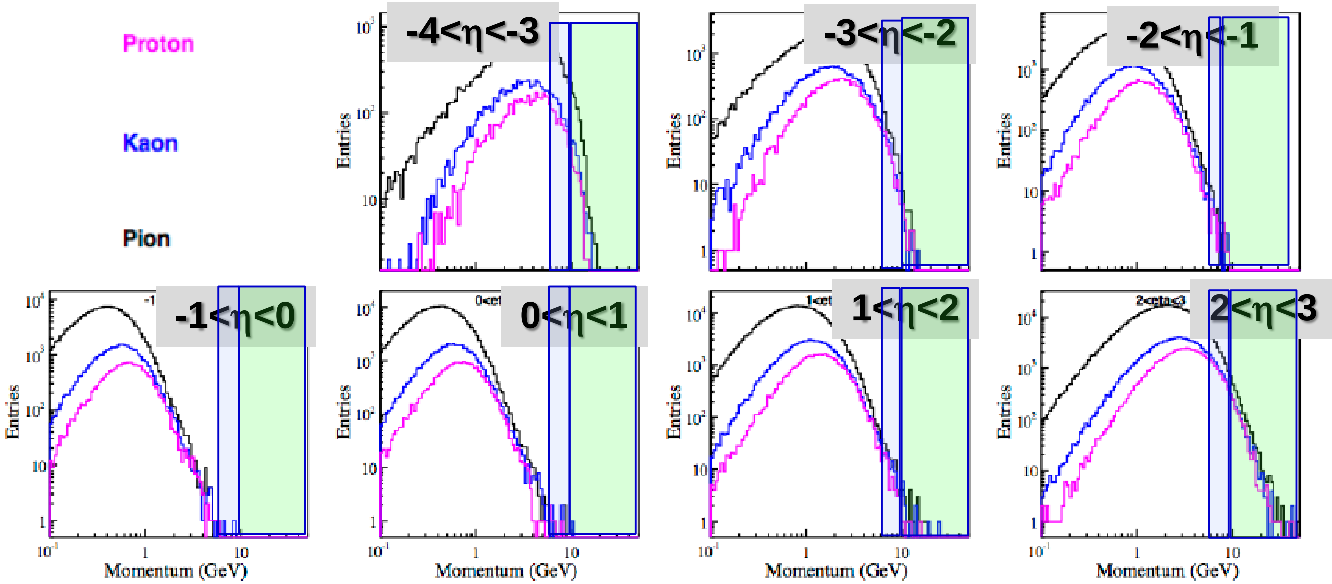
Of course, all the mistakes and biases are mine !

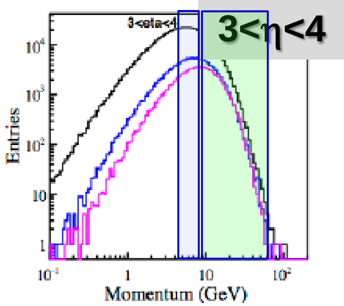


INTRODUCTION

NEEDs

20x250 GeV configuration; yields versus momentum in the $4 < \eta < 4$ range:





π/K ratio is about 3:1 -> depending on the desired efficiency and contamination this defines the required suppression factors

π/K/p separation → suppression factors ~100 required (and momentum distributions are very η-dependent)

A. Kiselev, EICUG meeting, Argonne, 2016

→ 3 σ separation can be marginal !

h-PID, 3 main domain:

1. **p < 6 GeV/c**

know techniques, extendable to a few GeV/c more (10 GeV/c) ?

2. **p >10 GeV/c**

known techniques IF an EXTENDED RADIATOR is used

3. **6 < p < 10 GeV/c**

Both handles must contribute

=====================

One more observation: the very low momenta can be critical as well

Fused silica:
π_thr = 0.13 GeV/c
k_thr = 0.4 GeV/c

Aerogel (n=1.05):
π_thr = 0.44 GeV/c
k_thr = 1.54 GeV/c

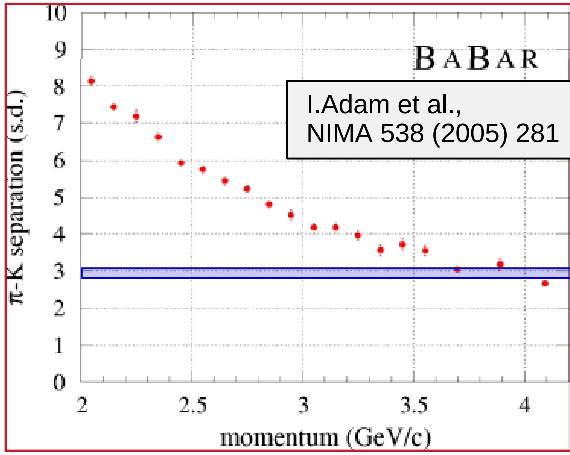
DIRC
& RELATED TOPICS

DIRC

The only DIRC operated so far:

Babar

π/K separation power:



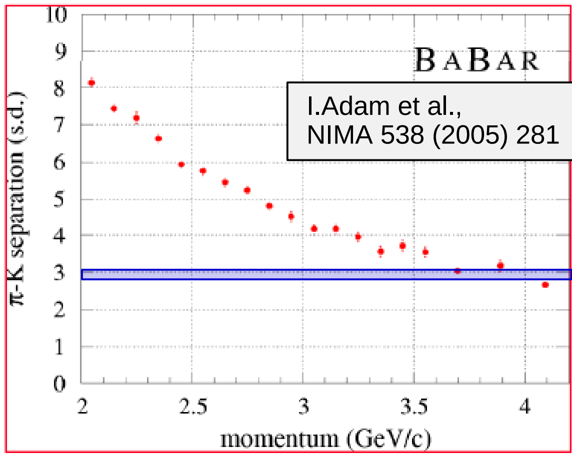
With fine time resolution …

DIRC

The only DIRC operated so far:

Babar

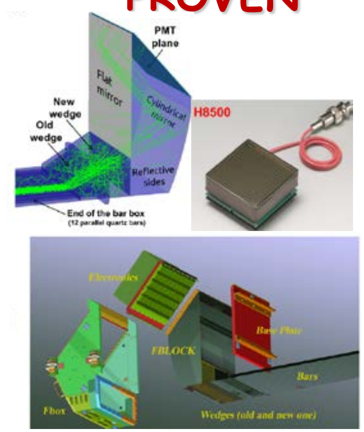
π/K separation power:

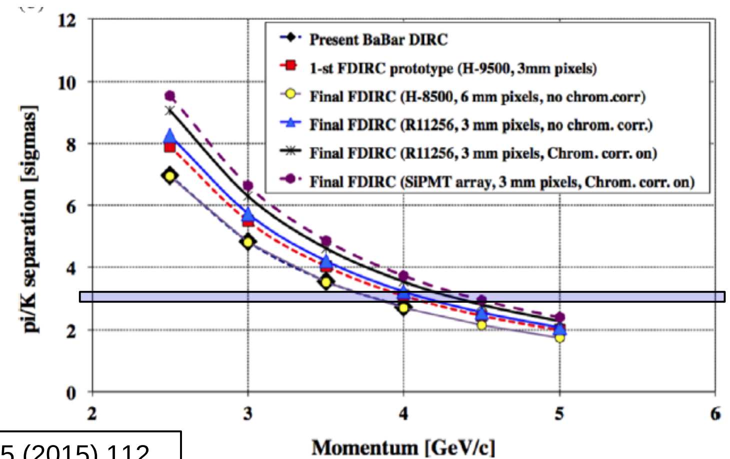


I.Adam et al., NIMA 538 (2005) 281

The concept of the focusing DIRC

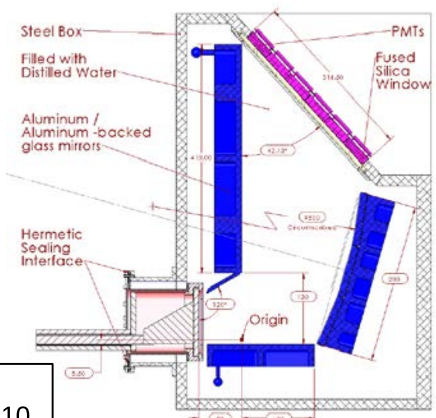
- fine timing allowing for **Chromatic Correction, PROVEN**





B. Deyet al., NIMA 775 (2015) 112

a FDIRC in Glue-X



GOAL:

3σ @ 4 GeV/c

J. Stevens et al., JINST 11 (2016) C07010

More exotic configuration: PANDA DISC-DIRC

- Barrel DIRC

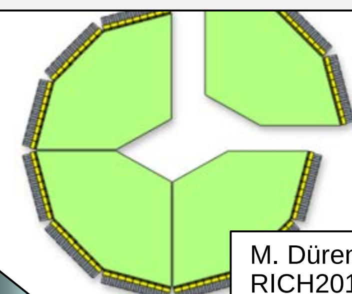
  Goal: 3 s.d. π/K separation up to 3.5 GeV/c

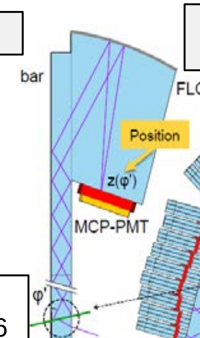
- Endcap Disc DIRC

  Goal: 4 s.d. π/K separation up to 4 GeV/c

J. Schwiening., RICH2016

Concepts tested in **WASA polymer DIRC**



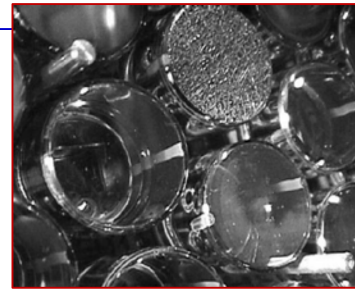


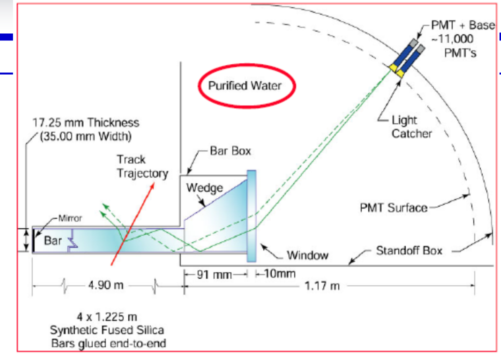
Focusing light guide: **LiF**

M. Düren, RICH2016

DIRC - PHOTODETECTORS

- **BABAR: standard PMTs**
  - Resolution by long lever arm





- **FDIRC: H-8500 MAPMTs ("flat panels")**
  - 100-200 ps time resolution

- **GlueX: H12700 64-channel MaPMT**

- **PANDA: MCP-PMT**

Readout Electronics

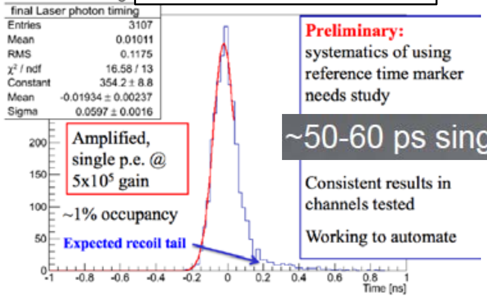
~100ps timing per photon for small MCP-PMT
pulses – amplification and bandwith optimization

