The PANDA Focussing-Lightguide Disc DIRC

Matthias Hoek

University of Glasgow

3rd PANDA Cherenkov Workshop, Giessen (Germany), 11. - 13. May 2009

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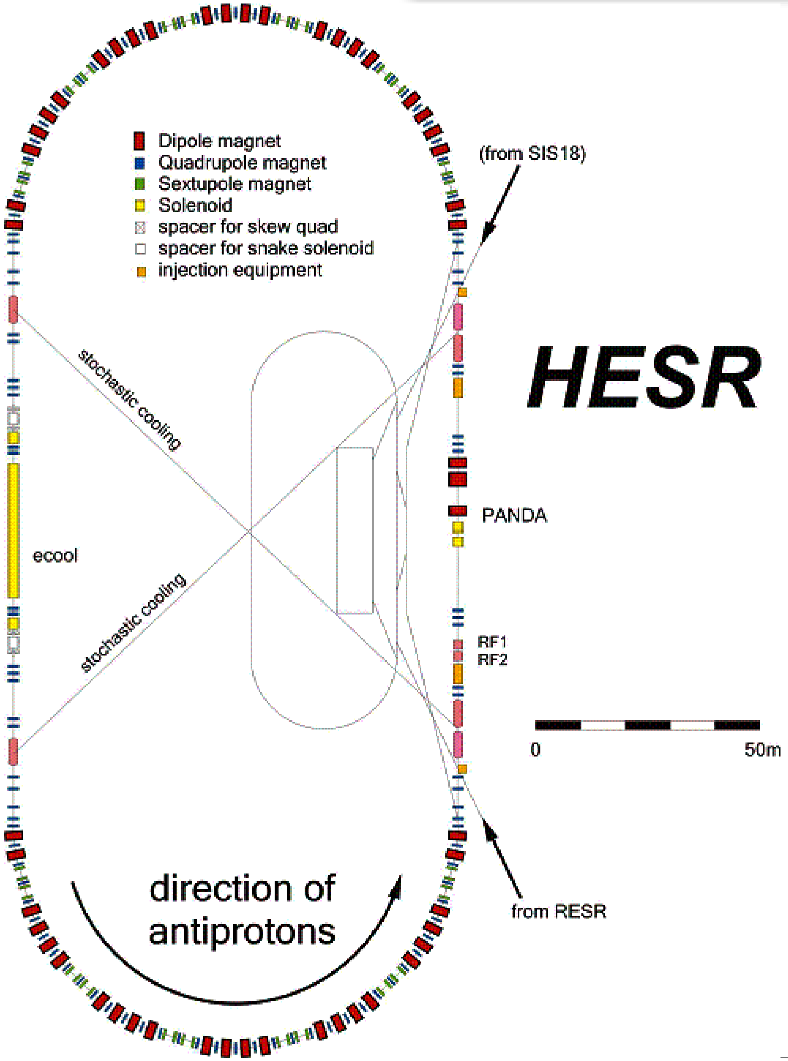
Overview

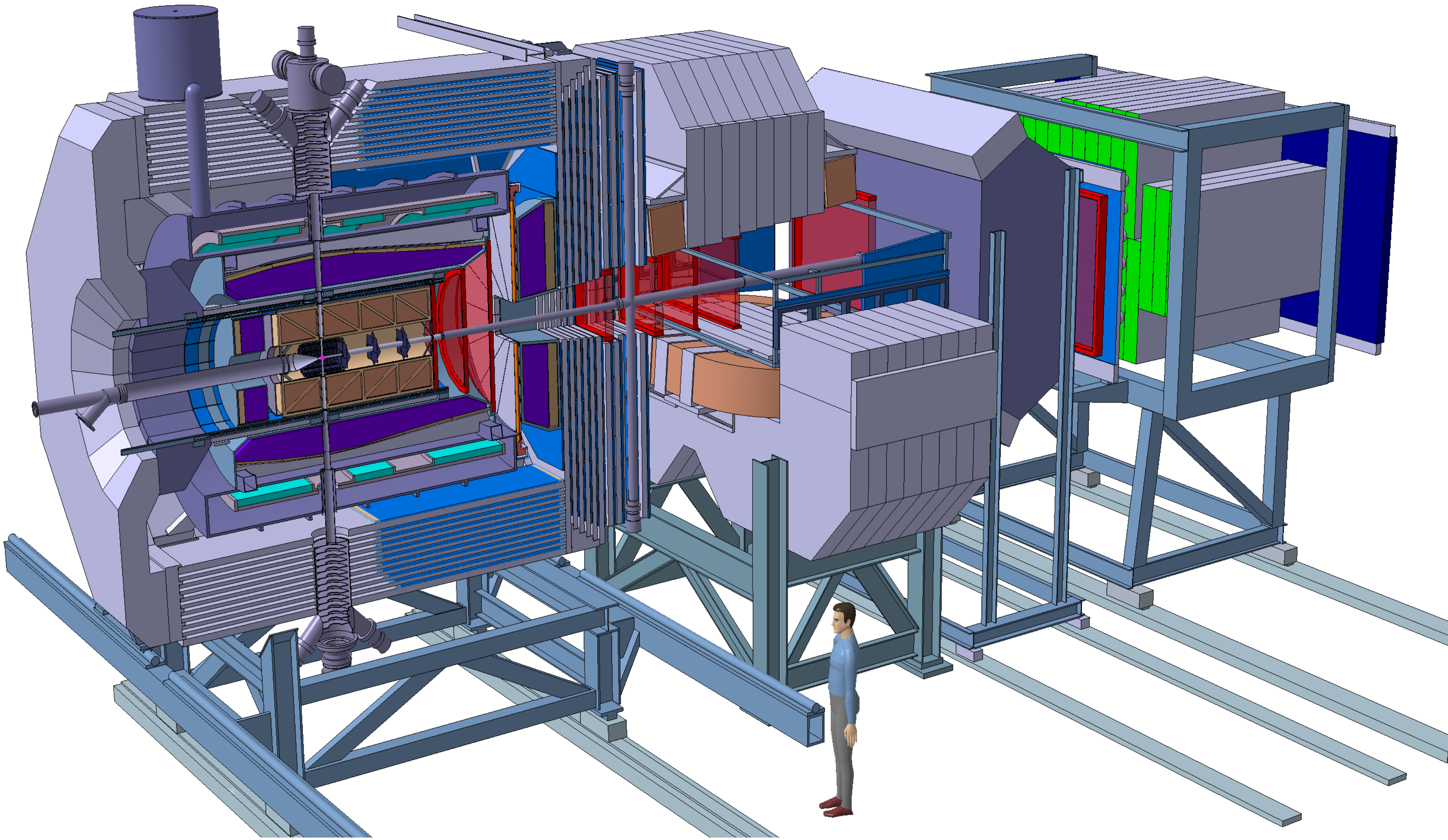
- Introduction
- Physics Requirements
- Detector Design
- Performance Predictions
- Outlook & Conclusions

