PANDA end-cap Cherenkov counter -a review attempt-

B. Seitz, University of Glasgow
Matthias Hoek, University of Glasgow
Klaus Föhl, University of Edinburgh

UNIVERSITY of GLASGOW

The task

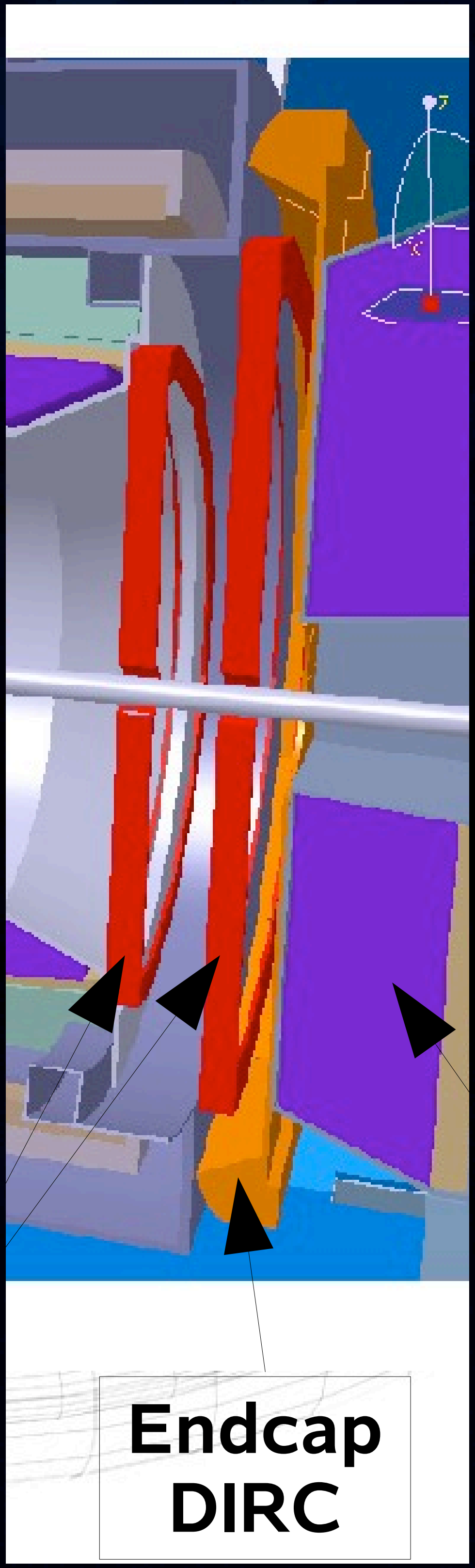
- PANDA is a fixed target experiment with a maximum energy of $\sqrt{s}$ = 5.5 GeV/c^2
- It aims, e.g. precision measurements of charmed mesons
- This defines the benchmark channels
- π/K/p separation is mandatory to achieve physics aims
- end-cap region has to cover 5(10) < θ < 25 deg
- momentum regions to be defined by physics programme

Cherenkov schemes

- DIRC
  - light transport by internal reflection
  - needs high quality surfaces
  - optical elements to enhance image
  - read-out outwith detector volume
  - 2D or (1+1)D reconstruction
- Proximity Imaging
  - No complicated optics
  - resolution depends on the ratio of radiator thickness and detection plane
  - read-out usually in the radiation field
  - 2D reconstruction
- Threshold Cherenkov

Possible locations

- default position:
  z = 1980mm in between the cryostat and the end-cap EMC
- length allowed by TB meeting in Feb '07:
  98mm incl. housing
- alternative position:
  z = 1800 - 1950mm inside the cryostat
- allows for more compact magnet design



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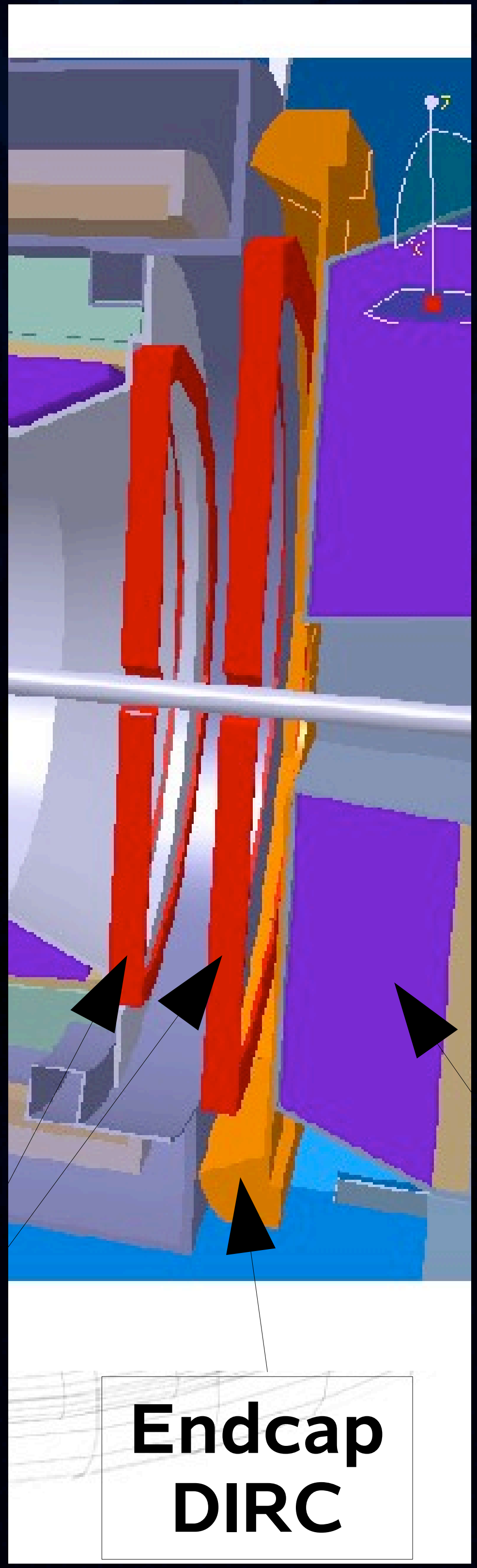
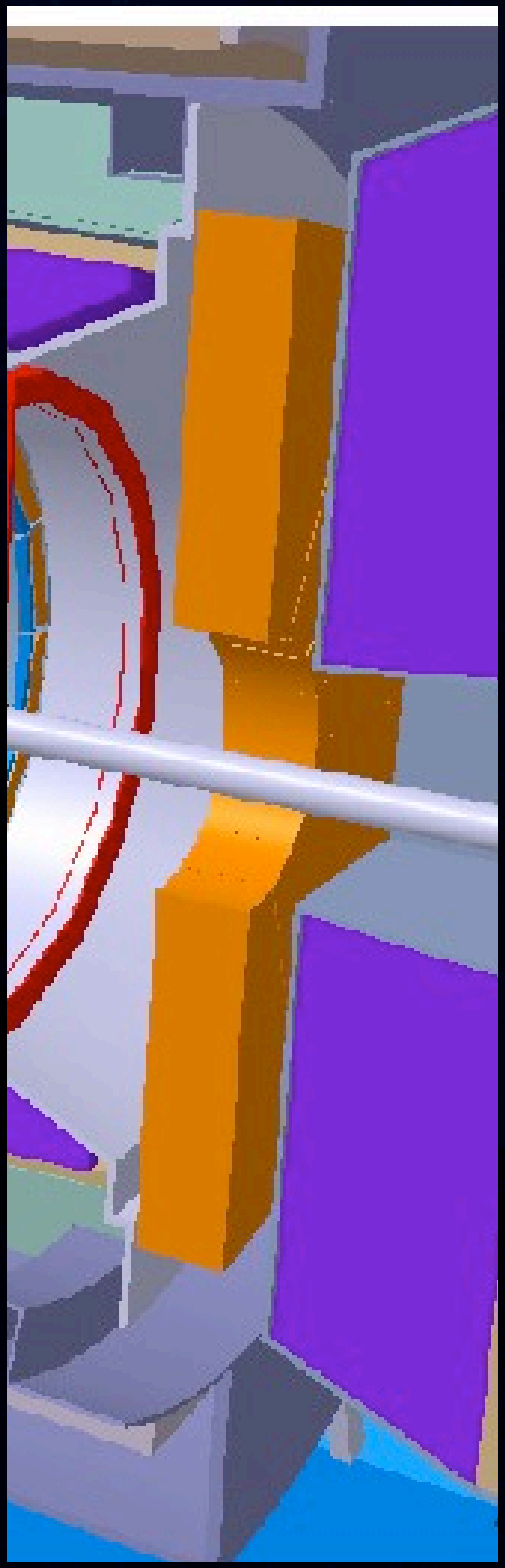