MORE WITH FINE TIME RESOLUTION PDs

BELLE II – TOP

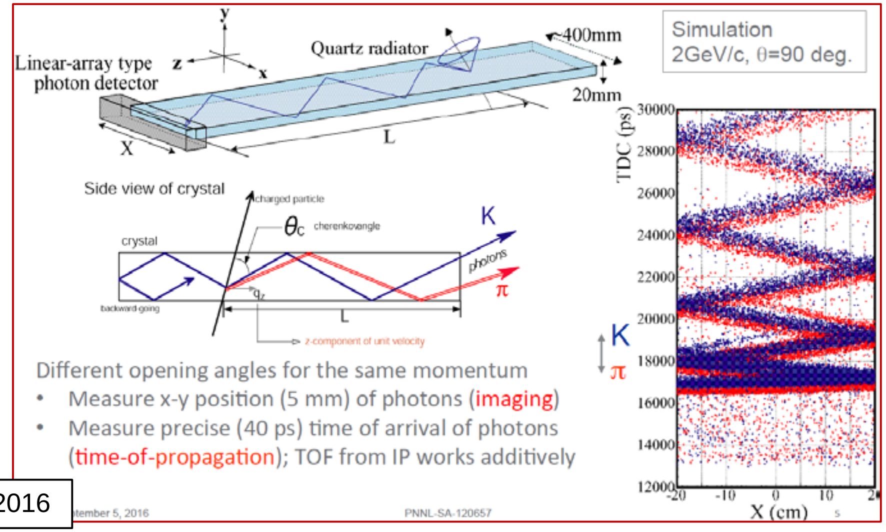
- First Cherenkov device using MCP-PMTs in an experiment

Single photon (laser)



~50-60 ps single hit

HAMAMATSU R10754-07 M16(N)



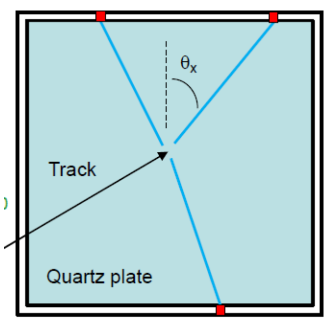
Simulation 2GeV/c, θ=90 deg.

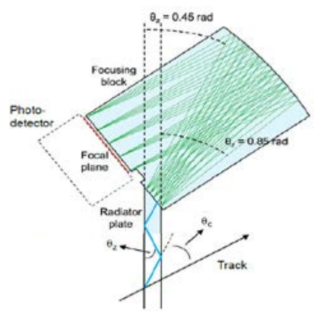
J. Fast, RICH 2016

TORCH (LHCb upgrade): a DIRC for TOF measurements using MCP-PMTs

- Overcoming:
  - the upper limit from θ_C saturation
  - the time-resolution limit from single photon

Detected photon

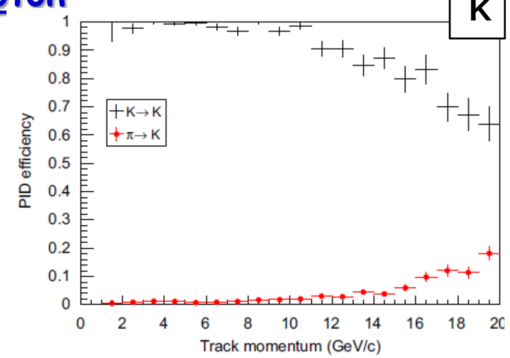




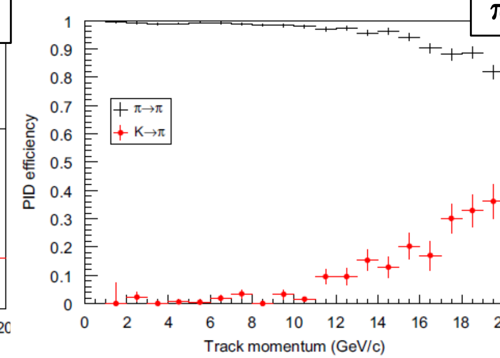
MC
10 m
σ_t = 12.5 ps

M.J.Charles, R. Forty, NIMA 639 (2011) 173

K



π

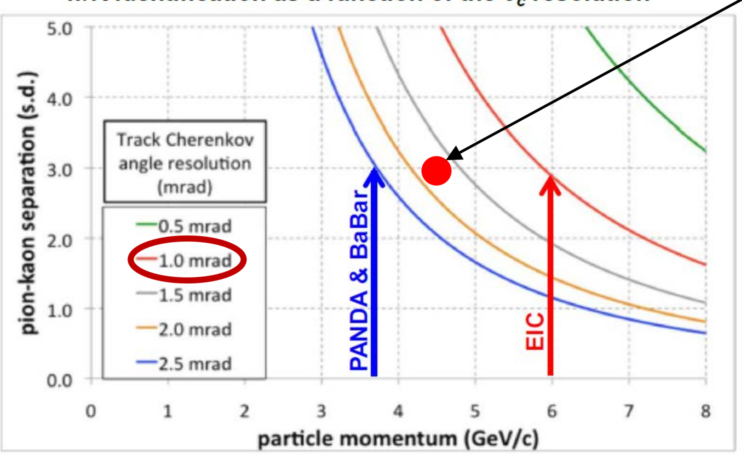


EIC DIRC

On going R&D for EIC

- **R&D including FDIRC & TOP concepts**
- **Goal**
  - p/K up to 10 GeV/c
  - π/K up to 6 GeV/c
  - e/π up to 1.8 GeV/c
- **Therefore needed:**

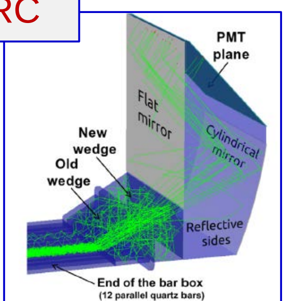
π/K identification as a function of the θ_c resolution



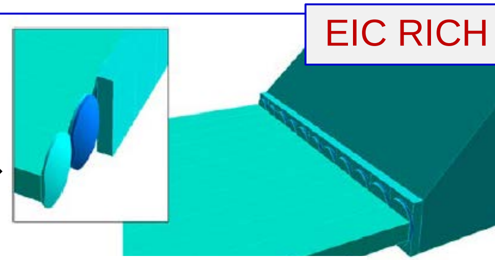
FDIRC
B. Deyet al., NIMA 775 (2015) 112

- **Handles:**
  - **New focusing element**
  - **Better timing** (electronics limits in FDIRC)

FDIRC



EIC RICH

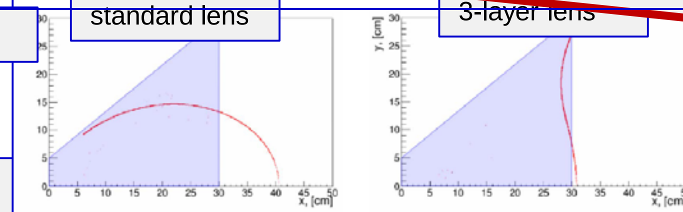


3 component lens

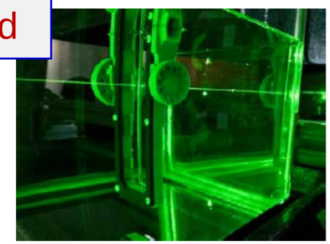
simulation

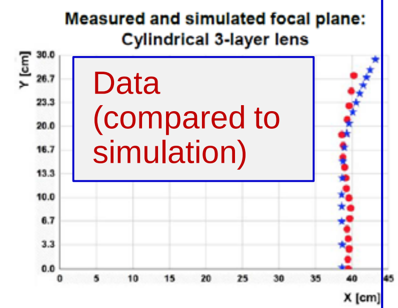
standard lens

3-layer lens



Promising & confirmed



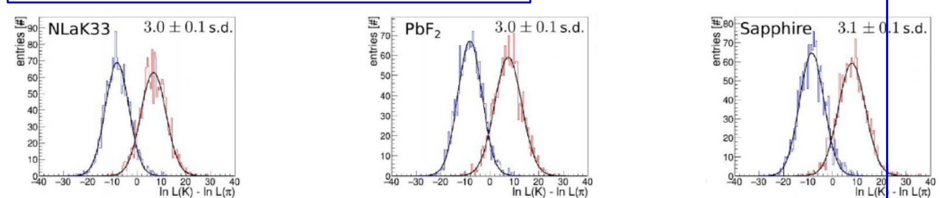


Data (compared to simulation)

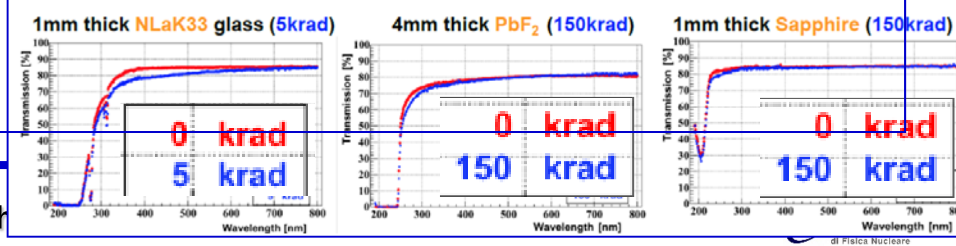
Majority of the material provided by G. Kalicy

3-layer lens material:
performance & radiation hardness

π-K separation at 6 GeV/c (MC)