Introduction – High Energy Storage Ring



- Cooled Antiprotons
- Momentum (Kinetic Energy) range 1.5 to 15 GeV/c (0.83 to 14.1 GeV)
- 10^{10} to 10^{11} particles stored
- Two Operation Modes
  - High Resolution (HR)
    - Luminosity 2×10^{31} $cm^{-2}s^{-1}$ for 10^{10} p
    - RMS momentum spread $< 2\times10^{-5}$
    - 1.5 to 9 GeV/c
  - High luminosity (HL)
    - Luminosity 2×10^{32} $cm^{-2}s^{-1}$ for 10^{11} p
    - RMS momentum spread $< 2\times10^{-4}$
    - 1.5 to 15 GeV/c

Introduction – PANDA Detector



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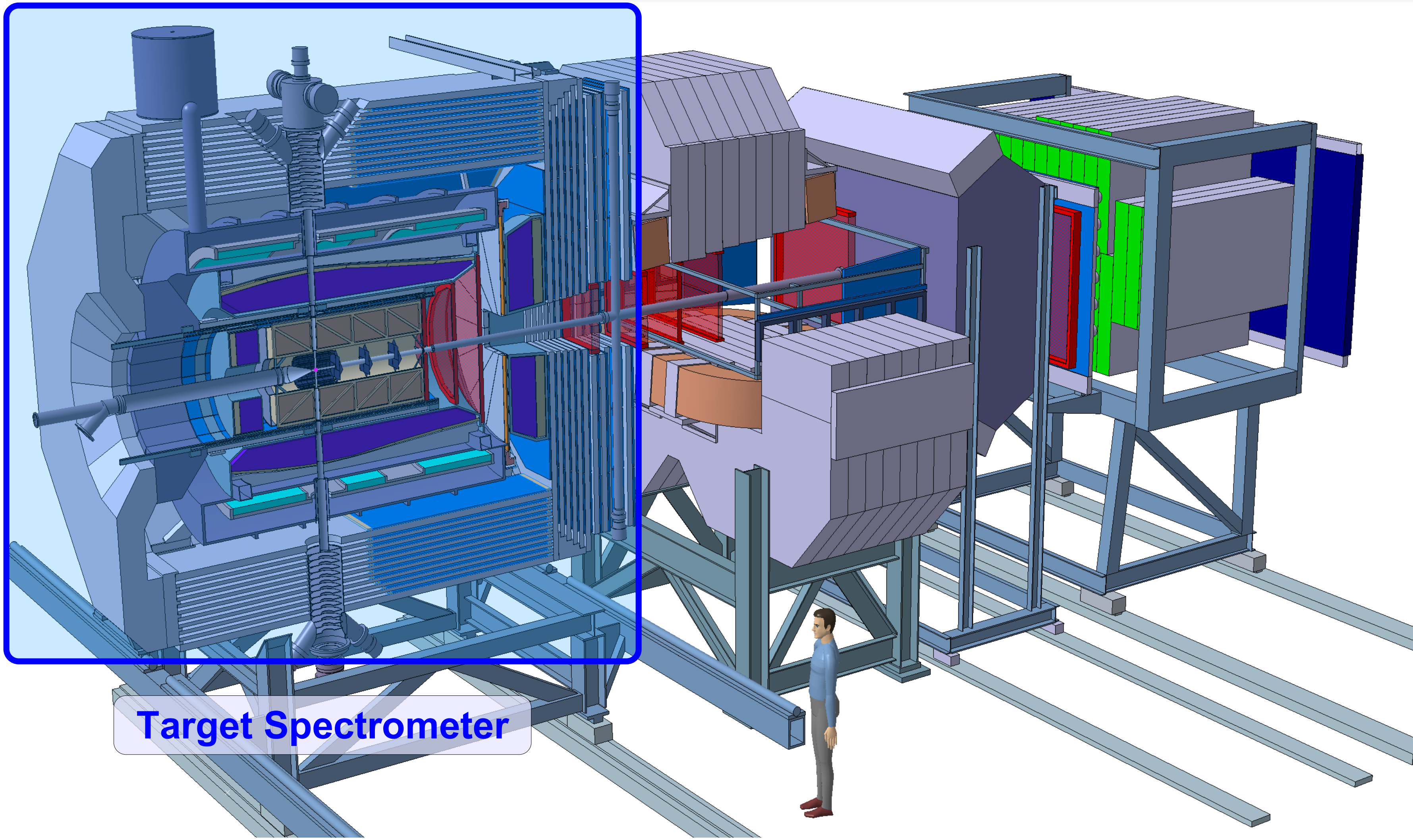

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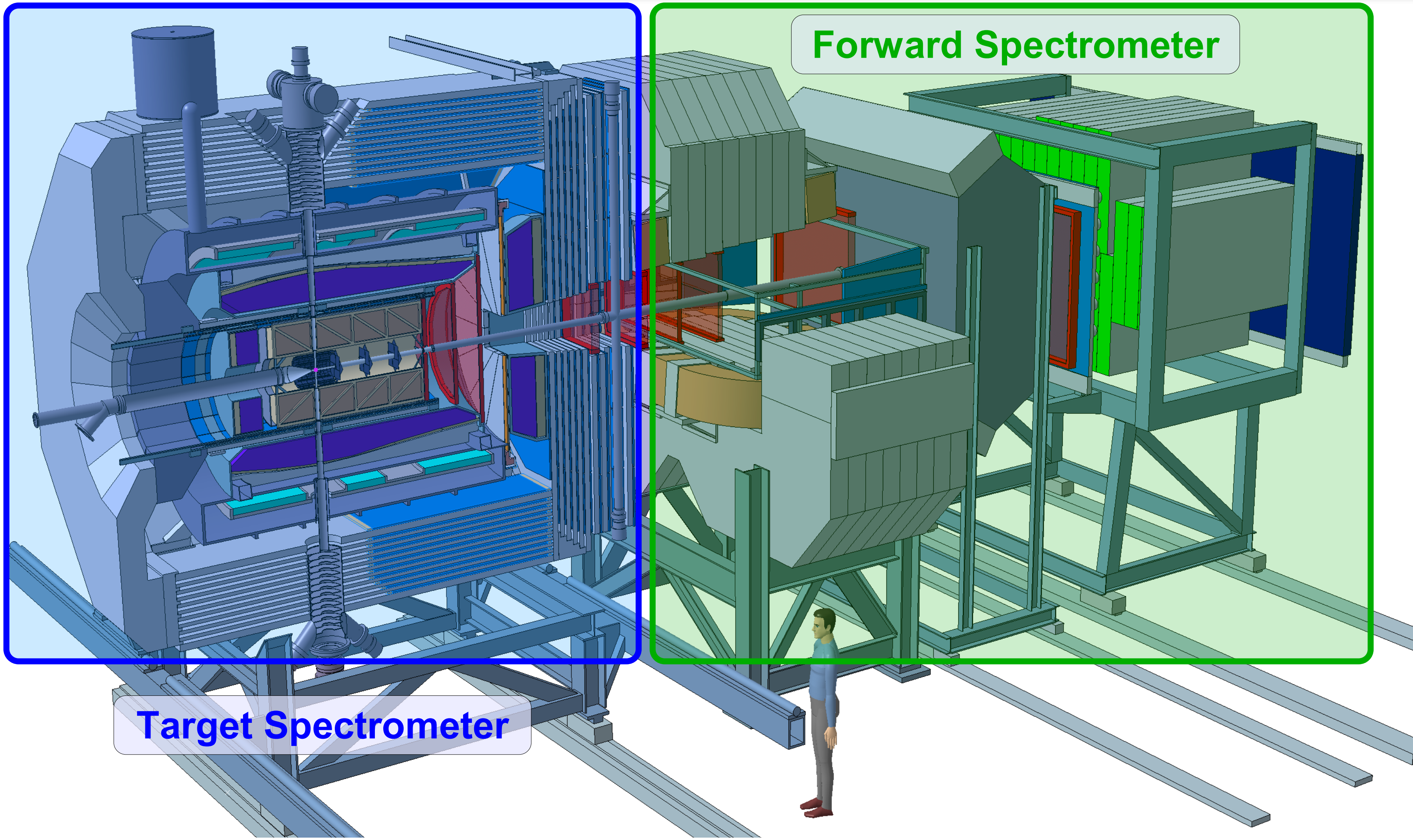