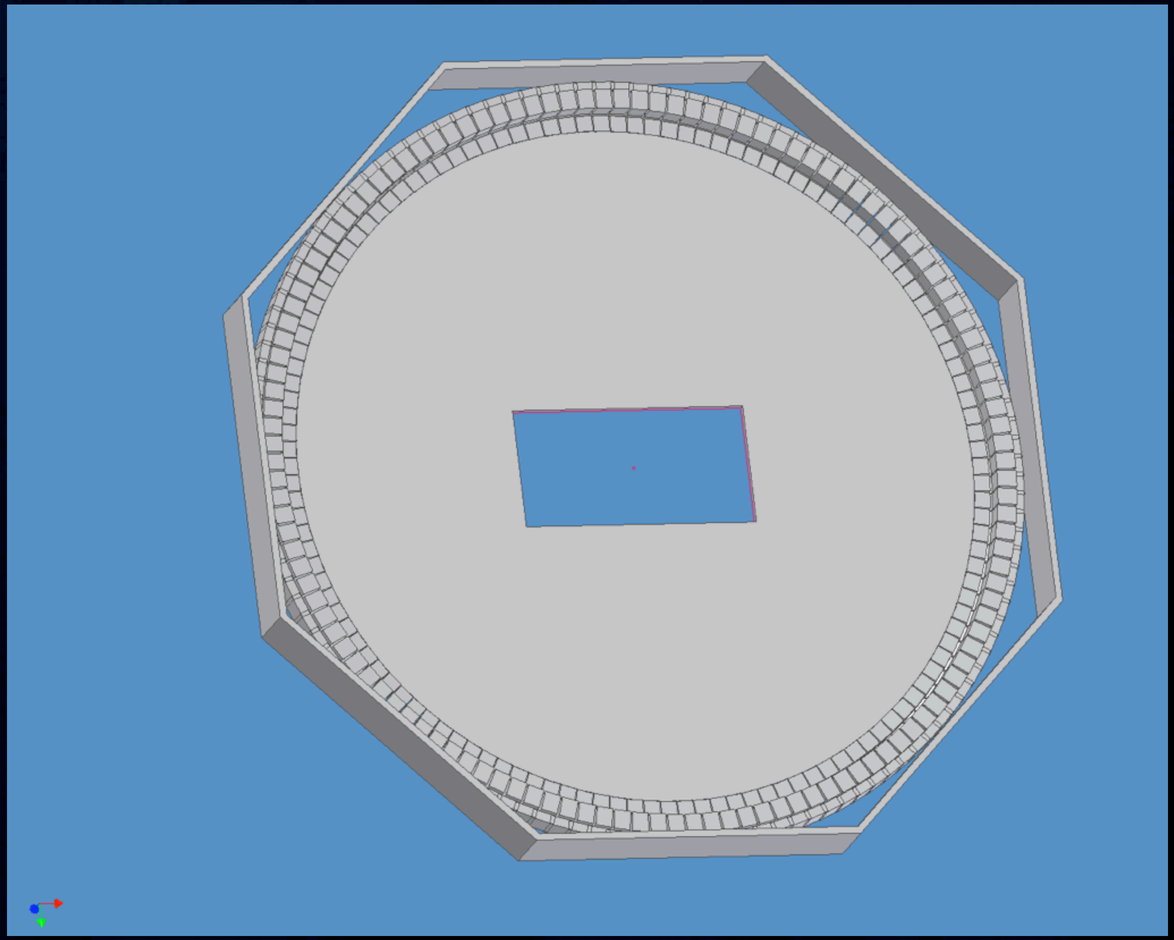
Cherenkov options

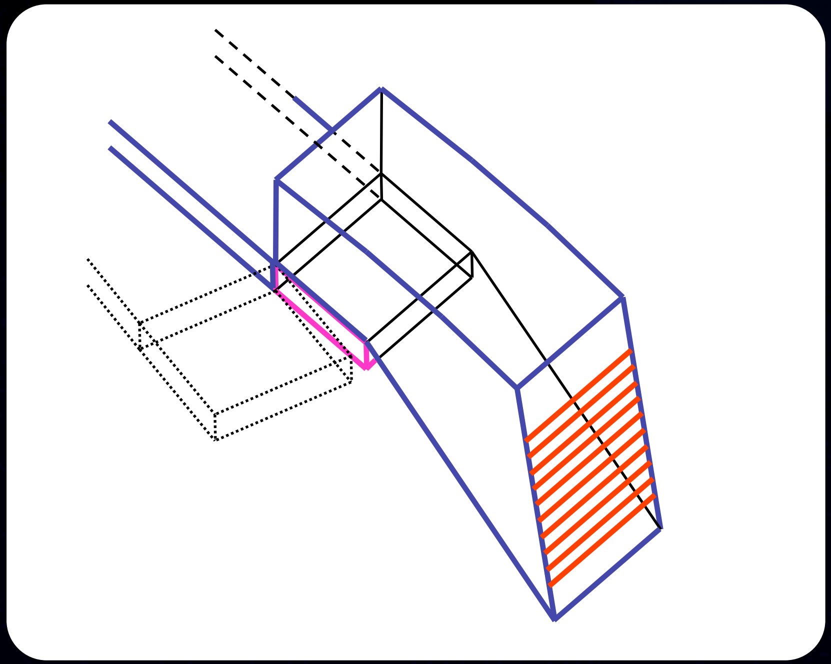
- Focussing disc DIRC option (Edinburgh/Glasgow design)
- Time-of-Propagation disc DIRC (Giessen design)
- Proximity imaging RICH counters
  - liquid radiator (ALICE HMPID)
  - solid radiator (CLEO RICH)
  - Aerogel (Belle upgrade)
- Staggered Aerogel Threshold counter (KEDR-ASIPH)

Note: all examples need (significant) modifications

Focussing disc DIRC

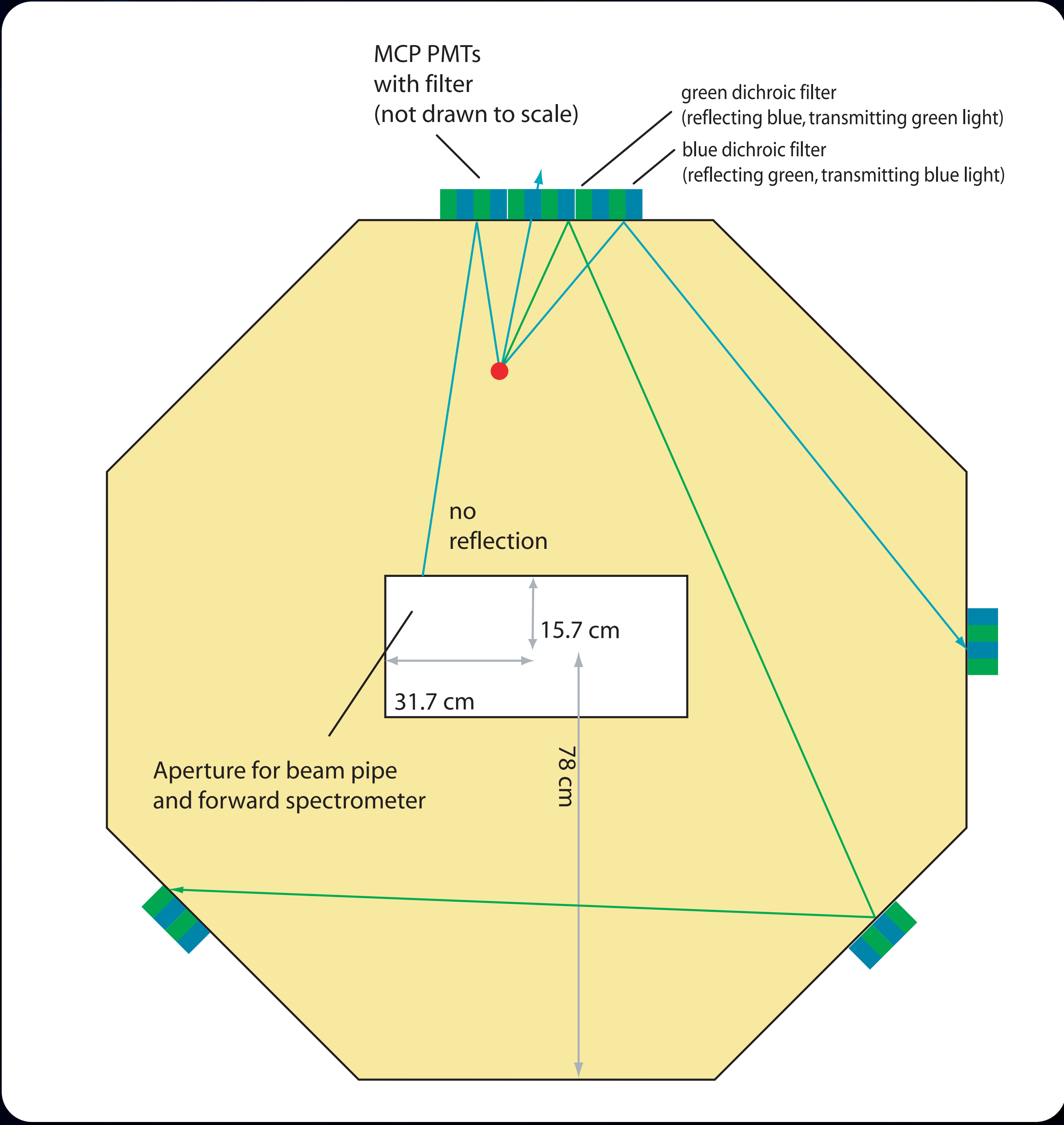
- 20 mm fused silica radiator
- imagining by focussing light guides on focal plane equipped with multi-pixel PMTs
- Cherenkov angle from two spatial co-ordinates, timing for event correlation (2D + t)
- optical dispersion correction
- possible at new location, but slight decrease in performance and mechanically more challenging





Time Of Propagation DIRC

- Cherenkov angle reconstruction by one spatial co-ordinate and ToP measurement (1+1)D
- dispersion correction by wavelength dependent photon detection (dichroic mirrors)
- less read-out channels compared to focussing disc
- needs time resolution < 70 ps
- design for default and new position