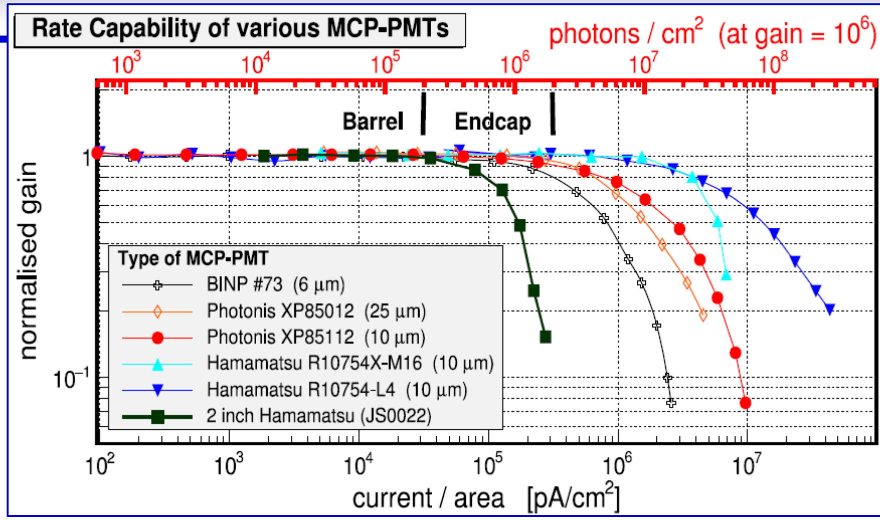
NLaK33 | Pb F2 | SAPPHIRE



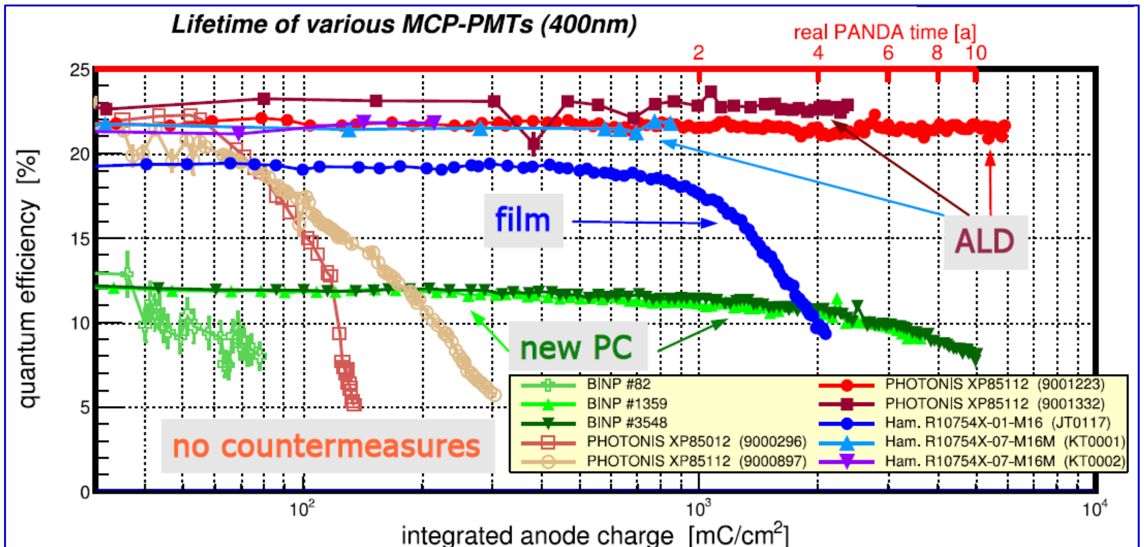
MORE ABOUT MCP-PMTs

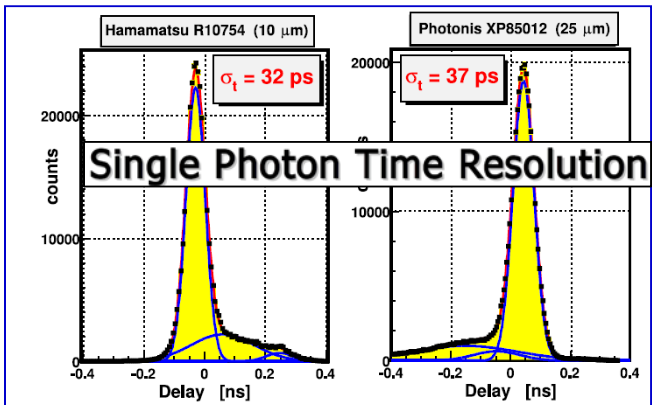
A. Lehmann,
CPAD 2017

- Single anode devices (1-2 cm Ø)
  - BINP (Novosibirsk)
  - Hamamatsu
  - Photek
- Multi-anode devices (1" and 2")
  - PHOTONIS Planacon (10, 25 μm)
    - 2" squared, 8x8 and 3x100 px
  - Hamamatsu R10754 and R13266
    - 1" squared, 10 μm, 4x4 px
    - 2" squared, 10 μm, 8x8 and 6x128 px
  - Photek (2" sq., 10 μm, 8x128 px)
  - ANL (6 cm^2, 10 μm, strip readout)
    - all glass body



Unfortunately, commercial MCP-PMTs are very expensive





The true step forward: ALD, up to 50 time longer lifetime

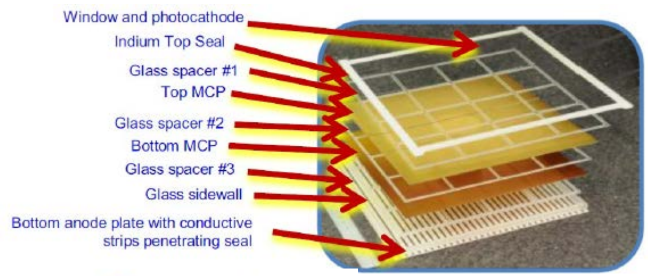
MCP-PMT: LARGE ? CHEAP ?

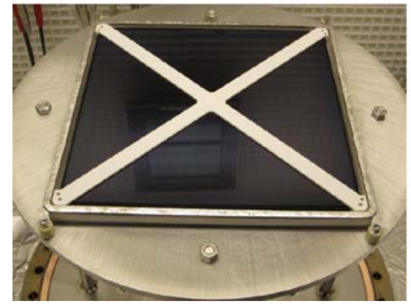
MINOT, Pisa Meeting 2018

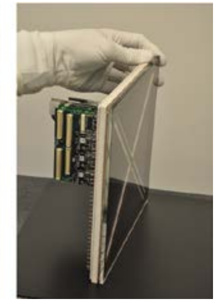
B.W. Adams et al., arXiv:1603.01843

LAPPD

(20x20 cm^2) MCP-PMTs







LAPPD #25 Performance Summary

Parameter	LAPPD 25
MCP resistance (Entry/Exit; MΩ)	10.7 / 14.2 MΩ at 875 V
QE	@365 nm: Max: 10%, Mean: 7.1%, s = 0.8% @455 nm: Mean: 10.2%
Gain	7.5 x10^6 @ 850/950 V (entry/exit)
Dark rate (Single 13.5 cm2 strip)	9.5 Cts/s cm2 @ 50 volts on the P/C, 850 V/MCP, and Threshold of 7.6x105 gain
After pulses	Typical for MCP PMT – about 3.5%
Along-strip Spatial Resolution Cross-strip	2.8 mm RMS (measured as 33.4 psec) 1.3 mm RMS
Time Resolution	64 psec resolution TTS MCP Pulse Rise time: 850 psec, FWHM: 1.1 nsec

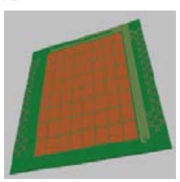
Large Area Photocathode production process is established
QE >20% demonstrated in sealed LAPPDs

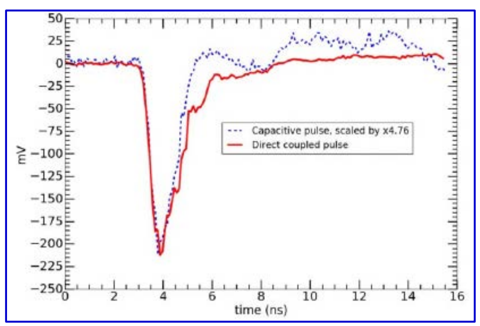
LAPPD S/N	Maximum %	Average %	Minimum %
LAPPD #13:	23.5	18.6±3.3	13.5
LAPPD #15:	25.8	22.3±3.0	15.7
LAPPD #22:	14.7	10.6	
LAPPD #25:	10	7.1	
LAPPD #29:	19.6	13.0±6.0	3
LAPPD #30:	22.9	17.2±2.5	13

GEN II Capacitive Coupling

A thin metal DC ground plane is deposited onto the inside of the detector.

User-designed read-out elements



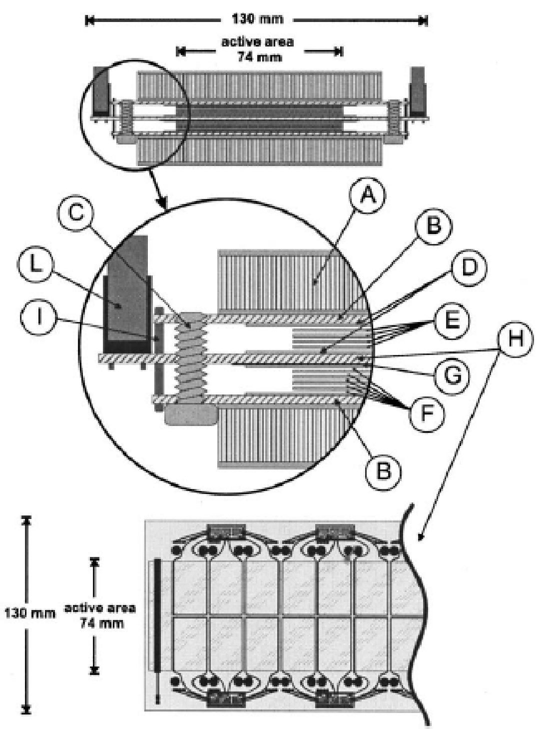


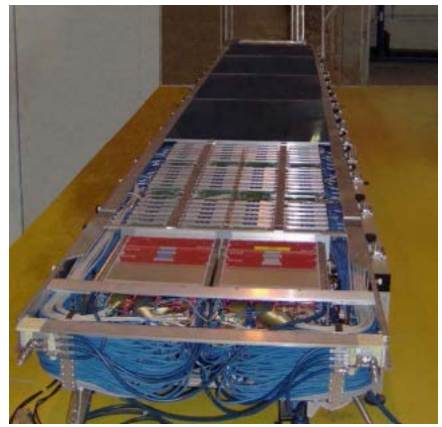
COMMENTS:

1. Still several years to converge (at least 5)
2. They will succeed IF THE MONEY FLOW goes on at current rate
3. No way to understand NOW the future price
4. Light and ~insensitive to B → potentially useful also where timing is not an issue

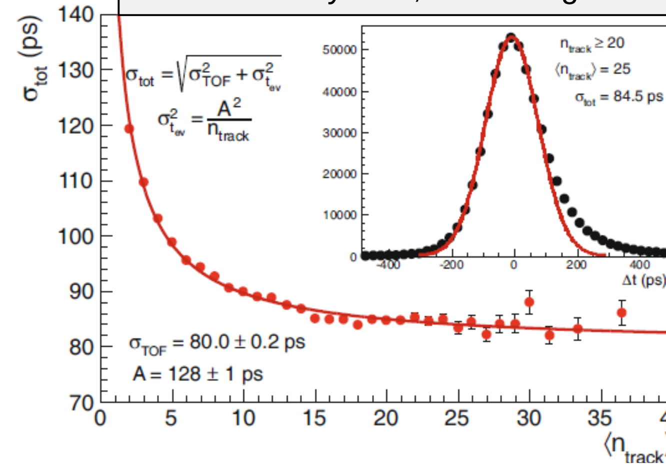
FINE TIME RESOLUTION BY mRPCs

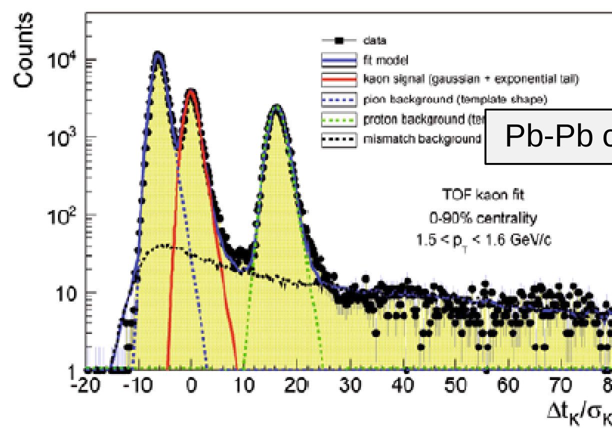
- **ALICE:** glass Multi-gap Resistive Plate Chamber (MRPC)
- **MRPCs in test beam, time resolution< 50 ps**
  - **electronics included**