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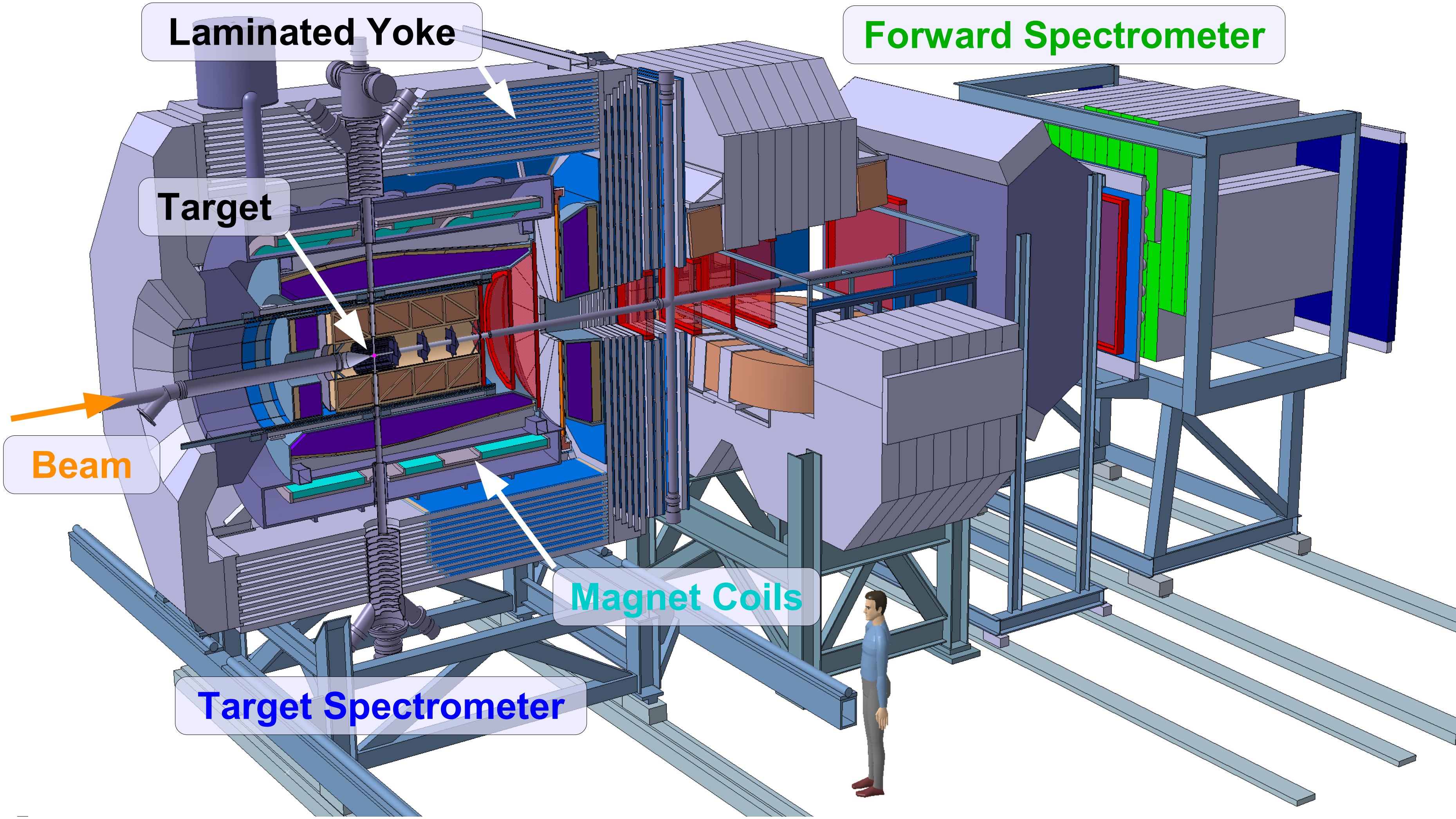