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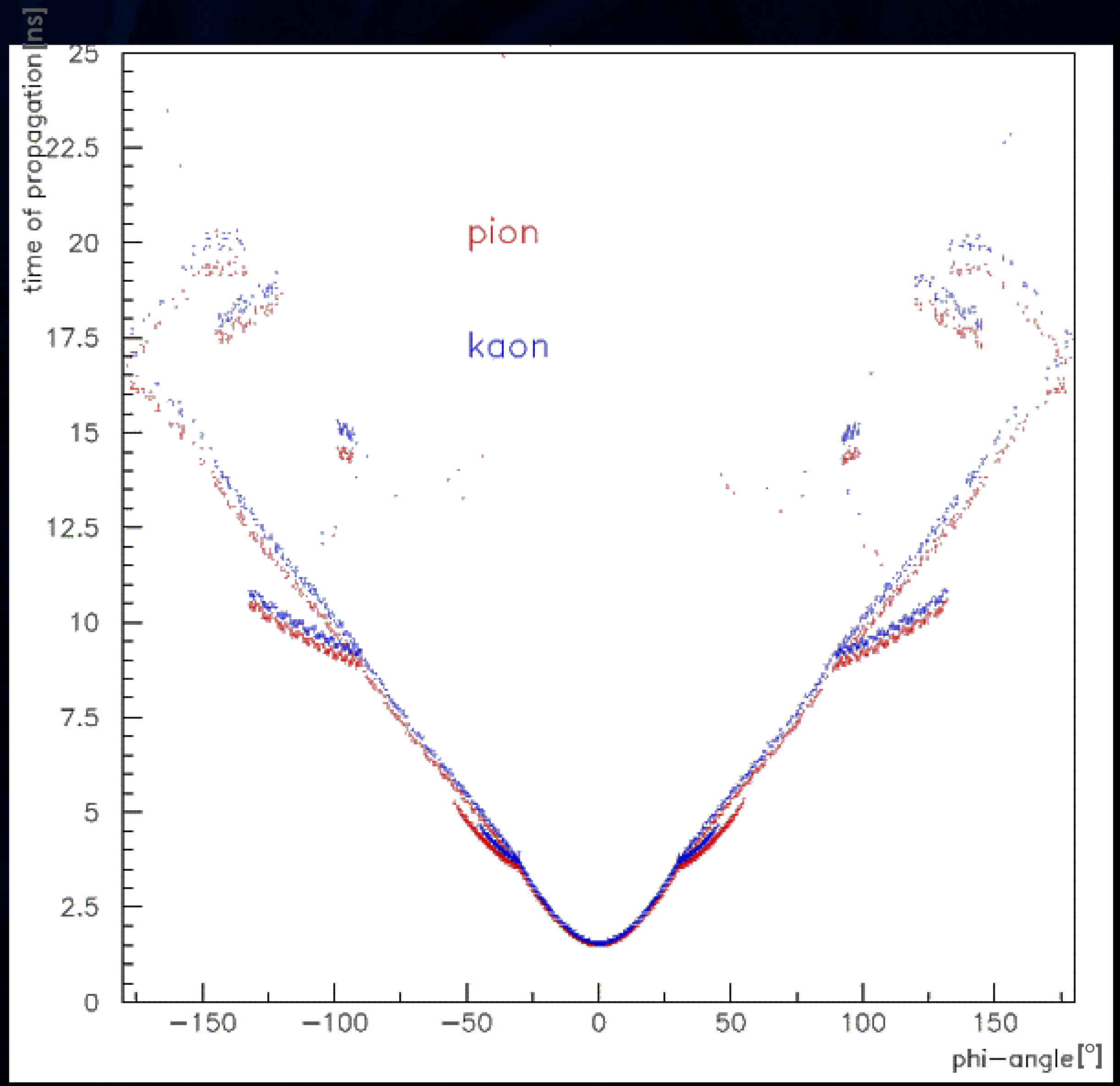
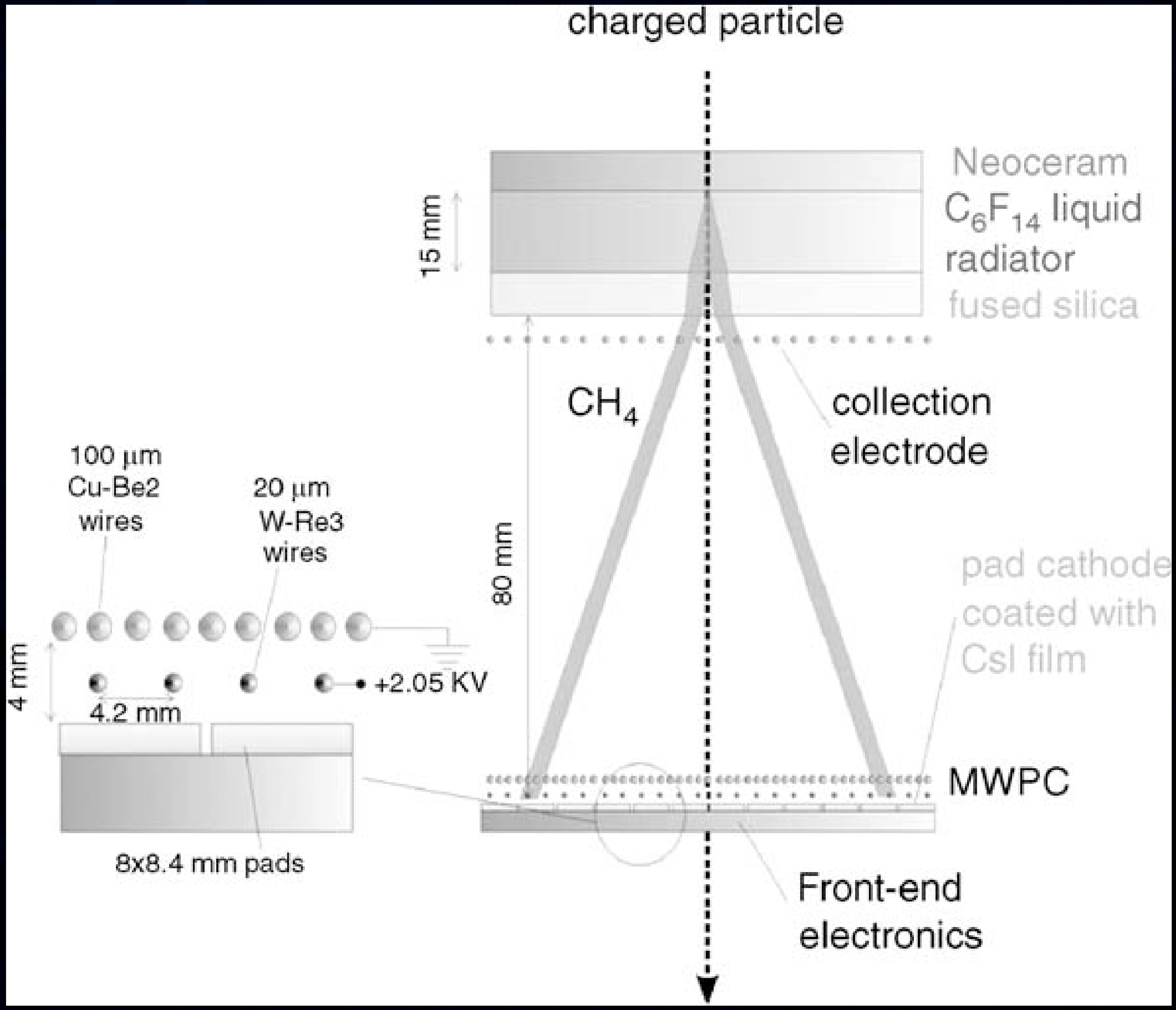


Liquid Radiator Proximity RICH

- Example: ALICE HMPID
- Liquid radiator (C_6F_{14})
- low dispersion
- UV transparent stand-off volume (needs UV transparent gas in vessel)
- CsI photo-cathode (UV light)
- needs purification
- Photon detection by CsI coated GEM (new development for PANDA)
- combine tracker and PID