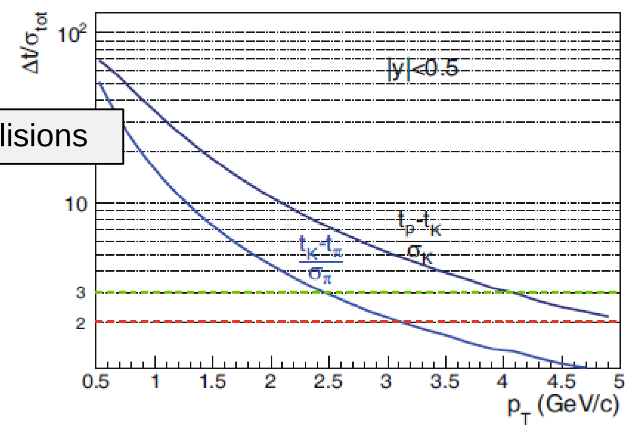


ALICE TOF system, track length: 4 m





Pb-Pb collisions



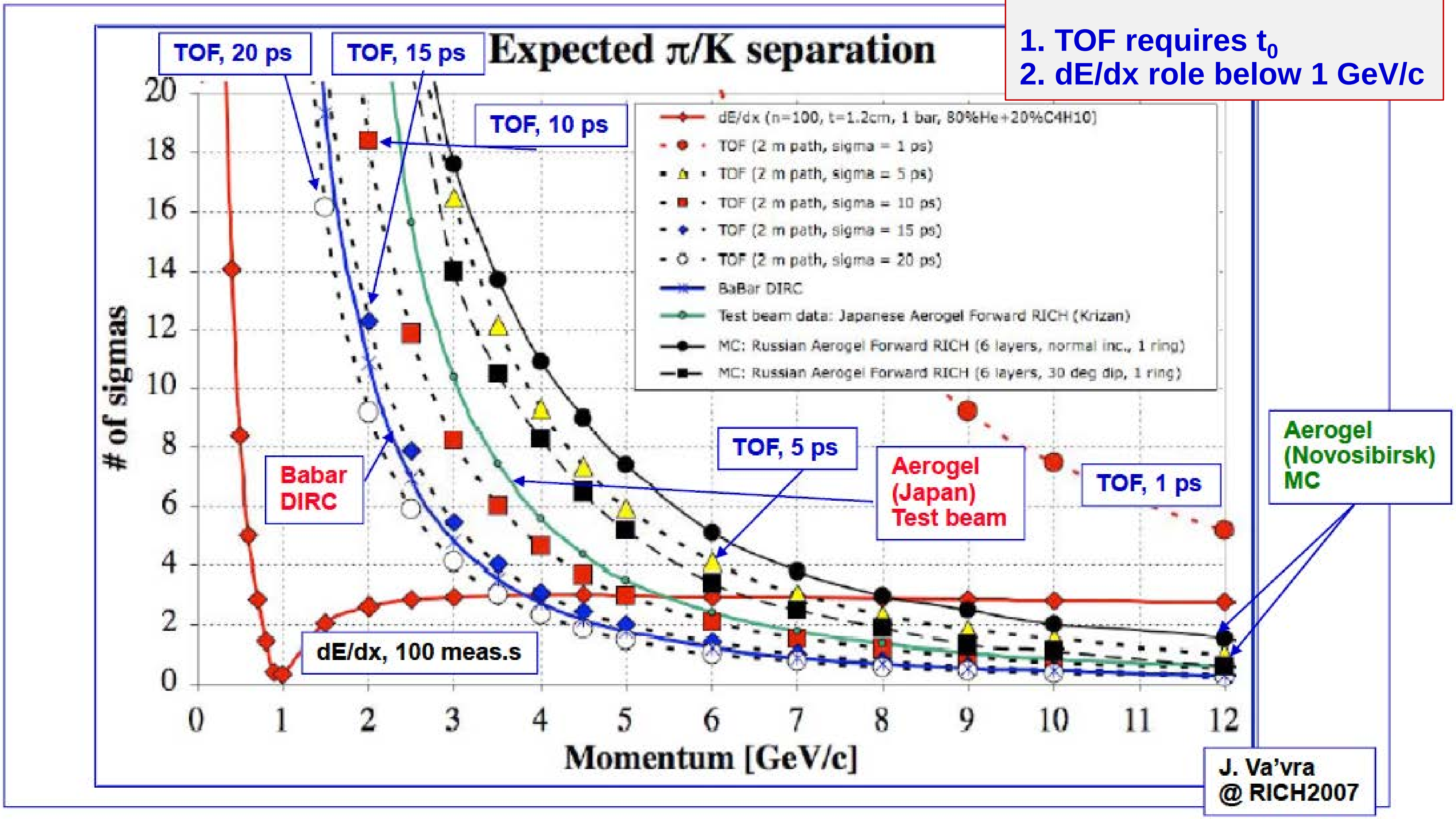
A. Akindinov et al., NIMA 532 (2004) 611

A. Akindinov et al., Eur. Phys. J. Plus 128 (2013) 44

CHERENKOV IMAGING, TOF & dE/dx

COMMENTS:

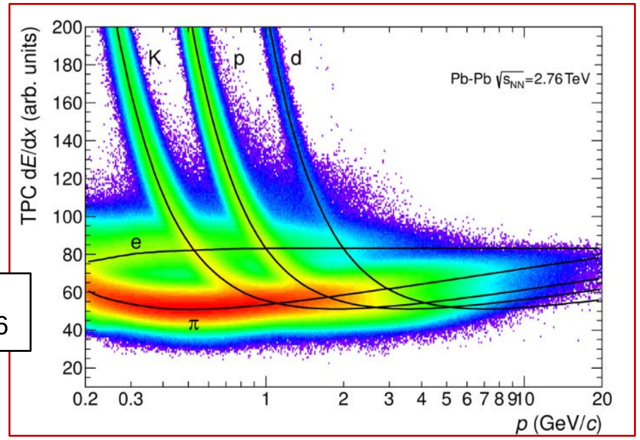
1. **TOF requires t_0**
2. **dE/dx role below 1 GeV/c**

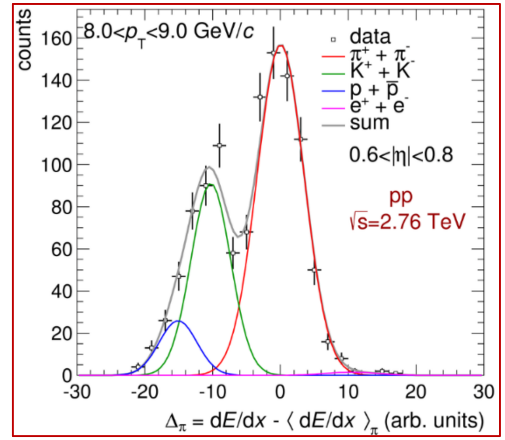


dE/dx is an important handle !

ALICE TPC (before upgrade)

J. Alme et al., NIMA 622 (2010) 316



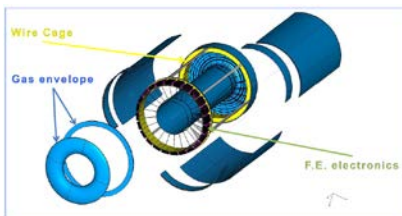


Cluster counting ?

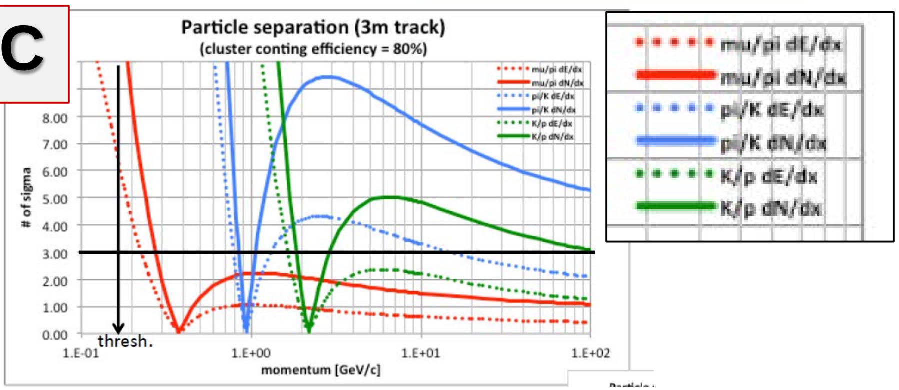
DRIFT CHAMBER,
3 m long, gas: 90% He - 10% iC4H10

F. Grancagnolo
INFN – Lecce, ITALY

WG11 Detector Design Meeting
CERN
17 October 2016



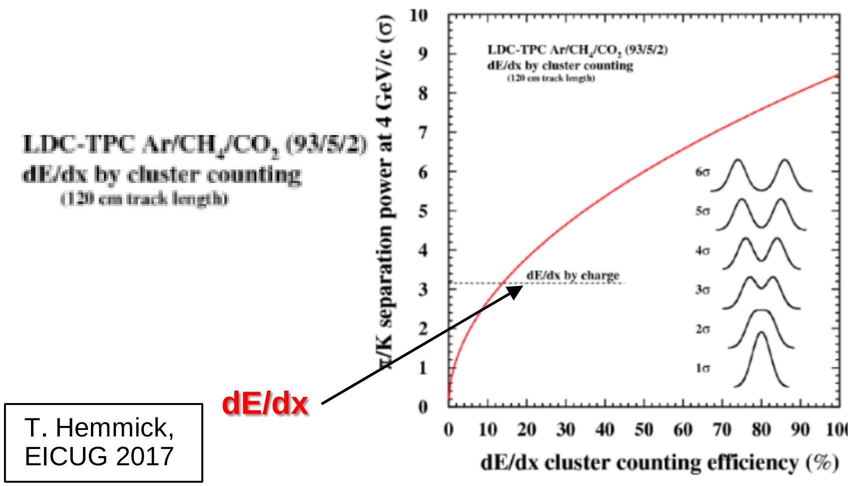
MC



Cluster counting in a TPC ?

namely, cluster counting with smearing due to diffusion

4 Gev K-π



T. Hemmick, EICUG 2017

DIRC & FRIENDS, MY SUMMARY

- DIRC: no other practical option for barrel

- a very special effort (manpower, money) for progress
  - FDIRC moves 3σ-limit from 3.7 to 4.5 GeV/c, EIC DIRC → 6 GeV/c

- crucial support in barrel region: dE/dx
  - No h-PID from DIRC above ~6 GeV/c
  - It has to be taken as a central requirement of the overall setup design

- TOF
  - To be seriously considered for the end-caps
  - Barrel region: short lever arm available

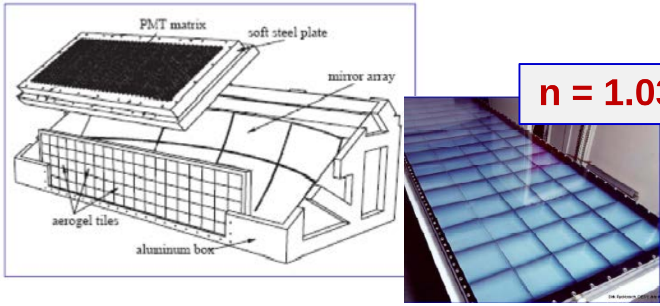
- MCP-PMTs
  - LAPPD if converging, other options are dramatically expensive
  - Good for DIRCs, TOF (time resolution)
  - *Good for other PID devices (QE in visible range, ~ insensitive to B)*