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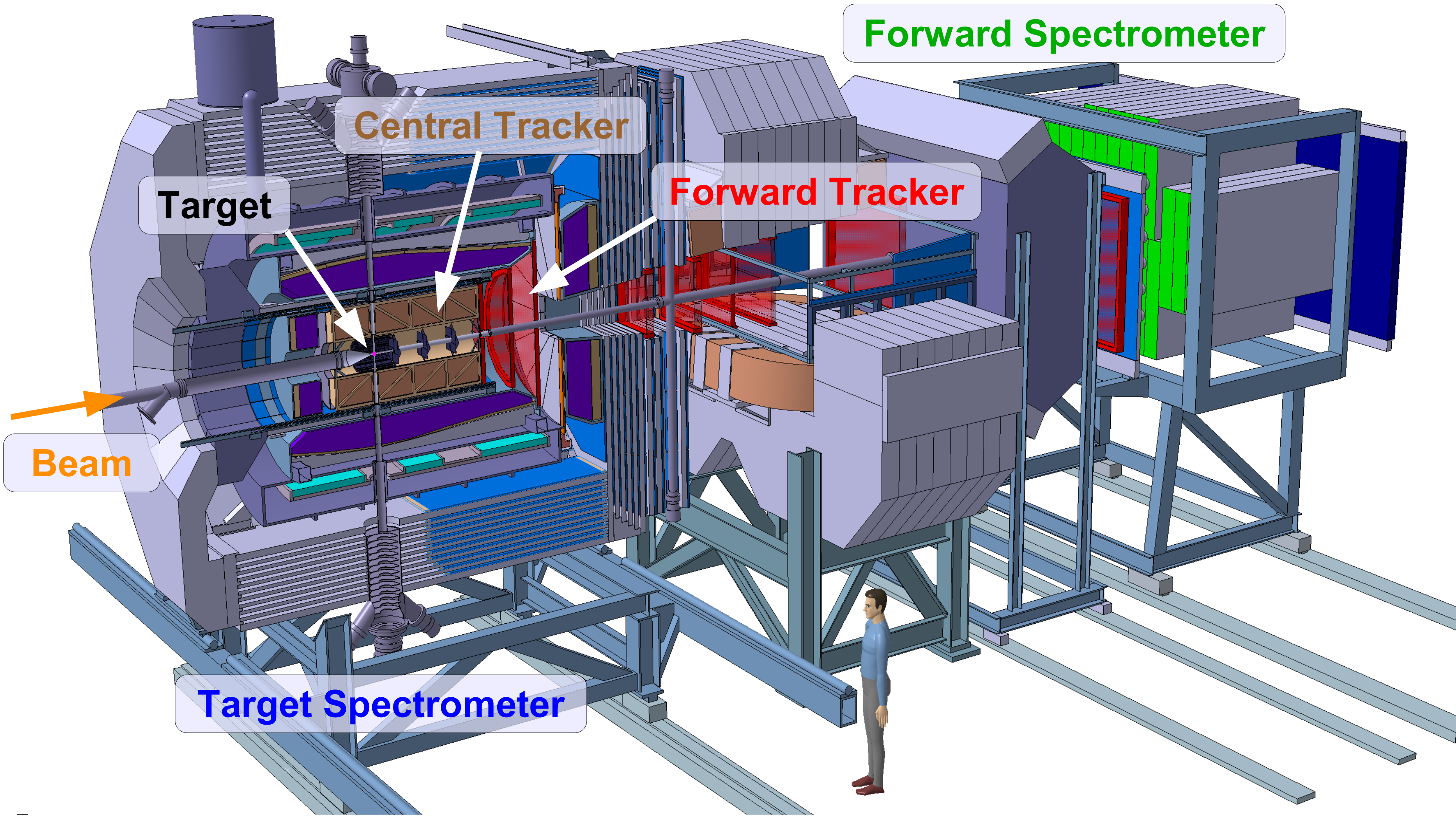

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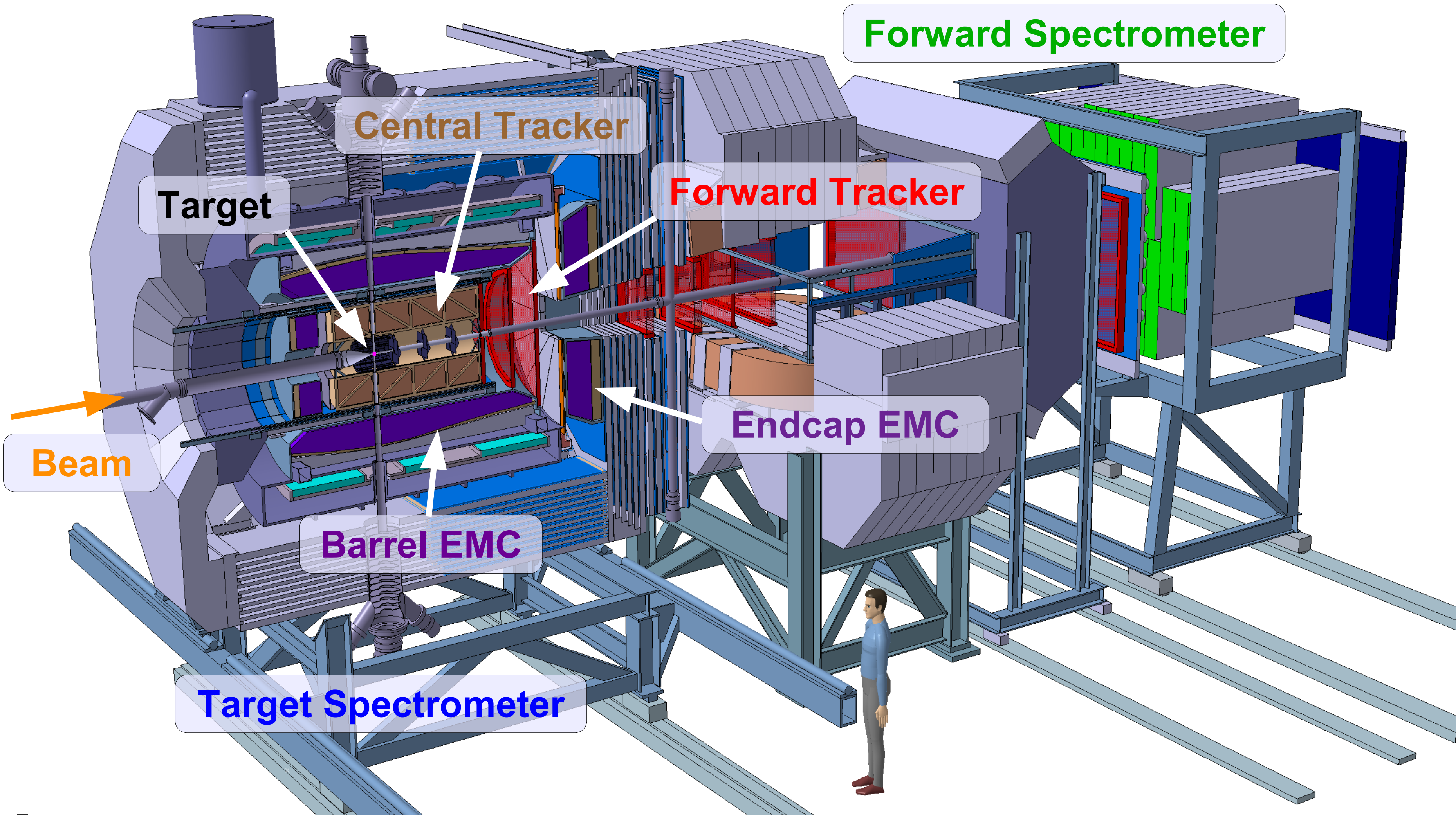