Note: angles not to scale

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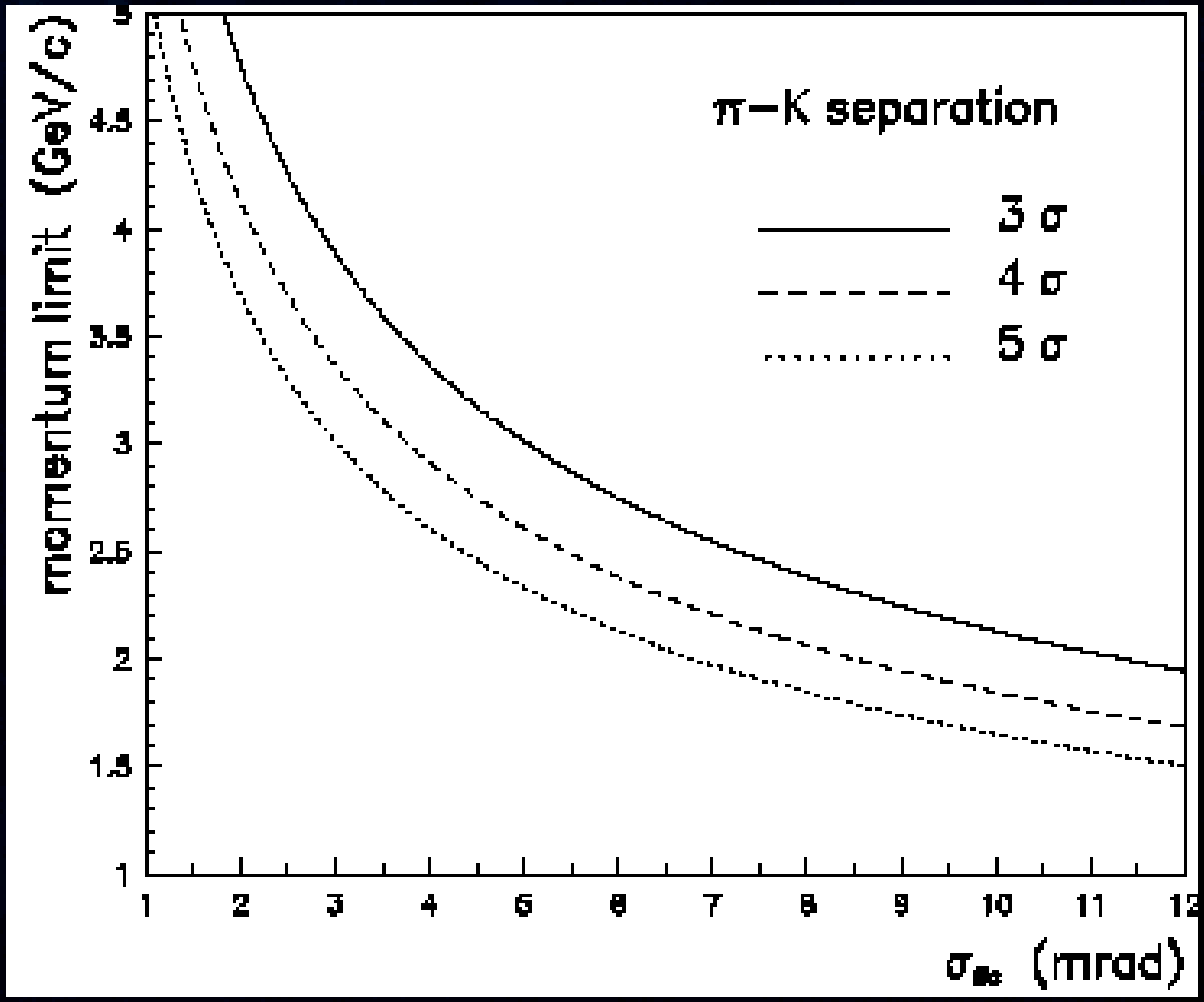

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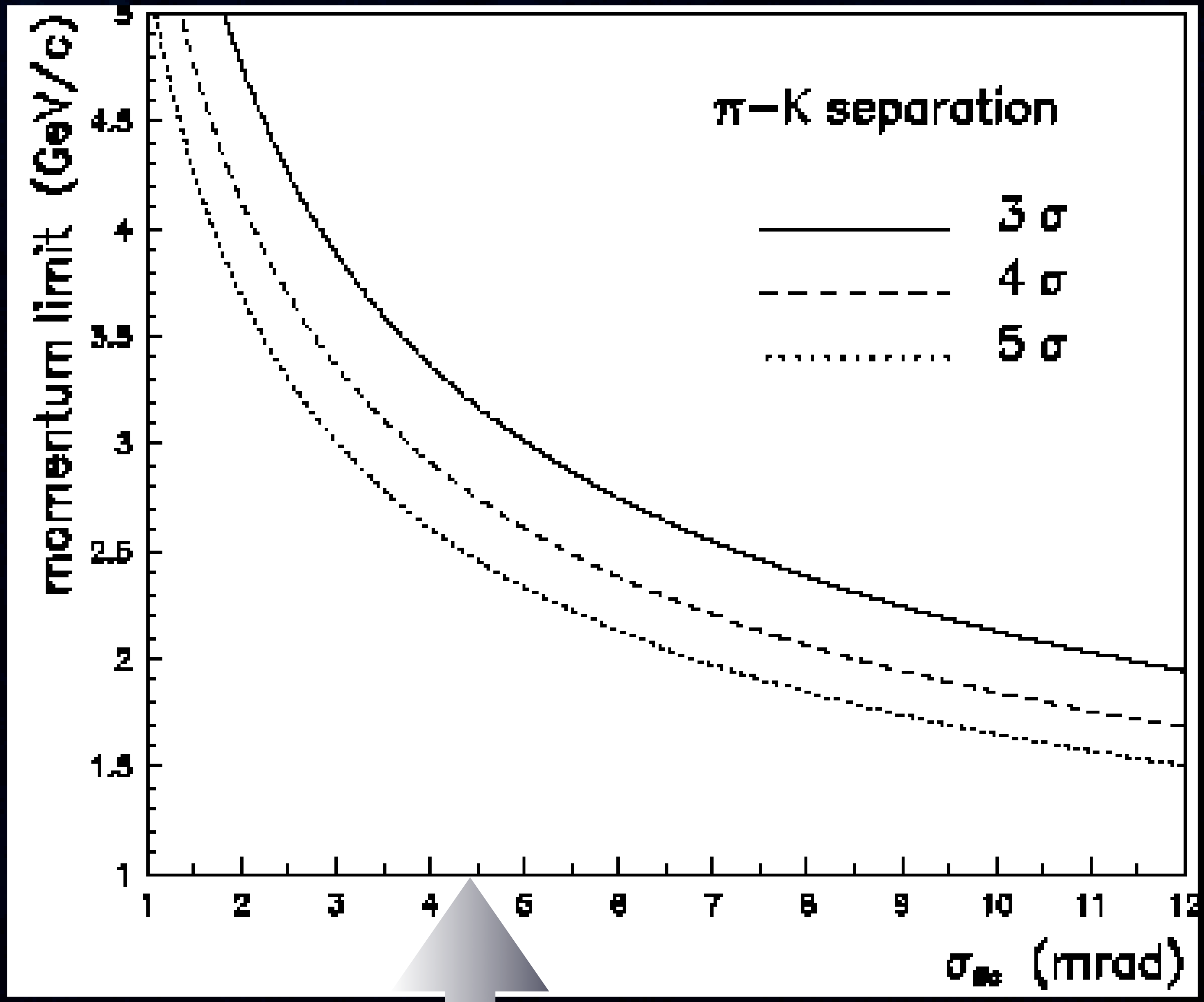

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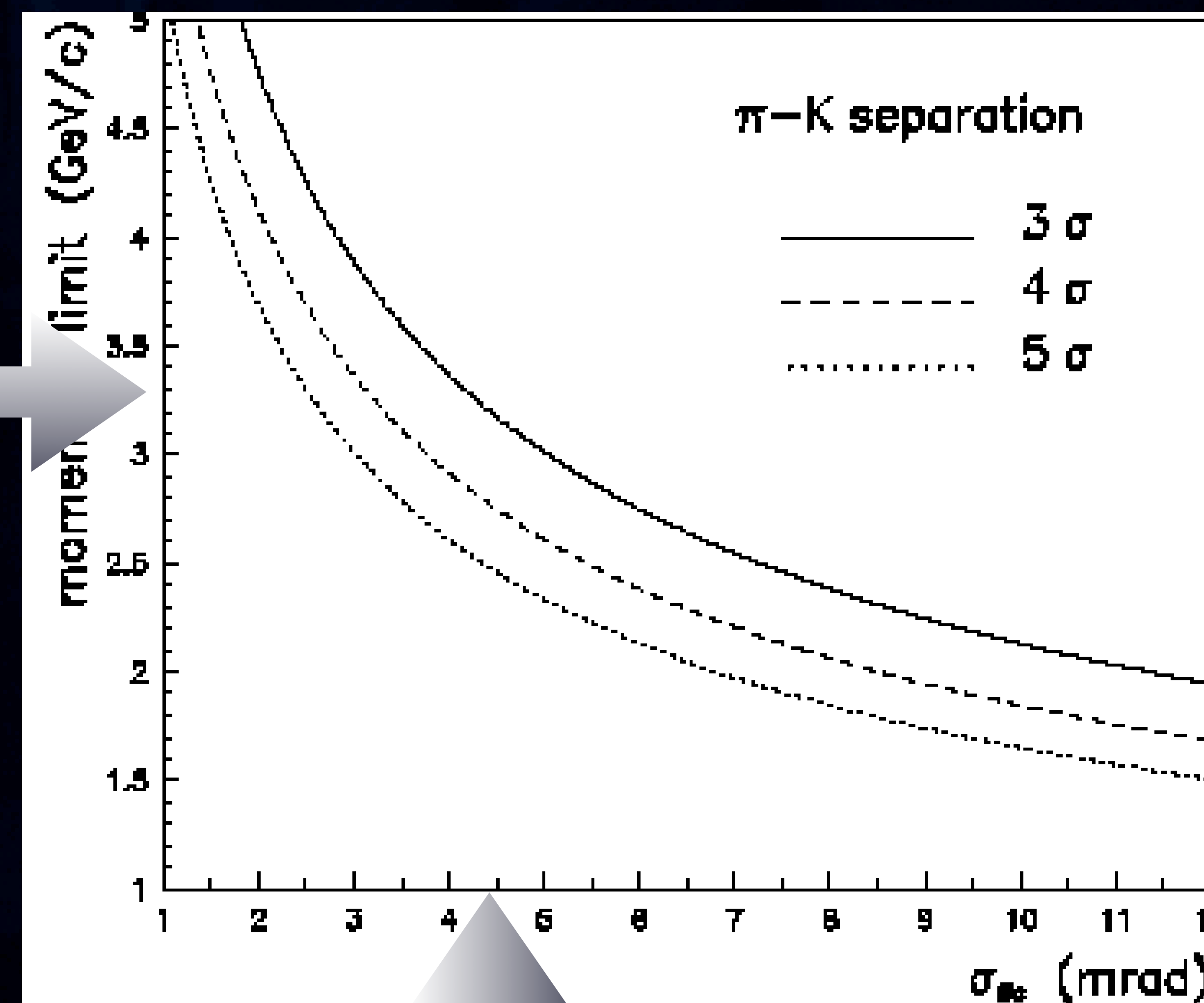