AEROGEL

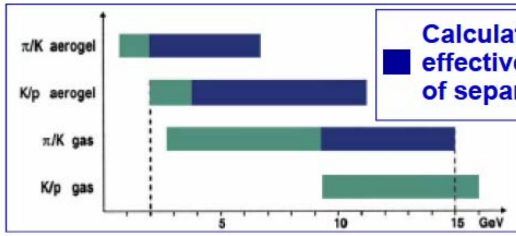
AEROGEL in CHERENKOV IMAGING, so far 1/2

HERMES

2 identical RICHes
Dual radiator:
Aerogel & C4F10

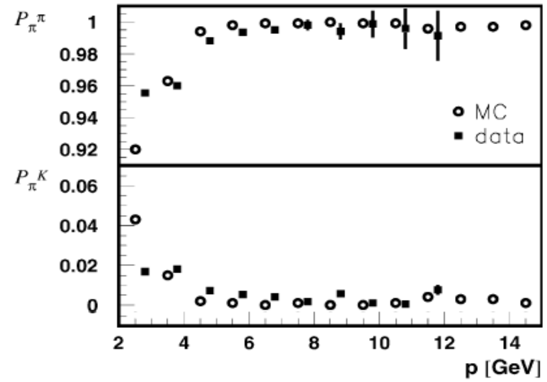


n = 1.03



Calculation: effective range of separation

N. Akopovet al.,
NIMA 479 (2002) 215



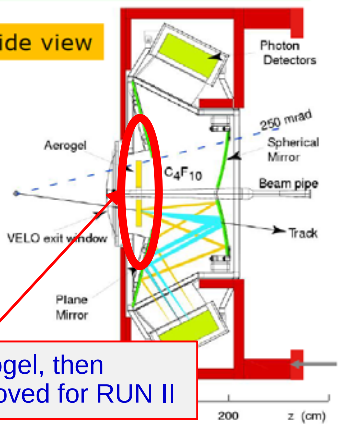
LHCb

RICH 1
Acceptance 25-300 mrad

2 Detectors
3 Radiators

RICH 2
Acceptance 15-120 mrad

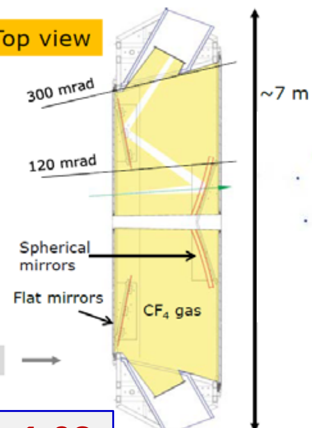
Side view



Aerogel, then
removed for RUN II

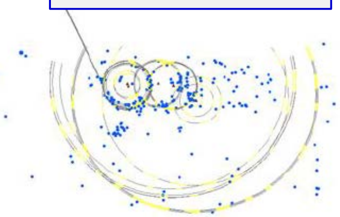
Note Scale Difference

Top view

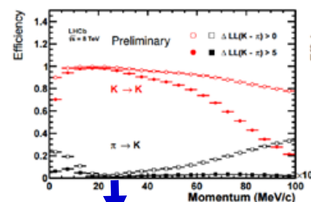


n = 1.03

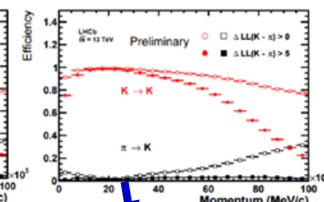
Image RICH1 In RUN I

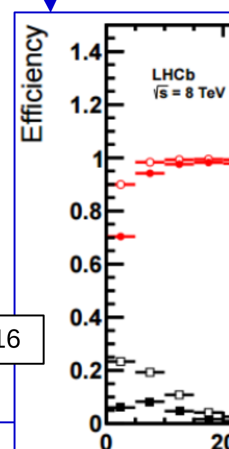


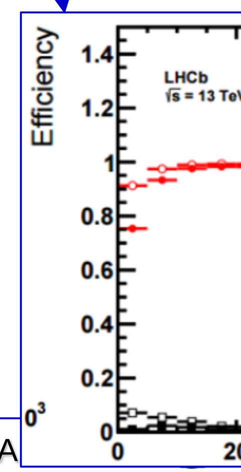
Run I



Run II (2015)







A. Papanestis, RICH2016

Aerogel rings very big
- Many photons, many track/photon combinations

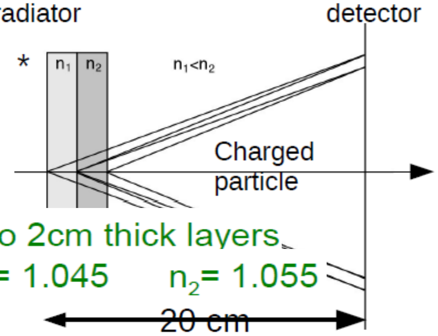
AREOGEL in CHERENKOV IMAGING, so far 2/2

BELLE II - ARICH

Goals and constraints:

- > 4 σ K/π separation @ 1-3.5 GeV/c
- operation in magnetic field 1.5T
- limited available space ~280 mm
- radiation tolerance (n,γ)

proximity focusing aerogel RICH

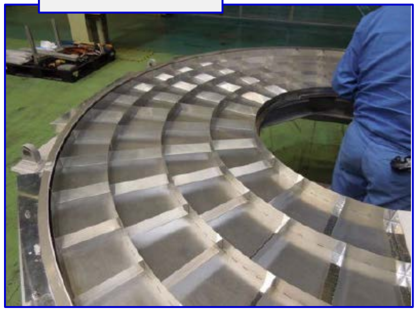


Two 2cm thick layers

n_1= 1.045 n_2= 1.055

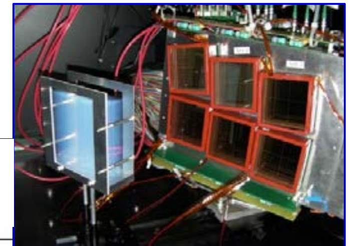
HAMAMATSU HAPD
Selected because of Radiation tolerance

ASSEMBLY



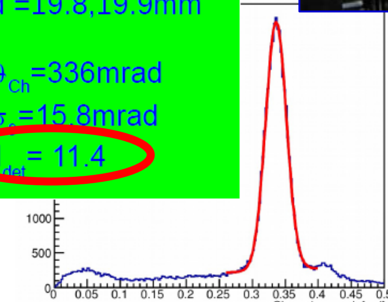
R. Pestotnik, RICH2016

TEST BEAM



double aerogel
- n_0=1.050,1.065
- d =19.8,19.9mm

ϑ_{Ch}=336mrad
σ_{ϑ}=15.8mrad
N_{det} = 11.4



>5.5 σ K / π separation at 4 GeV/c

CLAS12, starting operation

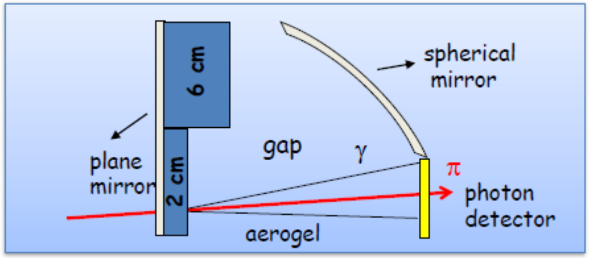
RICH goal: π/K/p identification from 3 up to 8 GeV/c and 25 degrees

~4σ pion-kaon separation for a pion rejection factor ~ 1:500

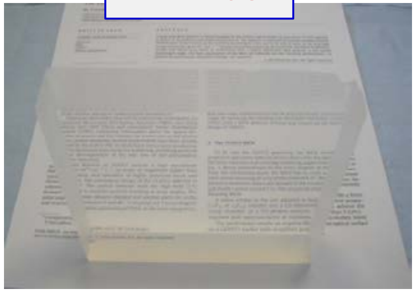
Implemented so far

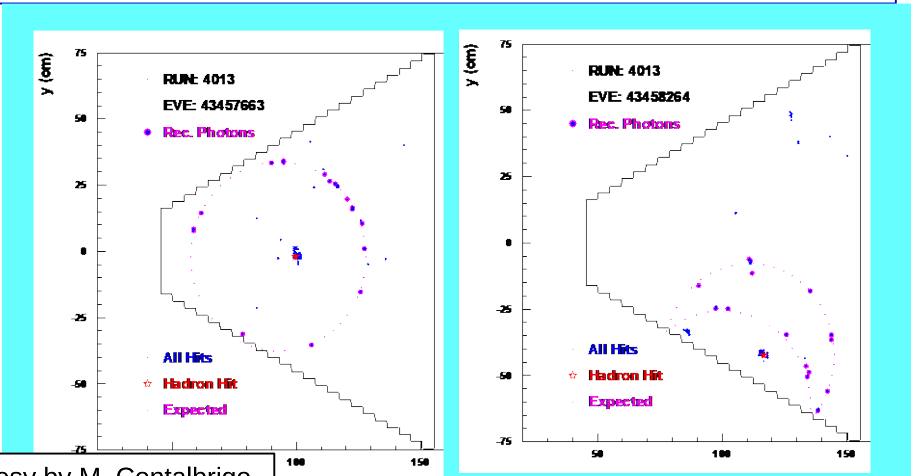
from test beam, 12 ph.s/ring expected for 2 cm-long tiles (TDR)

Direct rings and best performance for high momentum particles



n = 1.05





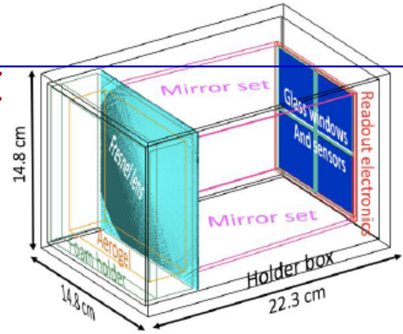
Courtesy by M. Contalbrigo

On going R&D for EIC

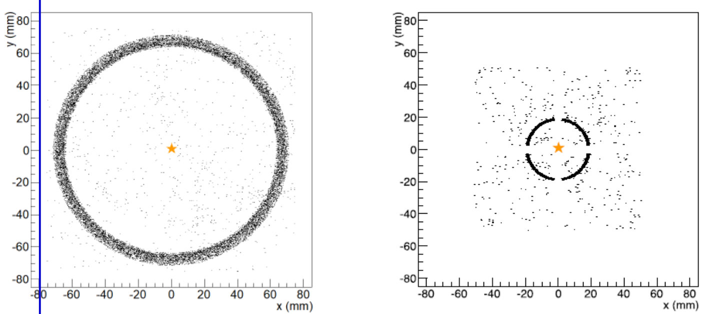
Modular RICH

(also considered for sPHENIX

- An important ingredient:
The Fresnel lens



Proximity Focusing Design | **mRICH Design**



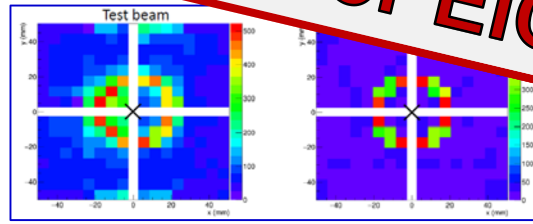
Larger and smeared ring | smaller and thinner ring