Introduction – Physics Program of PANDA

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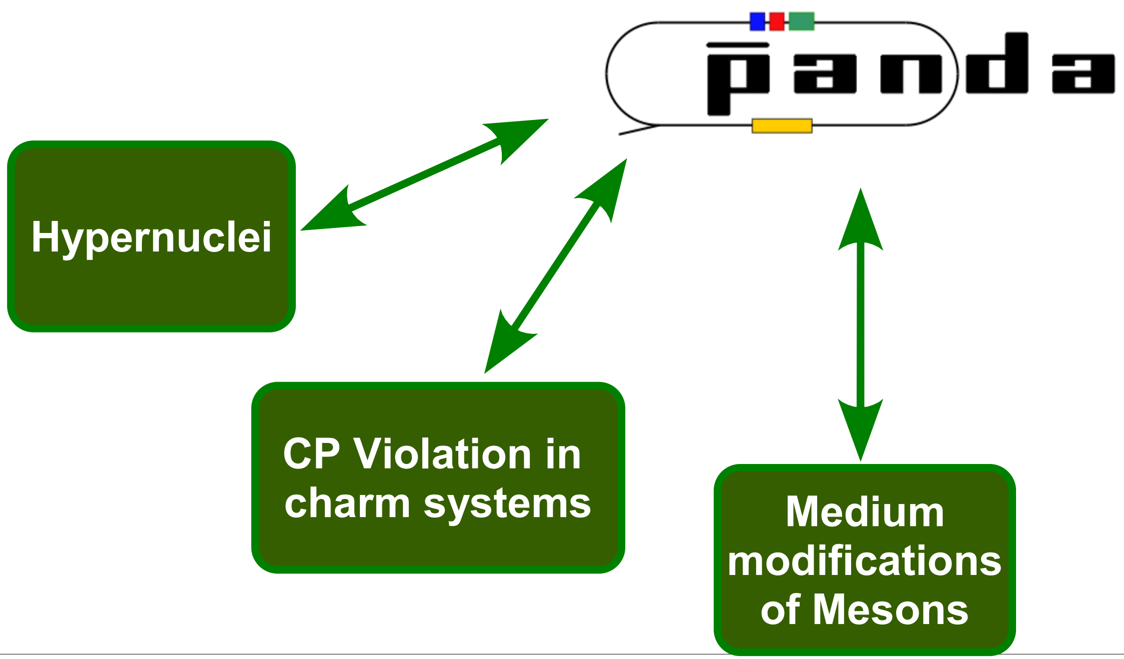

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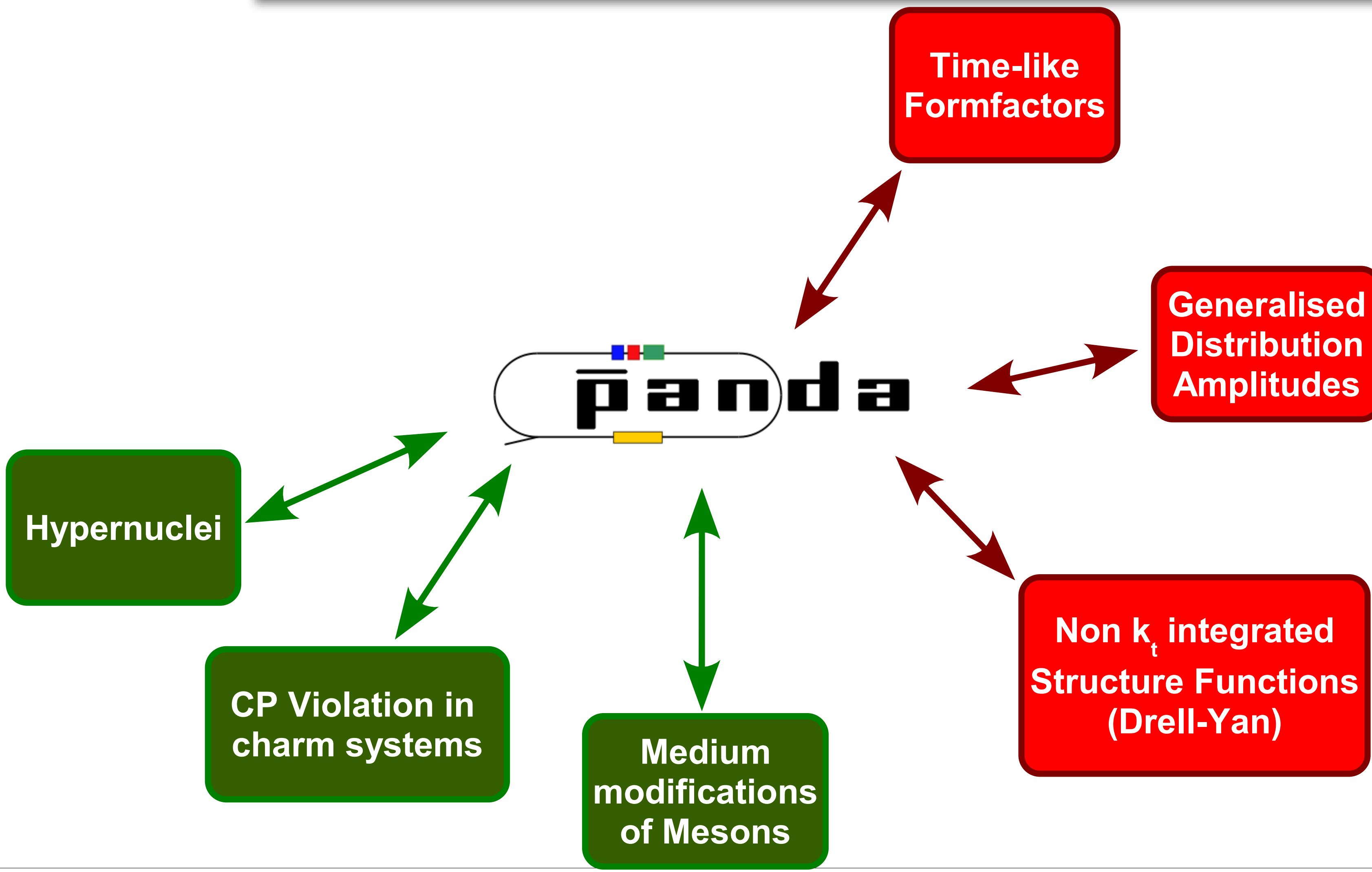