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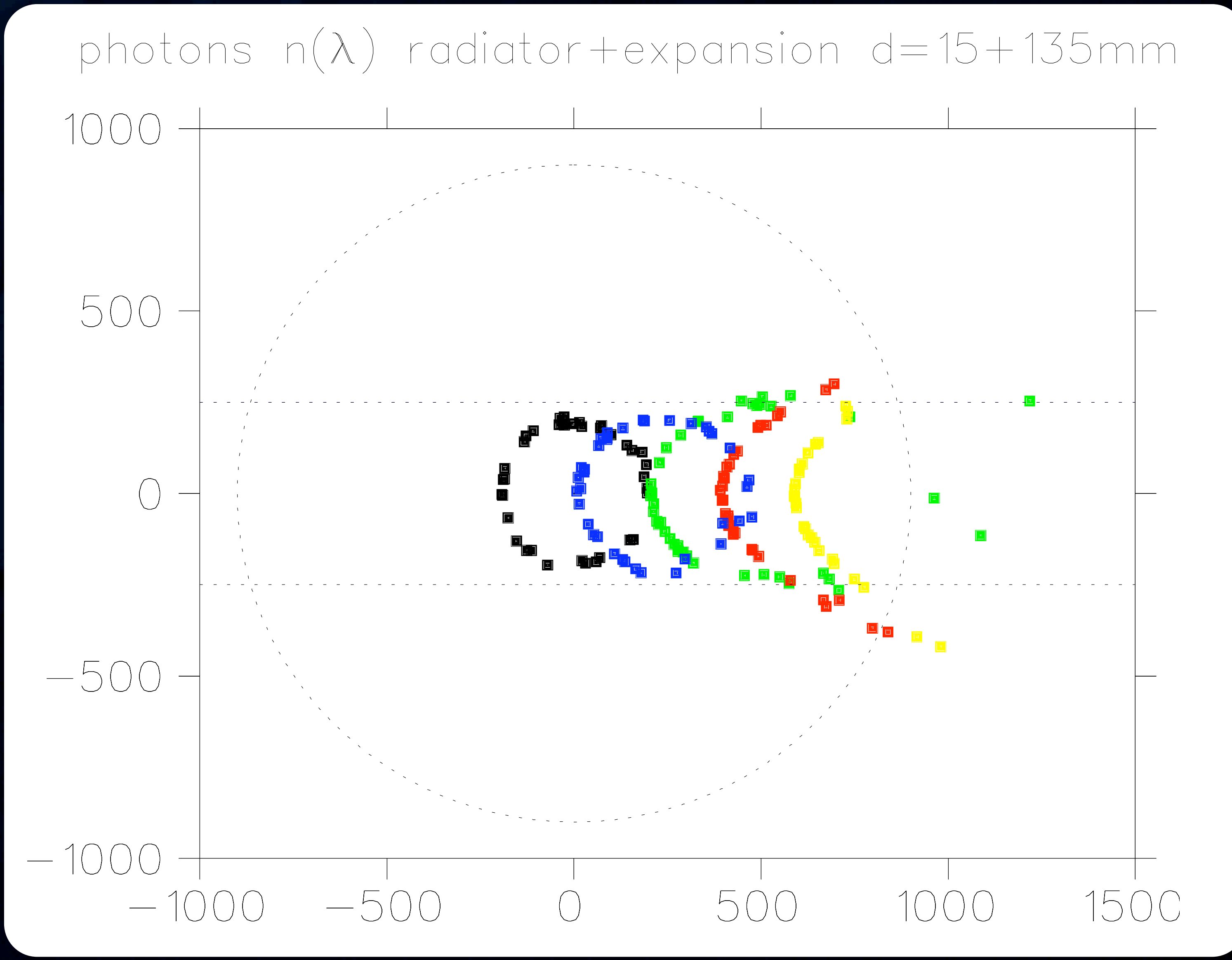
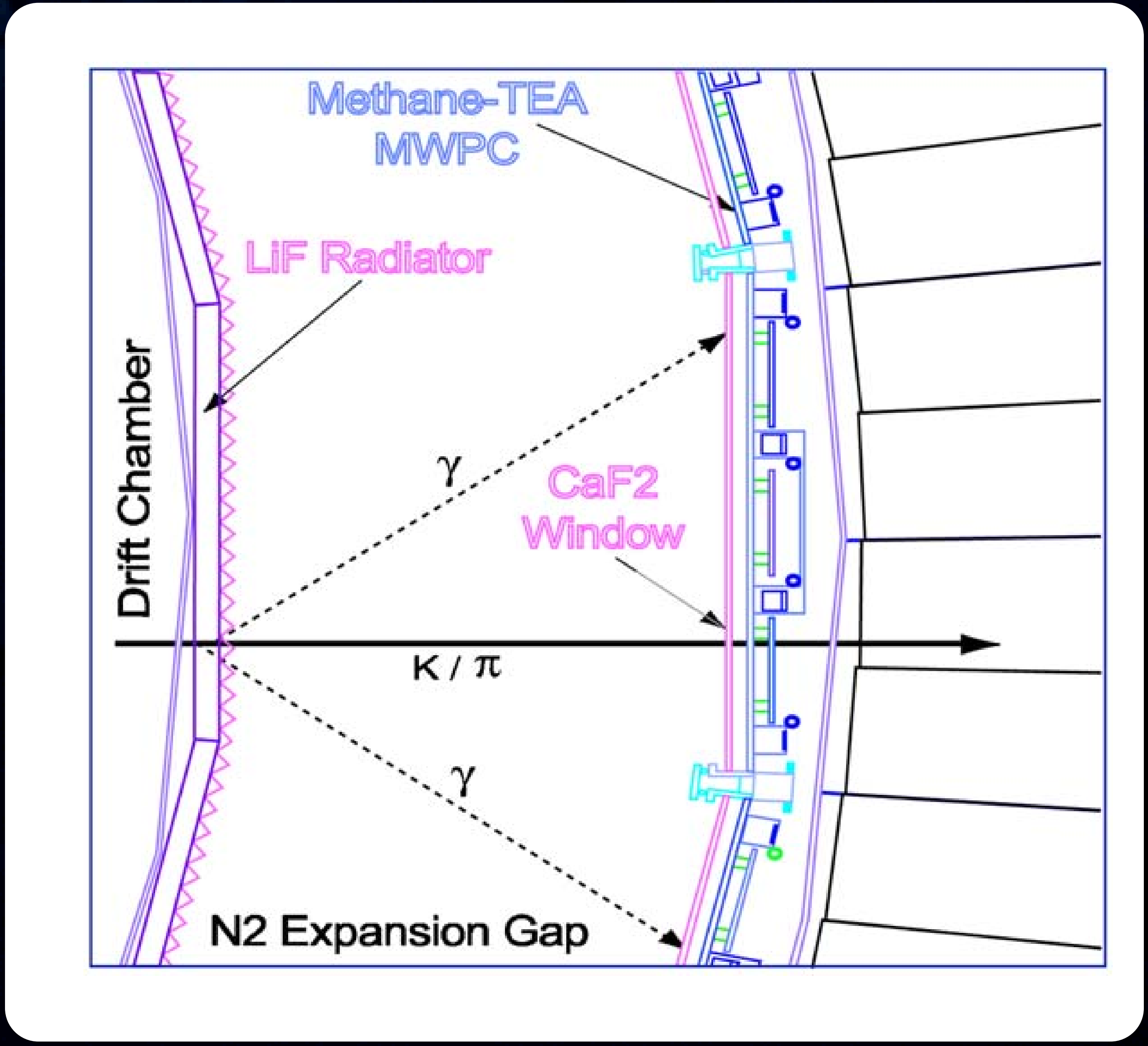


Solid Radiator Proximity RICH

- Example: CLEO-c RICH (uses LiF with CsI read-out)
- saw-tooth shaped fused silica radiator
- no need for purifier
- performance limited by dispersion (slightly worse than LRPI)
- photon detection by CsI coated GEMs
- combine tracker and PID