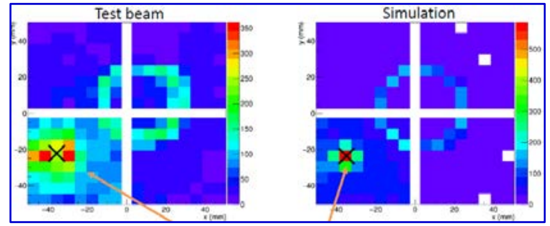
Implementation: version 1

1st Test Beam Results
from 120 GeV/c Proton Beam

33 mm areogel

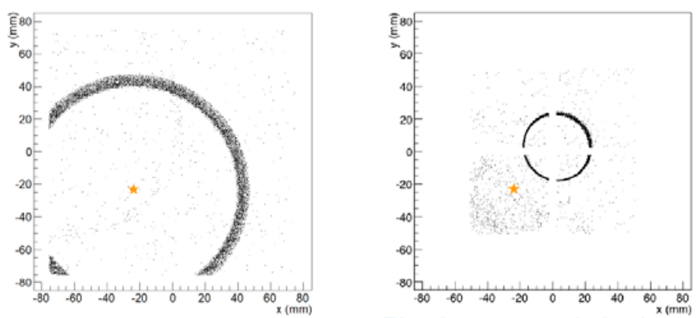
$N = 10.4$ (with n=1.03)





Noise around the beam spot :
Cherenkov photons generated inside the glass window under internal reflection

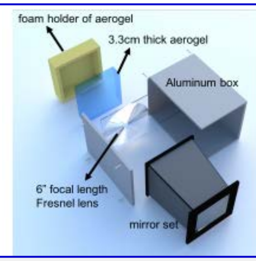
Proximity Focusing Design | **mRICH design**

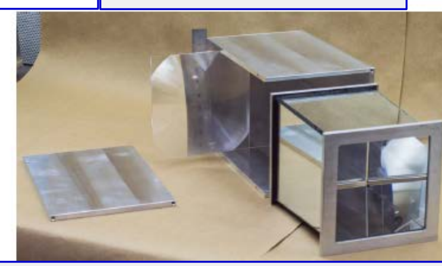


Implementation: version 2

1. Longer focal length Fresnel lens
2. smaller pixel size sensors

6 x 6 → 3 x 3 mm²





Waiting for the results from the recent test-beam with version 2

C.P. Wong, EICUG2017

MAPMTs used at the moment !

ABOUT AEROGEL ITSELF

Producers:

HERMES - Matsushita Electric Works, Japan (<u>no longer available</u>)

LHCb, AMS, CLAS12 – Bunker and Boreskov Institutes in Novosibirsk, Russia

BELLE II ARICH -

Mass Production

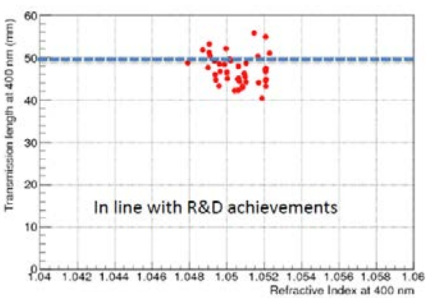
- **Japan Fine Ceramics Center (JFCC) for mass production.**
  - Panasonic no longer accepts new aerogel production.
  - Technology transfer by joint effort with us.
  - Recipe was provided from our side.

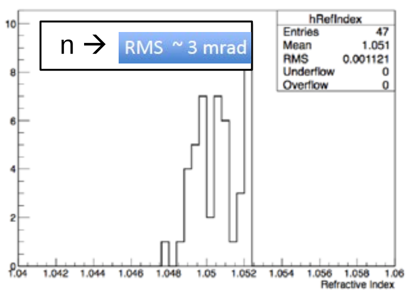
I.Adachi, RICH2016

Aerogel for CLAS12

M. Contalbrigo, RICH2016

Hygroscopic aerogel





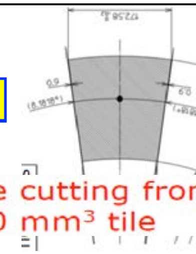
Aerogel for BELLE II

I.Adachi, RICH2016

Hydrophobic treatment

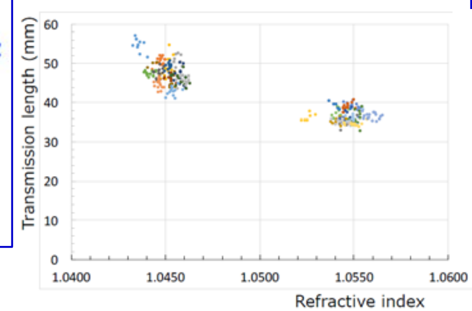
Provide long-term stability in optical property

Total 124 tiles for each refractive index
production over 13 months



Wedge shape cutting from 180×180×20 mm³ tile

- **Visual inspection**
  - **Crack/Chip/Milky area**
- **Dimensions/weight measurement**
- **Refractive index measurement**
  - **Fraunhofer technique**
- **Transparency measurement**
  - **Using a spectro-photometer**



Yield ~74%

AEROGEL, MY SUMMARY

- Clear and solid strategy for producer/production of aerogel
  - over long time-range

- p-range for effective h-PID to be understood
  - Effectiveness in very low p (<2 GeV/c) and high p (> 6 GeV/c) have to be established, wait for results from (respectively):
    - BELLE II ARICH
    - CLAS12 RICH
  - Effectiveness in *very low p and high p* in the same device possible ?

- Dual radiator architecture more critical
  - Go for a good aerogel RICH stand alone & a good gaseous RICH

- For forward hPID be open-mind
  - complement aerogel RICH with TOF

h-PID
@ HIGH MOMENTUM

h-PID @ HIGH p

What is needed:

- Gaseous radiator
- Focusing system (mirrors)
- Wide phase space acceptance

Not so much activity ongoing world-wide

- Presently only 2 running high-p & wide acceptance RICHes:
  - COMPASS
  - LHCb (2-counter system)
- Limited number of new projects:
  - 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)

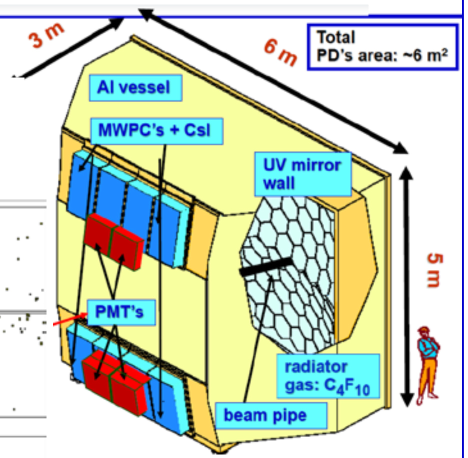
The challenges at EIC:

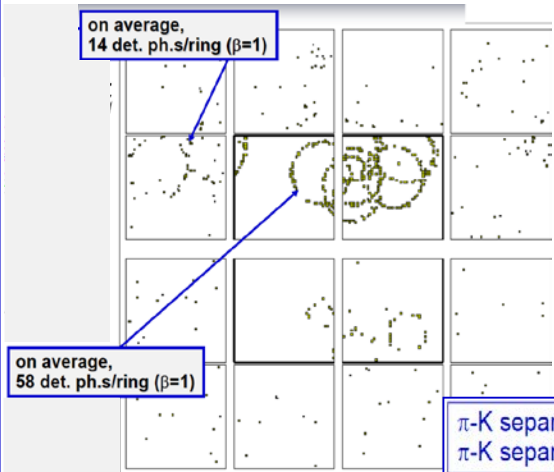
- No more than 1 m-long radiator
- Presence of magnetic field

LESSONS FROM HIGH p RICHes IN OPERATION

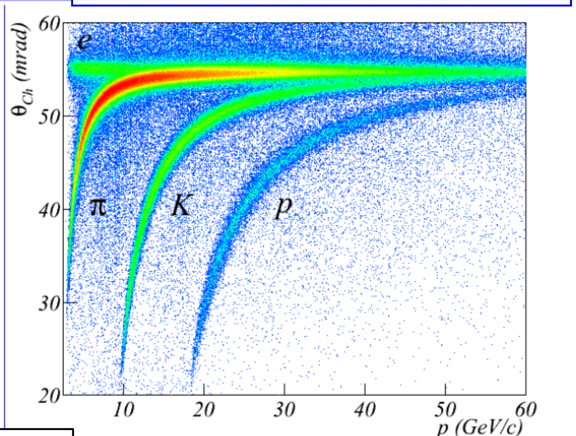
COMPASS

C_4F_{10} - 3 m
(n = 1.0015)





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



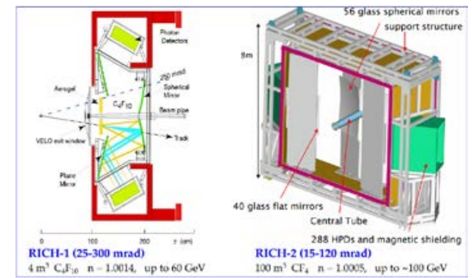
Effective QE range

CsI : 165-205 nm

MAPMTs (UV extended window) : 200-650 nm

P. Abbon et al., NIMA 616 (2010) 21

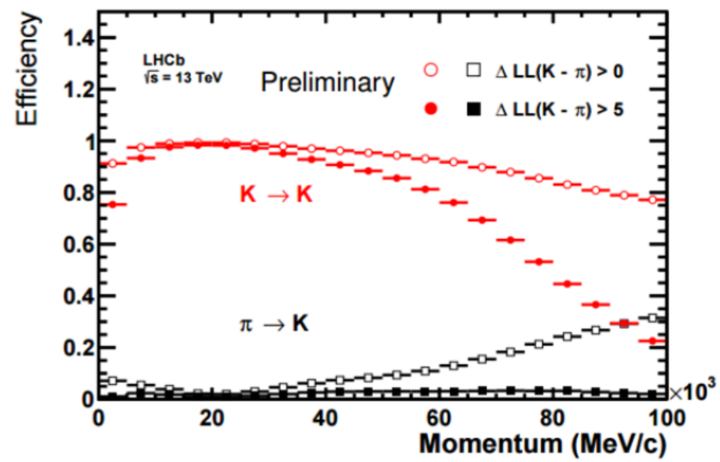
LHCb



Radiator	Aerogel	C_4F_{10}	CF_4
L	5 cm	85 cm	167 cm
n	1.03	1.0014	1.0005
Momentum	1–10 GeV/c	up to 60 GeV/c	up to 100 GeV/c
θ_C^{max}	242 mrad	53 mrad	32 mrad
$\sigma^{tot}(\theta_C)$	2.6 mrad	1.5 mrad	0.7 mrad
$\mathcal{N}_{pe}$	6.7	30.3	21.9