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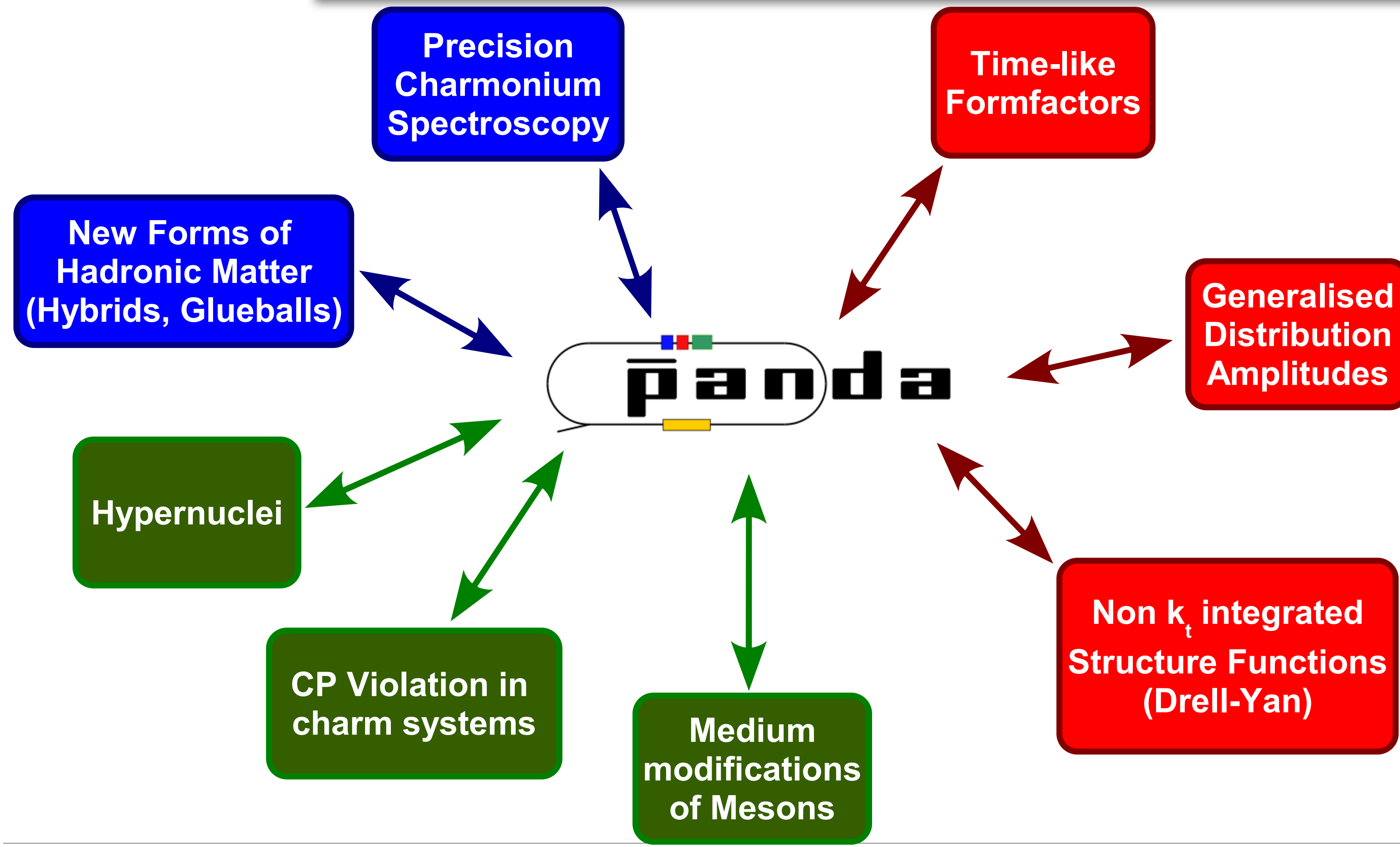
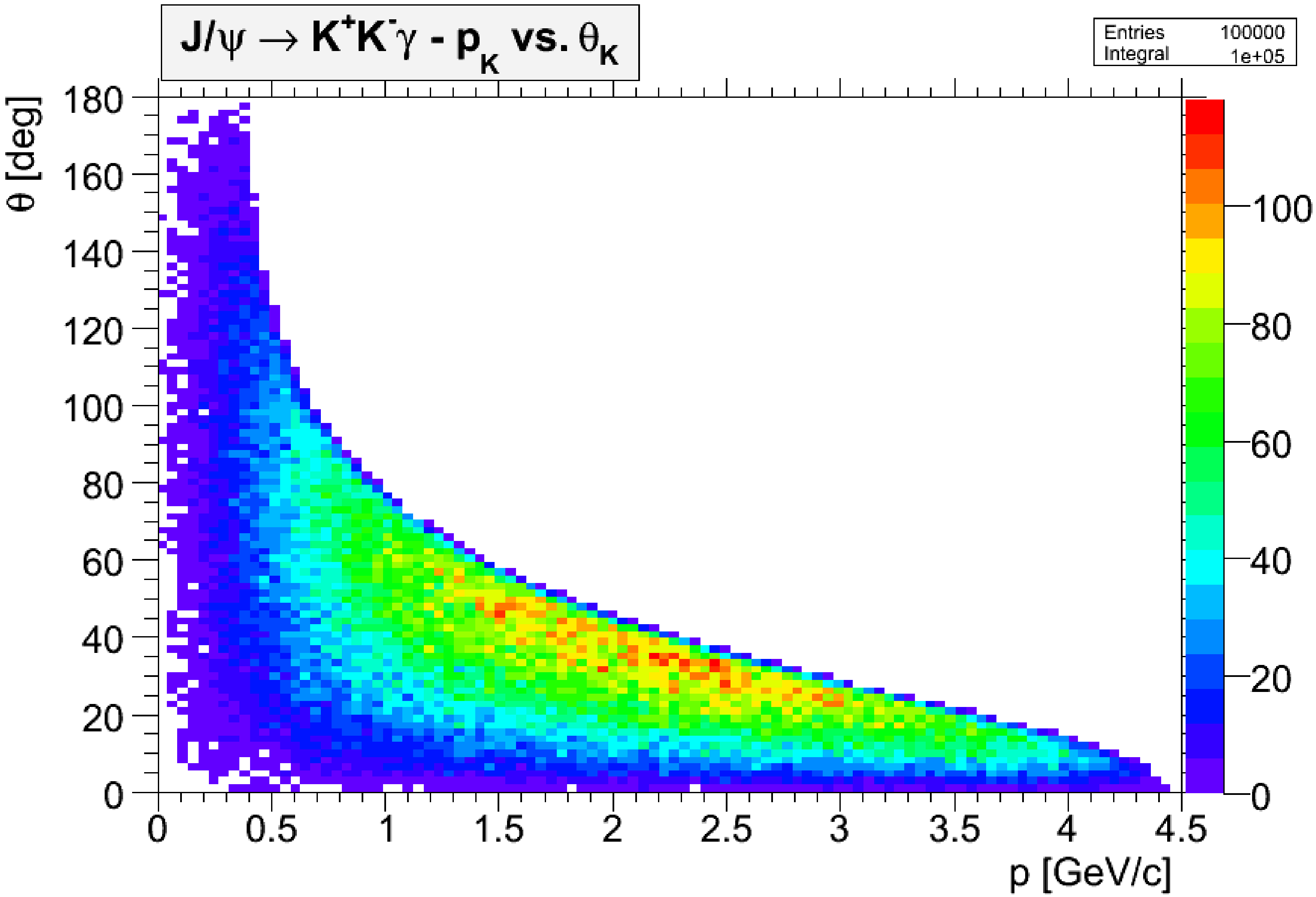