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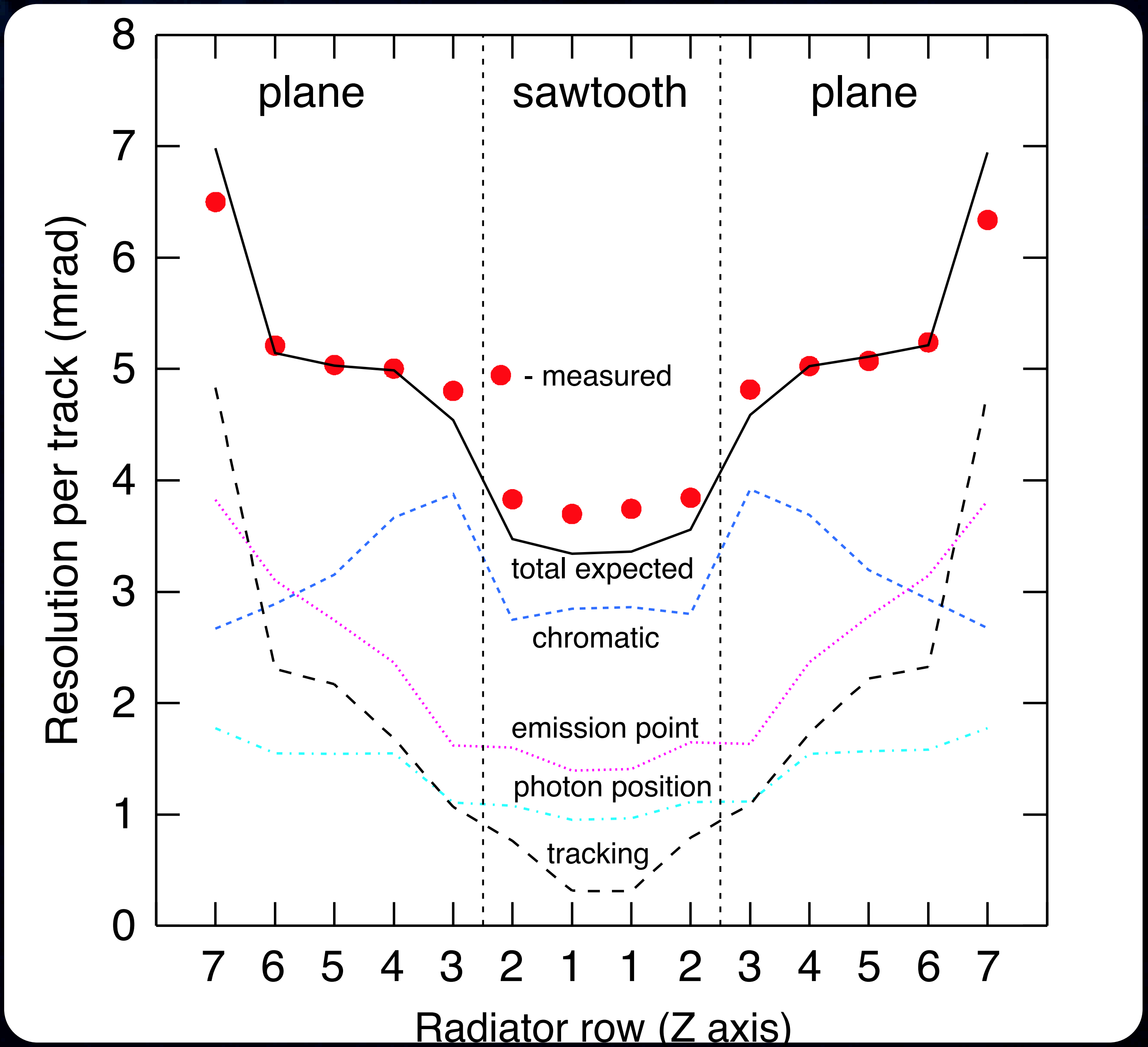
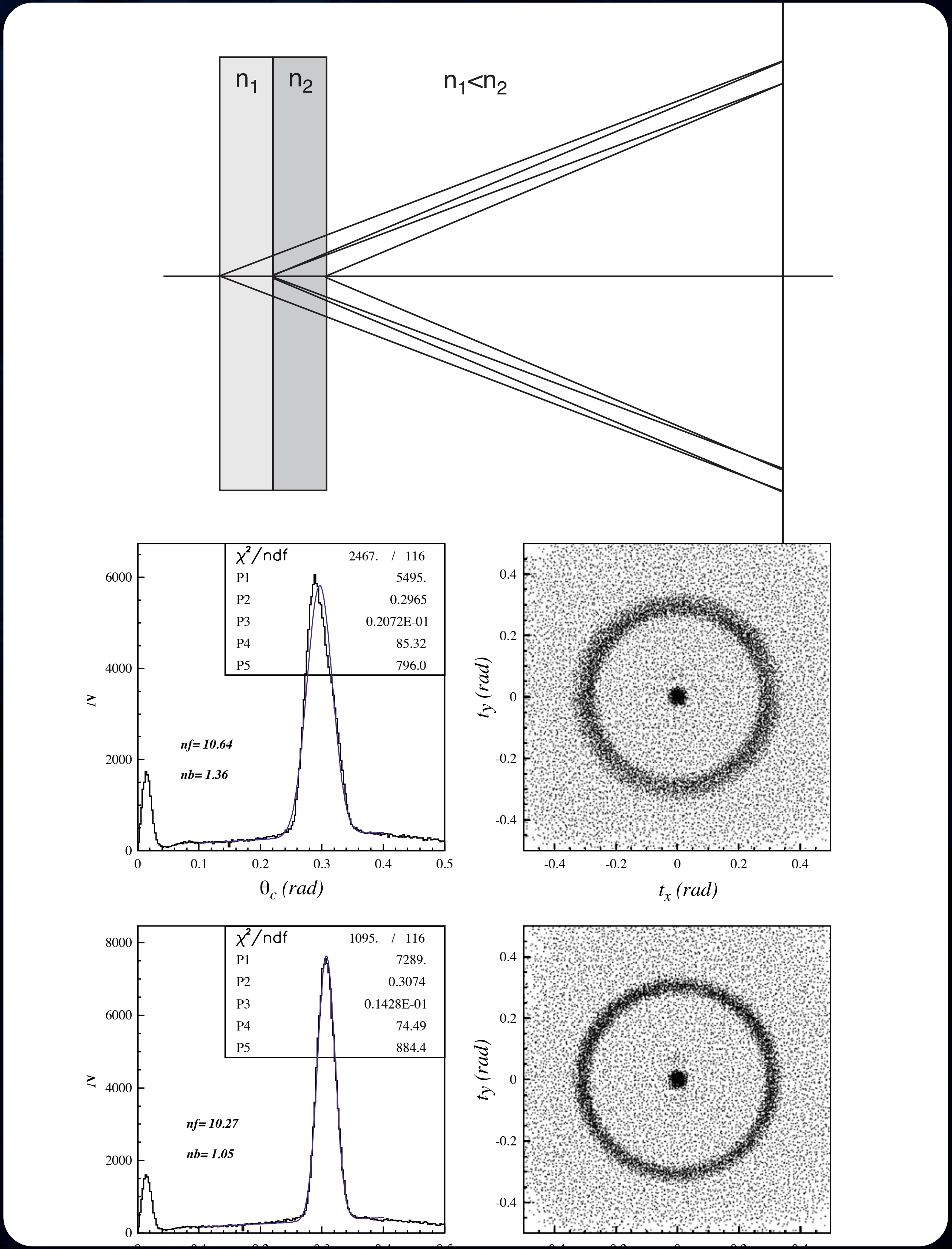


Aerogel proximity RICH (AeroP)

- focussing radiator RICH design tested for Belle endcap upgrade
- FARICH study uses 6 different indices
- Photon detection using MCP-PMT or proximity focussing HAPD
- working in the visible range
- Only limited space point resolution by measuring Cherenkov light produced



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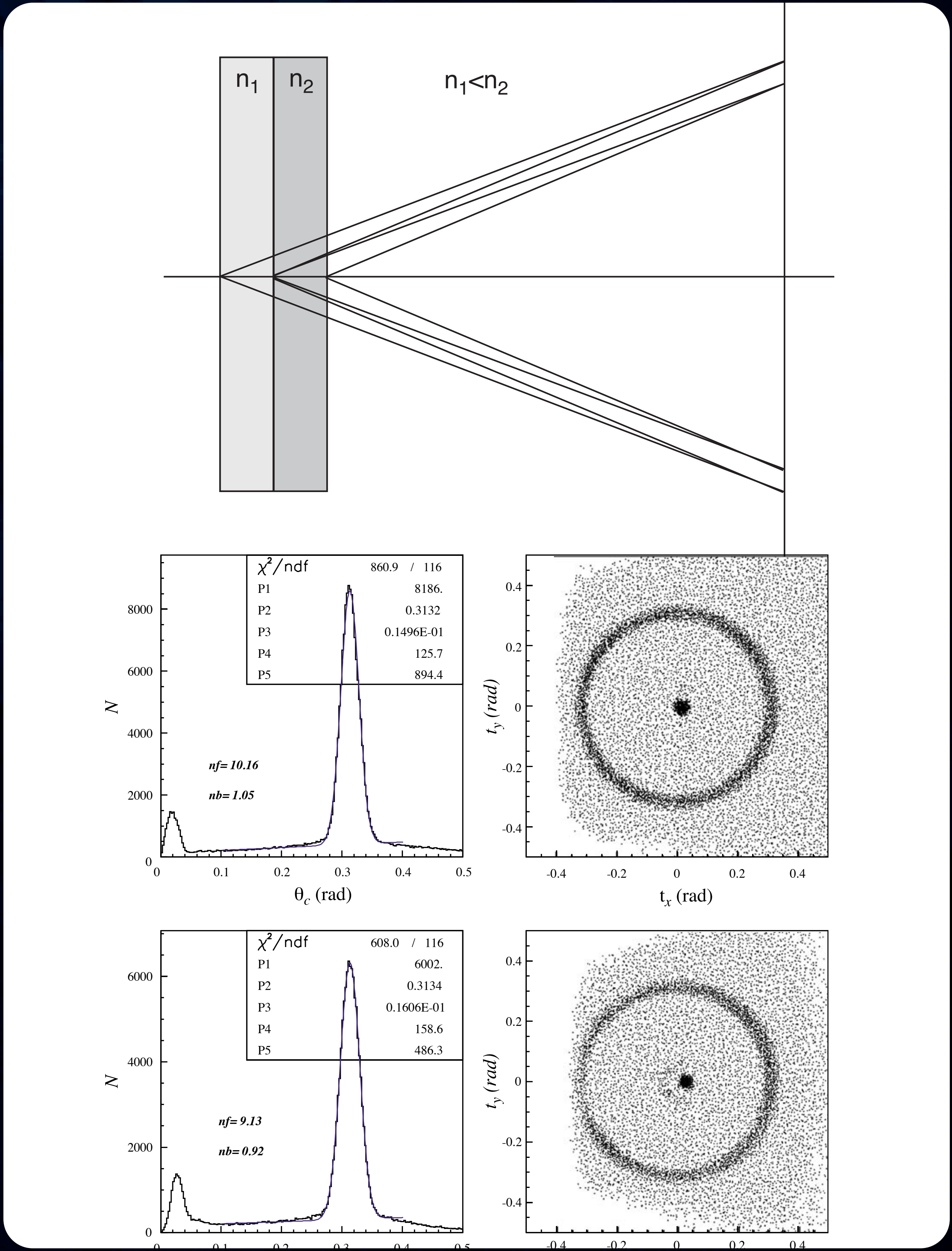