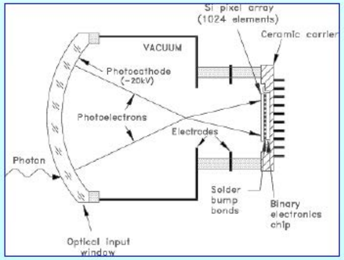
MC

A. Papanestic, RICH 2013



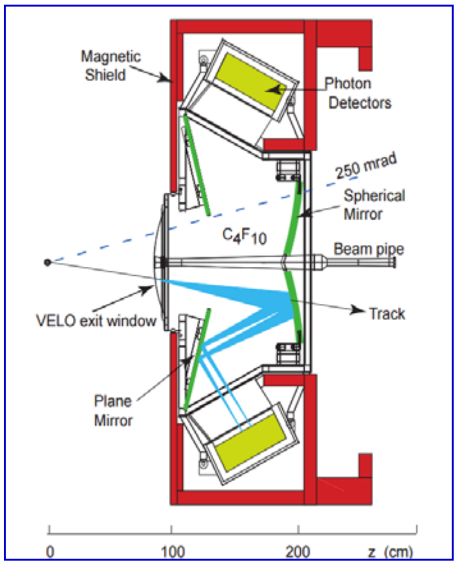
PMTs & MAGNETIC FIELD

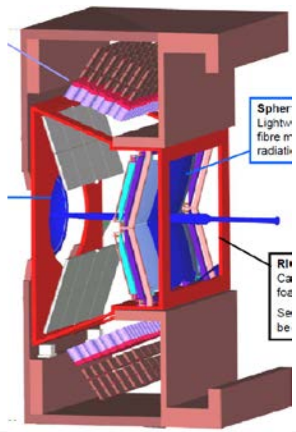
LHCb



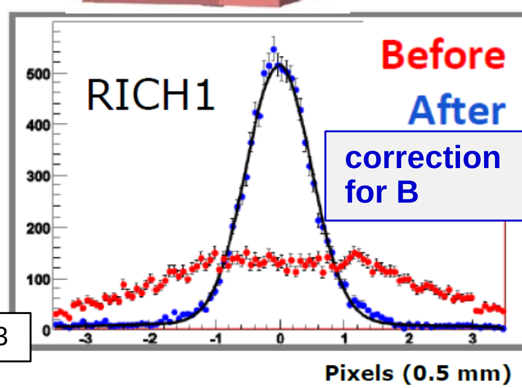
HPM, LHCb custom
1024 anods

Impressive mag. shielding





Nevertheless:

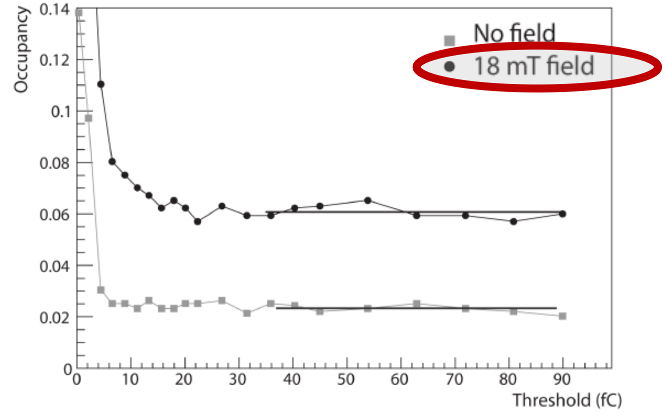


correction for B

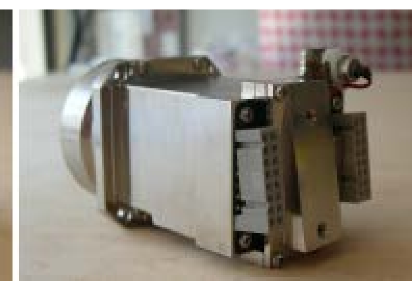
A. Papanestic, RICH 2013

COMPASS

P. Abbon et al., NIMA 616 (2010) 21



MAPMT type R7600-03-M16 by Hamamatsu



Individual soft iron shielding → B < 2 mT (external B ~ 20 mT)

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 MPGDs** (PHENIX HBD, no imaging, NEW: COMPASS RICH-1 2016 upgrade)

SiPMs

- **Silicon PMs** (not used so far in any experiment)
  - radiation hardness , intrinsic noise
  - cooling to moderate them → more material, complexity
  - Light-guides needed; effective active area in large-size setup ?

A FEW WORDS ABOUT SINGLE PHOTON DETECTORS
cont.

Time resolution (σ)

- PMTs, MAPMTs >/~ 0.3 ns
- MCP-PMT <100 ps
- SiPM <100 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 < 205 nm

Operation in magnetic field

- PMTs, MAPMTs, HPMTs NO

- MCP-PMT, MWPCs, MPGDs YES
- SiPM YES

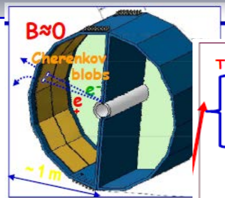
COSTS

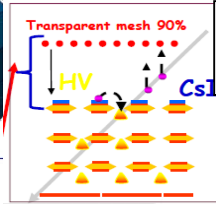
- Gaseous - $ (0.2-0.4 M / m^2)
- MAPMTs - $$ (0.5-1 M / m^2)
- MCP-PMT - $$$ (???)
  - LAPPD ?
- SiPM – which density related to which lightguides ?

FURTHER R&D OF MPGD-BASED PDs

On going R&D for EIC

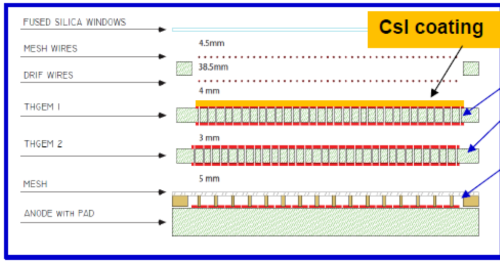
First: HBD





W. Anderson et al., NIMA 646 (2011) 35

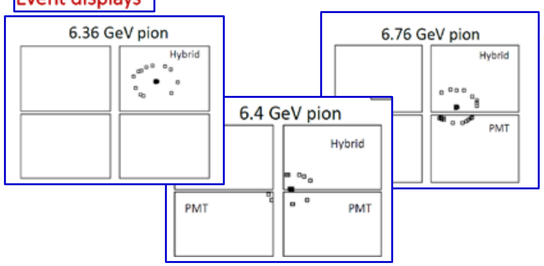
Status of the art: new COMPASS RICH PDs



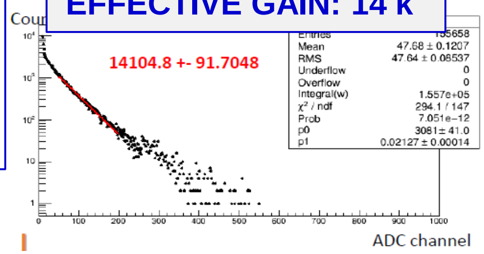
THGEMs

MICROMEGAS

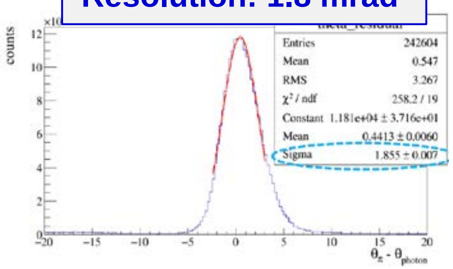
Event displays



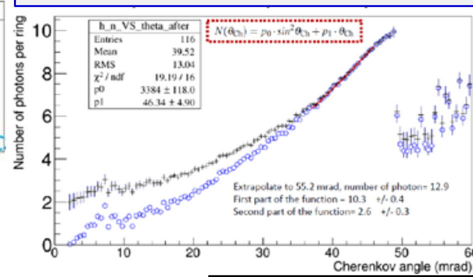
EFFECTIVE GAIN: 14 k



Resolution: 1.8 mrad

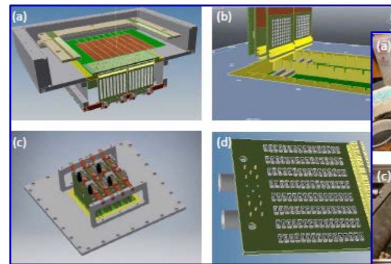


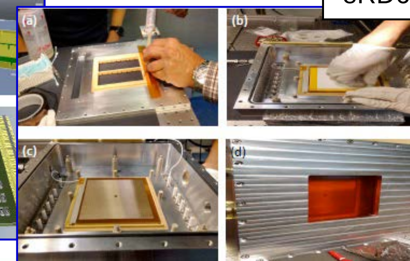
n. of photons/ring : 10 (β → 1)



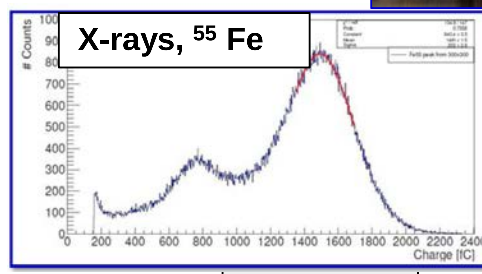
On going R&D: miniaturized pad-size

eRD6, July 2018 report

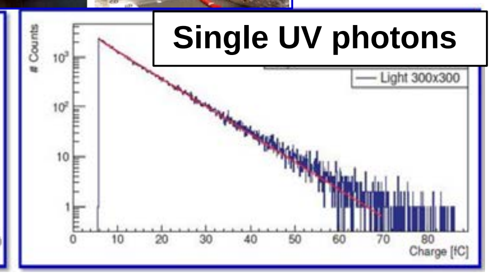




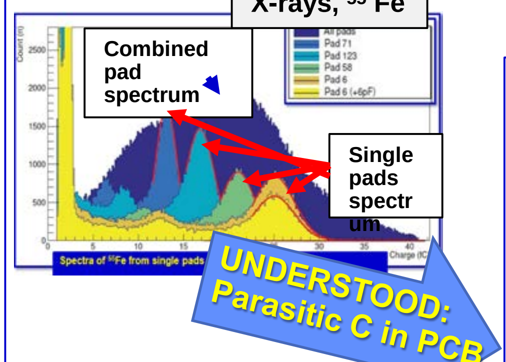
X-rays, ^{55} Fe



Single UV photons

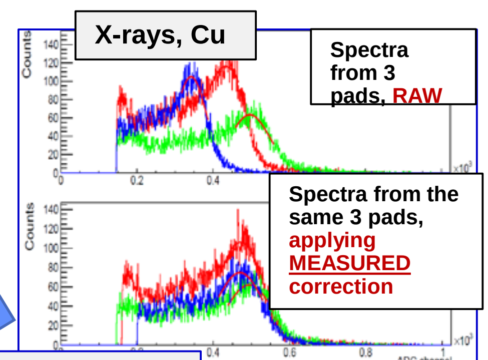


X-rays, ^{55} Fe



UNDERSTOOD: Parasitic C in PCB

X-rays, Cu



Next steps:

- Prototype, version2
- Operation in CF4
- THGEM vs GEM as photocathode substrate