Physics Requirements - Detector Acceptance



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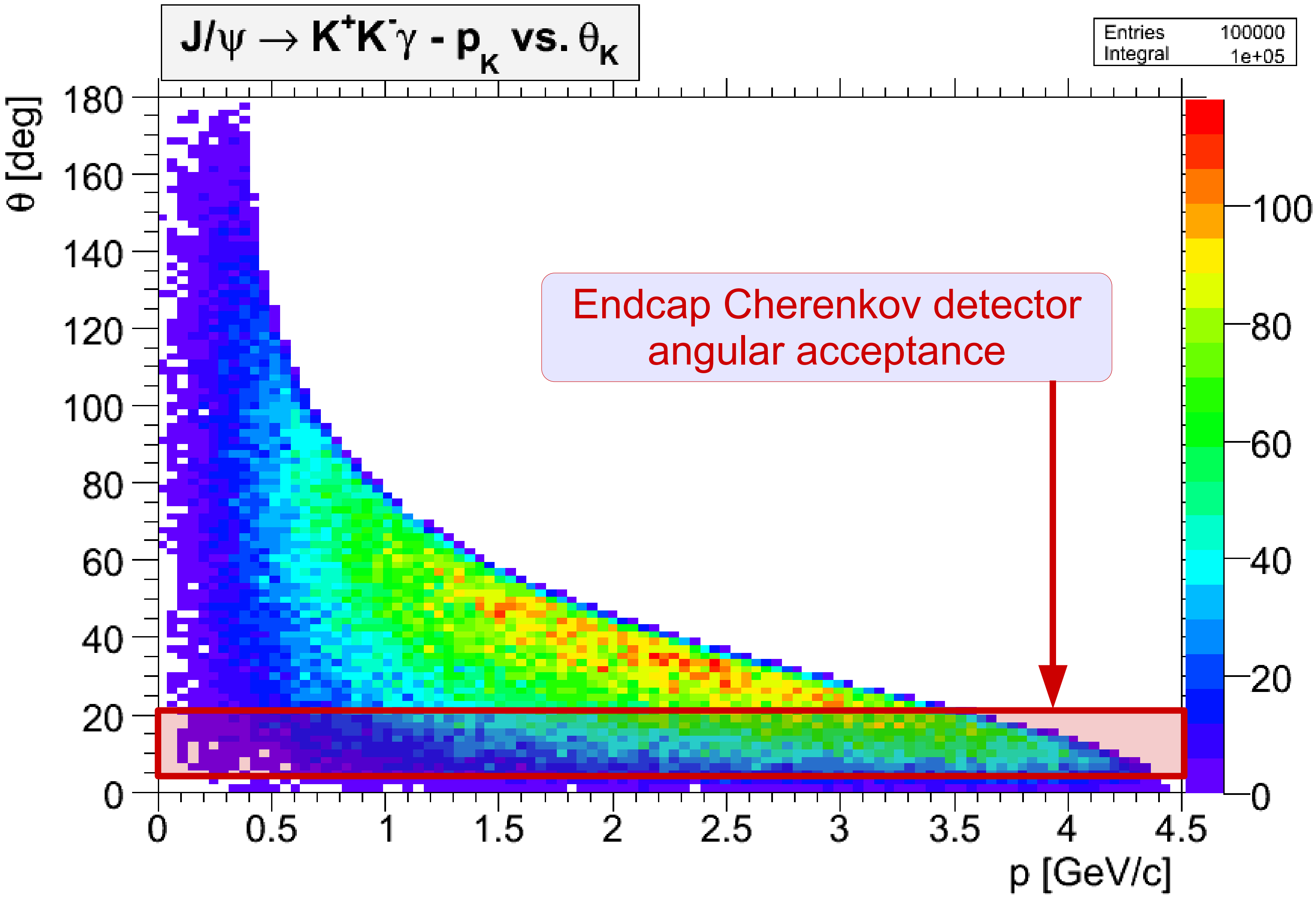

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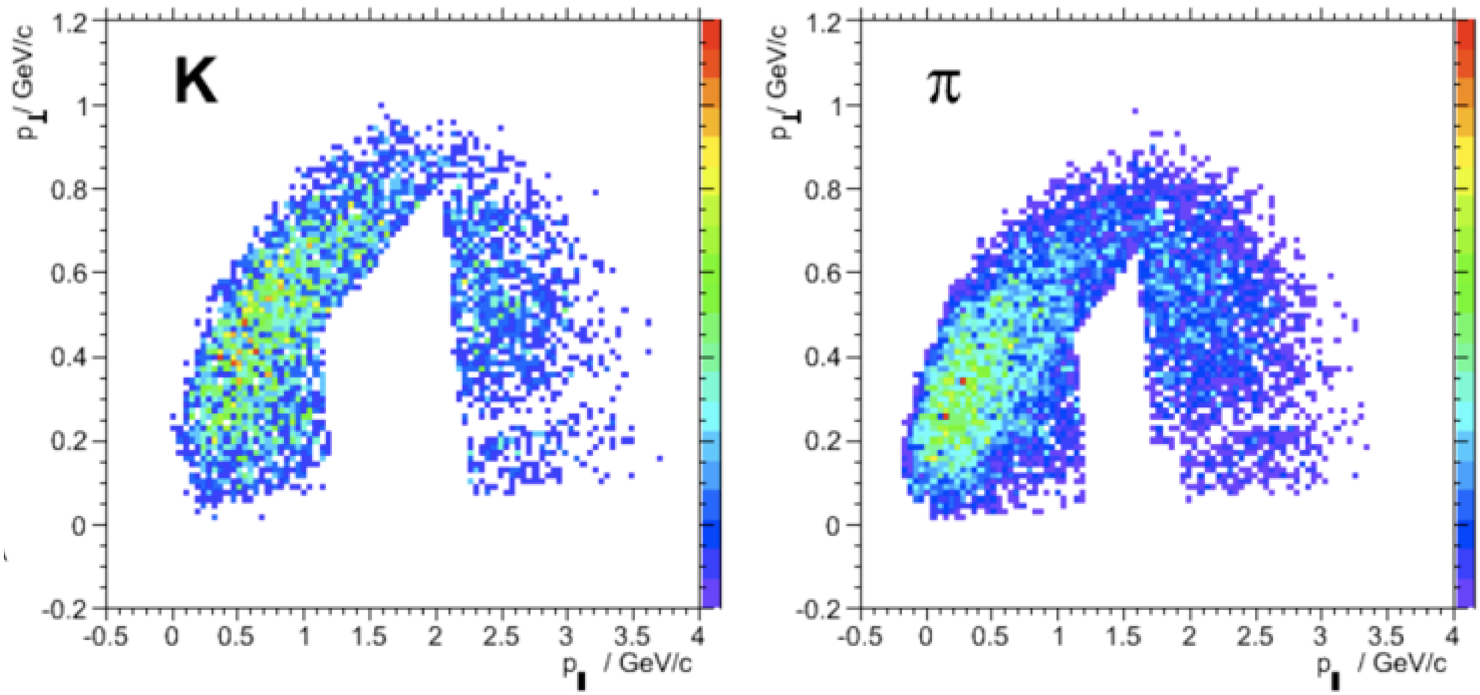
D^+D^- Decay