Threshold Cherenkov (AeroT)

- Example KEDR ASIPH
- Use two Aerogel refractive indices for yes/no answer on π/K
- N_{pe} will add to resolution
- might use large area APD for photon detection
- relies on interplay of WLS and PMT

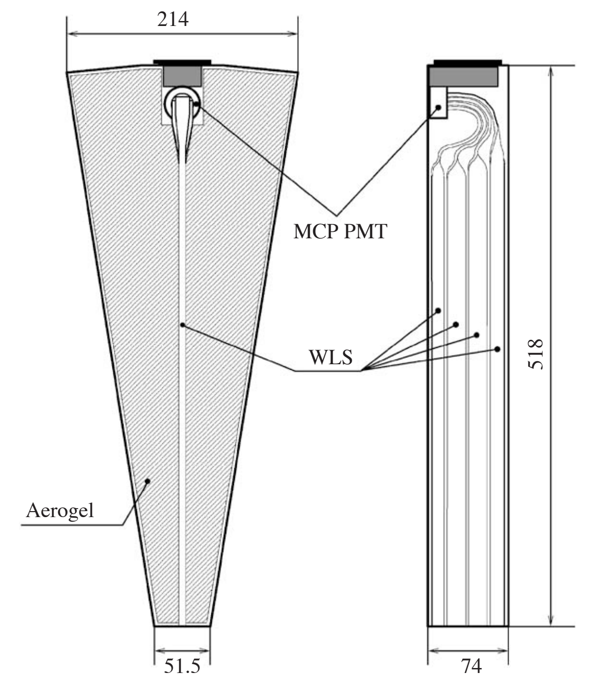


Fig. 2. The endcap ASHIPH counter of the KEDR detector. The sizes are in millimeters.

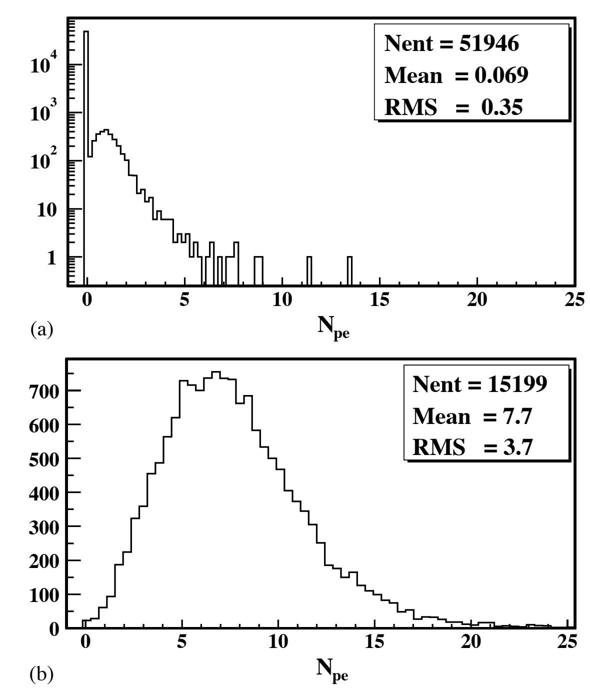


Fig. 5. The amplitude spectra for kaons (a) and pions (b), $p = 0.86$ GeV/c.

A.Y. Barnyakov et al. NIM A 494 (2002) 424

Some thought on costs

- DIRC costs equally given by fused silica prices and read-out
- reliable estimates for PMTs and fused silica
- Several groups actively working and investing in R&D for DIRC counters
- read-out electronics is the biggest uncertainty
- costs for proximity imaging driven by number of read-out channels (might be shared with cost for tracker)
- Development cost for large area CsI GEM ?

Optimising Cherenkov counters

- Performance depends on
  - number of photons
  - figure of merit
  - Cherenkov angle resolution
- Use parametrisations for N_0
- Use weight function for chromatic error
- include multiple scattering and image resolution

$$N = N_0 L Z^2 \sin^2\theta_c$$

$$N_0 = \frac{\alpha}{\hbar c}\int Q(E)T(E)R(E)dE$$

$$\sigma_{\theta_c} = \sqrt{\frac{\sigma_{msc}^2 + \sigma_{chr}^2 + \sigma_{PI}^2}{N}}$$

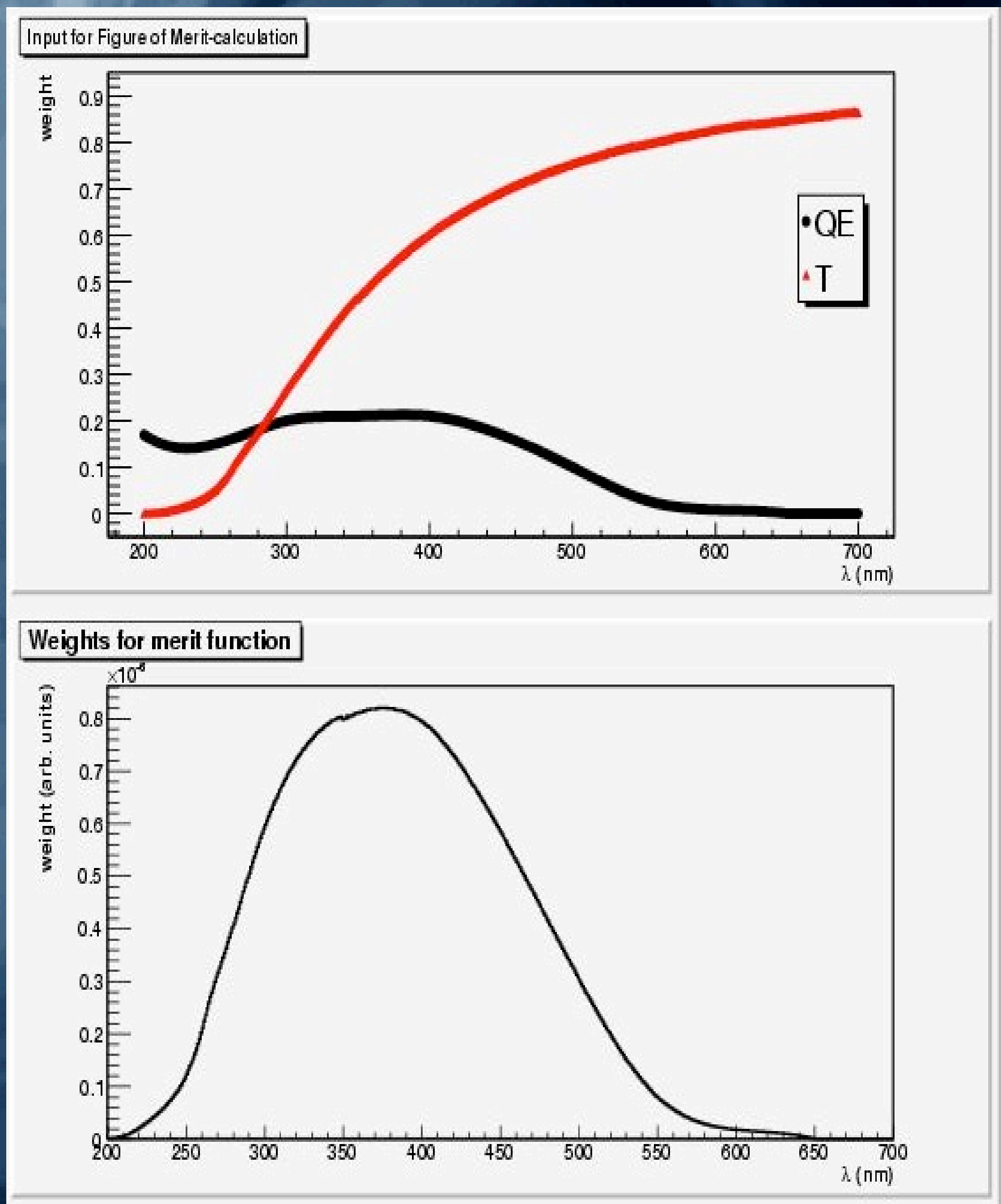
$$\sigma_{\theta_i}^{chr} = \frac{\sigma_n}{\beta n^2 \sin\theta_c} \qquad \sigma_{\theta_i}^{msc} = \frac{\theta_{RMS}}{\sqrt{6}}$$