F. Tessarotto, RICH2018

ABOUT GASES

- C_4F_{10} (n = 1.0015, θ_max: 55 mrad)
  - π threshold : 2.5 GeV/c
  - K threshold : 9.0 GeV/c
  - n_det.ph.s (β=1) / 1m : ~ 30 (visible range, from LHCb)
    : ~ 5 (CsI + quartz range, from COMPASS)
  - To exploit PID up to 50-60 GeV/c : σ_C_ph < 1.5 mrad (vis. range)

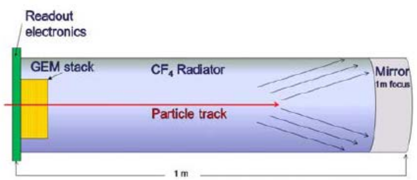
- CF_4 (n = 1.0005, θ_max: 32 mrad)
  - π threshold : 4.4 GeV/c
  - K threshold : 15.6 GeV/c
  - n_det.ph.s (β=1) / 1m : ~ 13 (visible range, from LHCb)
  - n_det.ph.s (β=1) / 1m : ~ 10 (CsI & window-less RICH, λ ~ 120nm) (next slide)
  - to exploit PID up > 60 GeV/c : σ_C_ph < 0.7 mrad

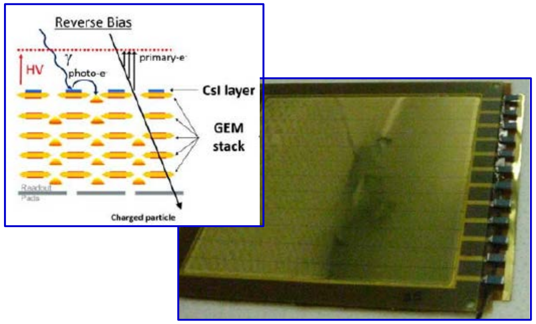
- C_2F_6 (n = 1.0009, θ_max: 42 mrad)
  - Scintillation in the UV region …
  - In general, any intermediate n can be obtained with mixtures: C_4F_{10} & N_2

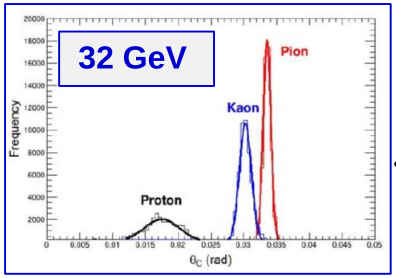
COMPLEMENTARY INFORMATION

CF_4 windowless RICH concept, test-beam results

M. Blatnik et al., IEEE NS 62 (2015) 3256



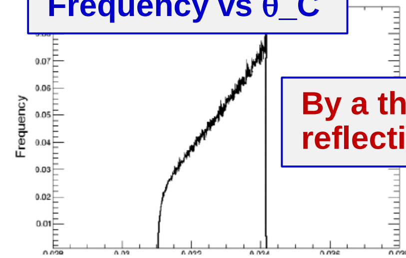




Pad-size ~ 5 mm

n_det_ph.s : 10

Frequency vs θ_C

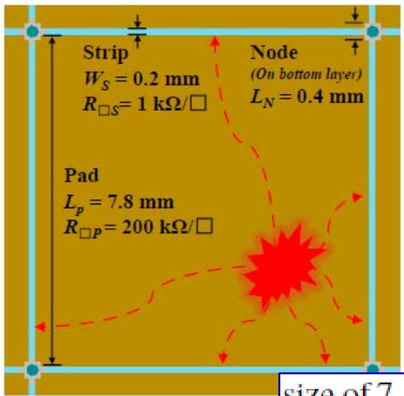


By a thin-film reflecting mirror

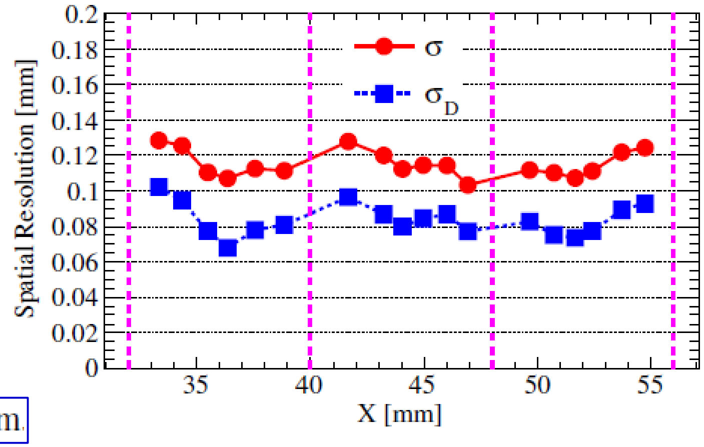
28 38 mrad

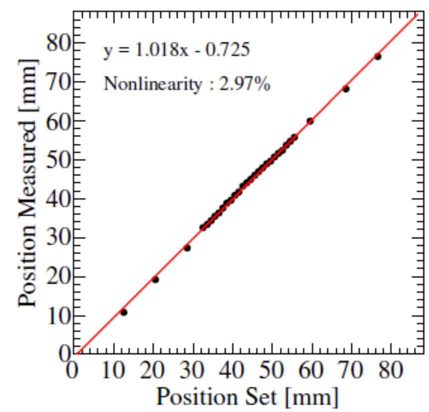
An economic approach towards increased space resolution with pads in gaseous detectors

X. D. Ju et al., JINST 12 (2017) P10008



size of 7.8 mm × 7.8 mm





H-PID @ HIGH MOMENTUM, MY SUMMARY

- Only 2 options for 1 m-long radiator:
  - Gas & visible-range photodetectors
    - LAPPD, if mature
    - SiPM, if mature for Cherenkov imaging applications
    - C_4F_{10} or CF_4 can selected, after careful evaluation of pro's and contra's
  - Gas and windowless architecture with MPGD-based PDs
    - Consolidation by further test-beam studies
    - Mass production of demanding mirrors can be afforded ?
      - Effort at SBU for large-scale production of thin-film mirrors
    - Only CF_4 can be selected
  - IMPORTANT: there is not yet a fully mature model
- Increased space resolution of the PDs is a MUST for 1 m-long radiator

Ongoing R&D for h-PID @ EIC

- several already discussed
- MC studies are not included

A LIST

Ongoing

- mRICH with aerogel and SiPMs, *already discussed*
- EIC DIRC, *already discussed*
- Fast read-out electronics for pixelized detectors, *necessary complement of the EIC DIRC development*
- LAPPD studies, *already discussed*
- Further developments of MPGD-based PDs , *already discussed*
- Improved MRPCs
- PDs in high-B

New from 2019

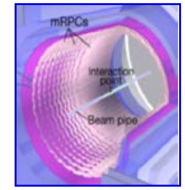
- dRICH prototype with SiPM read-out (following long-going MC activities)

Blue skies R&D *(next slide)*

- Meta-Materials for Detection of Cherenkov Radiation (NEW)
- Hydrogenated NanoDiamond (H-ND) photocathodes for gaseous PDs

eRD14, July 2018 report

MRPCs with more and thinner glass layers for TOF



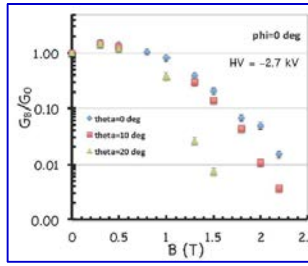
intrinsic time resolution:

- demonstrated: 24 ps
- aiming at 5-10 ps

eRD14, July 2018 report

MCP-PMTs tested in high-B

Role of the pore size



Infrastructure for the evaluation of time resolution in high-B now available

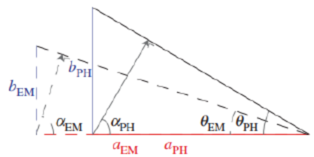
- Longitudinal and transverse B effects to be accessed:

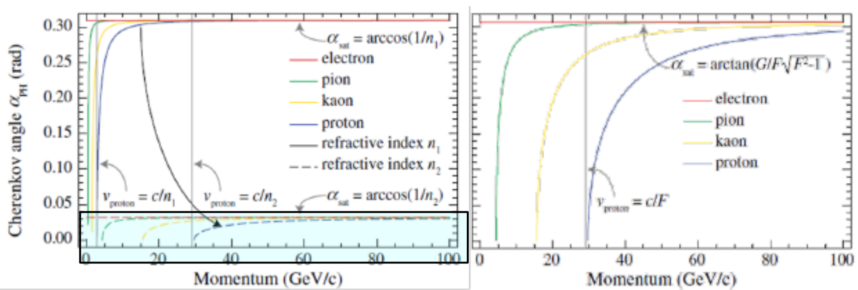
characteristics with $(B, \theta, \varphi, \text{HV})$.

BLUE SKIES R&D

Meta-Materials for Detection of Cherenkov Radiation

Man-made optical material with programmed anisotropy: modify the Cherenkov angle





CF4

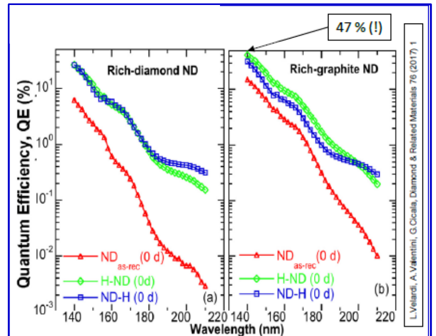
META - CF4

Feasibility in 2-D and 3 -D ?

IF YES → RICH prototype

Hydrogenated NanoDiamond (H-ND) photocathodes for gaseous PDs

Starting point



NEW :

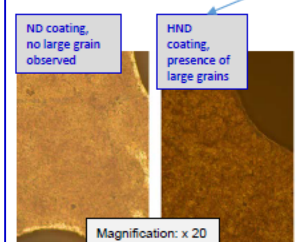
Photocathodes: diamon film obtained with Spray Technique making use of NC powder

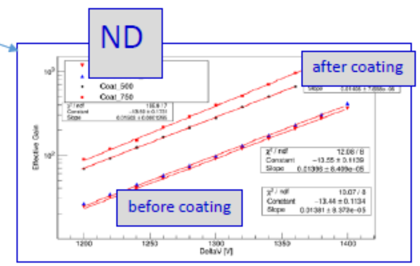
- *Spray technique: T ~ 120˚C (instead of >800° as in standard techniques)*

S. Dalla Torre

Preliminary exercises

- 6 small-size THGEMs (30 x 30 mm^2) fully characterized before and after coating with ND powder & Hydrogenated ND (HND) powder:
- ND : systematically higher gain
- HND : systematically lower breakdown
  HV, morphology ?





h-PID ongoing R&D for EIC, MY SUMMARY

- An overall good panorama to provide input for choices
  - Important also to form a community to elaborate choices as soon as the EIC context is mature
- A relevant open question
  - The use of SiPM in RICHes
    - a very long way to go to understood if SiPM are real options for RICHes
- My favorite R&D activities (addressing the most crucial points):
  - EIC DIRC
    - Ultimate performance of the DIRC concept
  - LAPPD
    - Relevant for DIRC, TOP, high-p RICH … (almost for everything !)
  - Going further with MPGD PDs
    - it supports one of the two only options for hPID @ high-p
- The blue skies R&D, not to be abandoned:
    - It is not obvious that they will converge or that they will be on time for EIC
    - Nevertheless a relevant novel project (EIC) must have space also for a bit of dream and you never know …

THANK YOU !