$$\sigma_{\theta}^{PI} = \frac{L\sin\theta\cos\theta}{\sqrt{12}D}$$

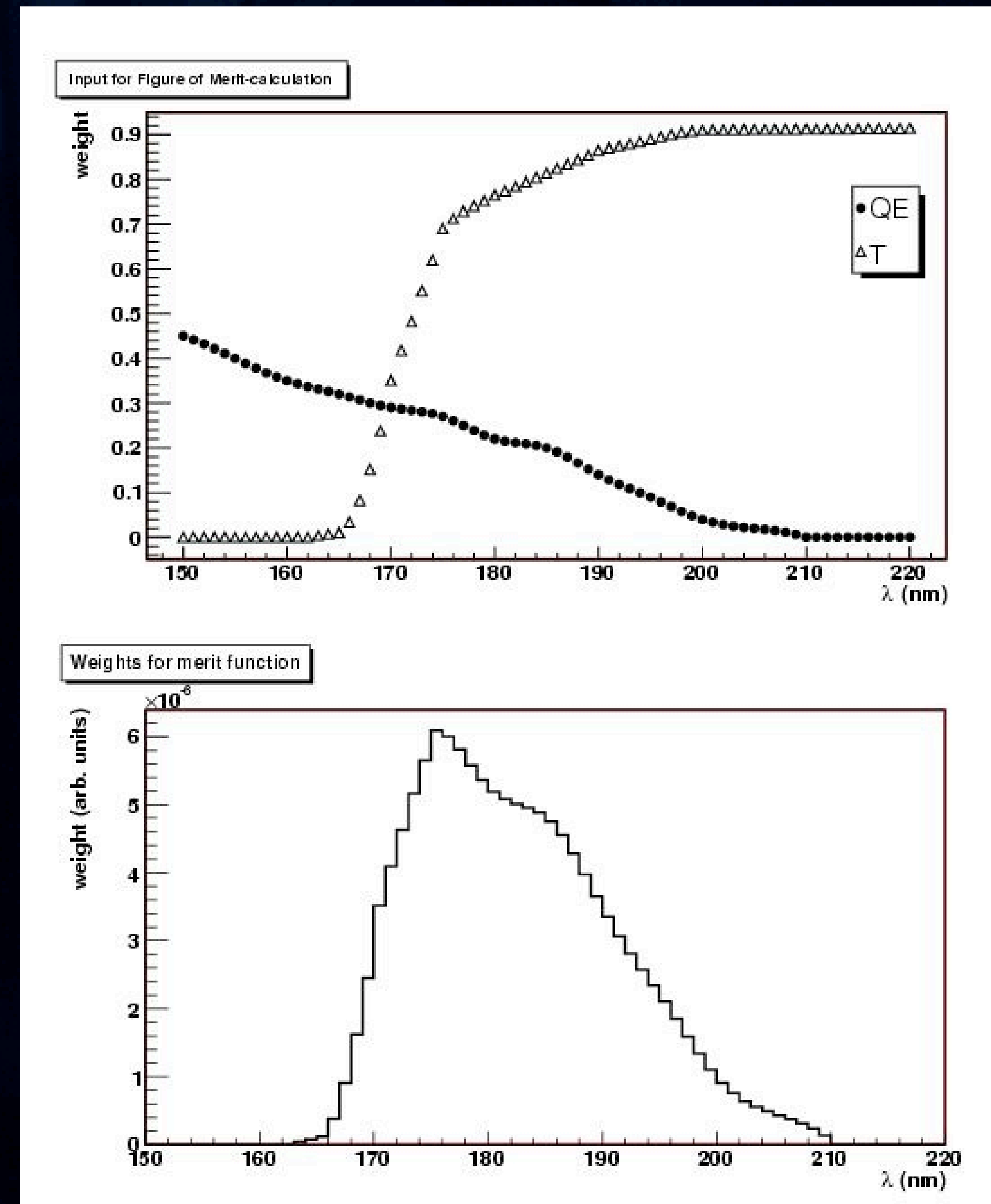
$$p_{max} \approx \sqrt{\frac{\beta\Delta m^2}{2n_\sigma\sigma_\theta}}$$

from NIM A 433 (1999) 17 and NIM A 521 (2004) 367

Calculating N_0



Example: Aerogel radiator and Burle Planacon MCP-PM



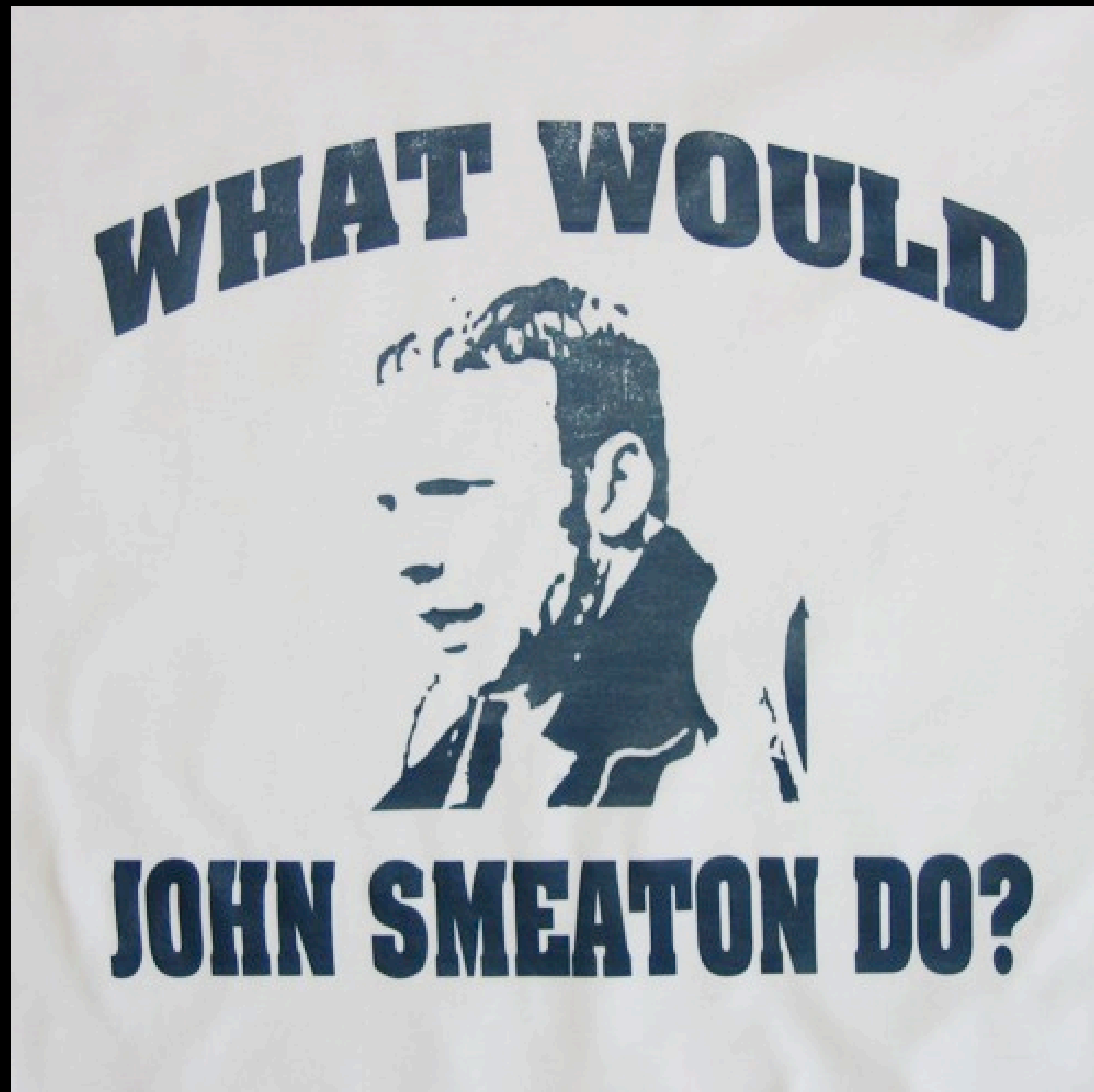
Example: CsI cathode with C_6F_{14} radiator and fused silica window

Performance comparison

	FDD	ToP	LRPI	SRPI	AeroP	AeroT
length	<100 mm	<100 mm	~180mm	~180mm	~250mm	~180mm
Read Out	TDC	TDC	TDC/ADC	TDC/ADC	TDC	TDC/ADC
N_{ch}	~4500	960	>35000	>35000	35000	~1000
P/D	PMT	PMT	CsIGEM	CsIGEM	PMT	PMT
spec	UV/VIS	UV/VIS	VUV	VUV	VIS	VIS
tracking	no	yes/no	yes	yes	no (?)	no
trigger	need track	need track	need track	need track	need track	simple
pattern	2D + t	(1+1)D	2D + t	2D + t	2D + t	1D + t
running	simple	simple	purifier/gas	gas	dry N_2 ?	dry N_2 ?
R&D risc	data rate	rate/ Δt	CsI GEM	CsI GEM	HAPD	WLS

Performance comparison

	FDD	ToP	LRPI	SRPI	AeroP	AeroT
X_0	0.17	0.17	0.20	0.24	0.14	0.03
N_0(1/cm)	125	-	60	57	76	?
N_{pe}	135	70	36	68	18	10
p_{min} (GeV)	0.6 (0.2)	0.6 (0.2)	0.84	0.56	2.75	?
p_{max} (GeV)	6.5	6	3.3	2.8	7.5	?
σ_θ	0.45	-	4.1	3.9	2.7	-
Δt	O(ns)	<70 ps	O(10 ns)	O(10 ns)	O(ns)	O(ns)
acceptance	full	edge	edge	edge	edge	full


WHAT WOULD
JOHN SMEATON DO?

Decision criteria

- Physics performance:
  - Do p_{min} and p_{max} match physics aims ?
    Are there significant limitation for future discoveries ? What physics compromises does the choice imply ?
  - What limitation does a PID choice imply for other detector components (tracking, forward EMC) ? How about acceptance gaps ? Homogenous response ?
- Technological criteria:
  - Can the detector design be accommodated mechanically ?
  - Can the DAQ handle the data rate ?
  - Are we confident to master the R & D risks (give manpower and time constraints) ?
  - Ease of operation and maintenance, handling of substances involved ?
  - Hardware trigger possible ? Resolution of multiple hits ? Background suppression ?
- Other criteria:
  - What know-how is available in the groups involved ? What within PANDA ?
  - Do we find the money for a particular solution ? How about overall cost ? Are we willing to trade investment for running cost ? Can costs be shared with tracker ?
  - What are the timelines for a decision ?