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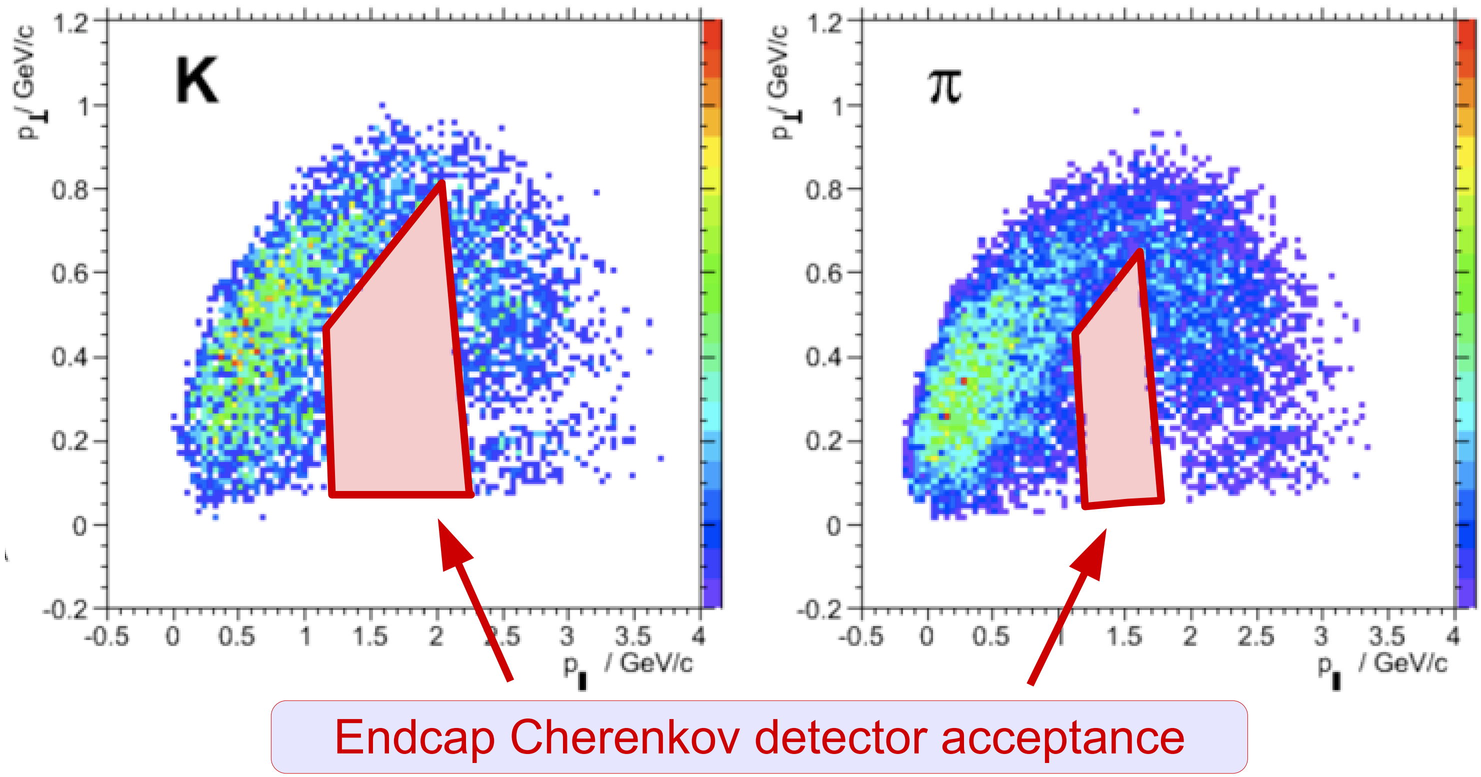
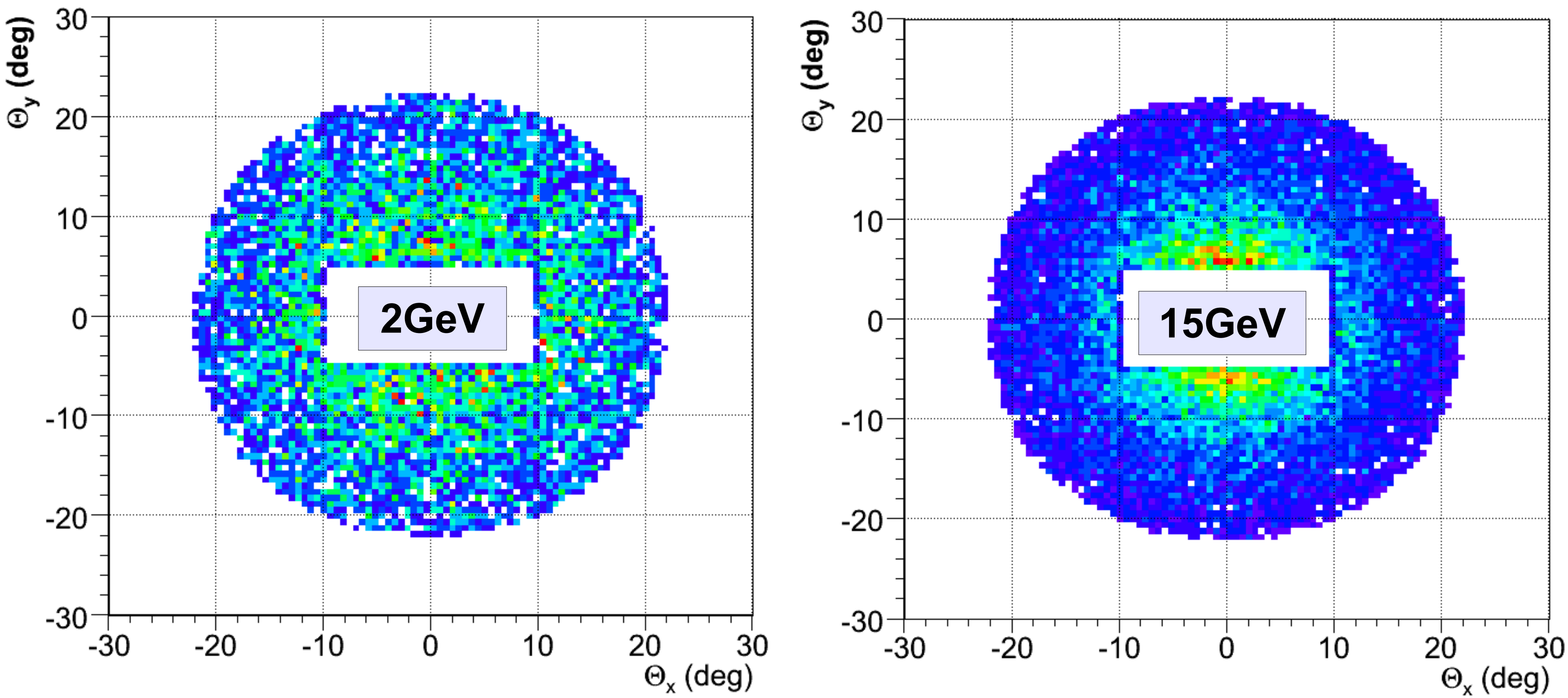
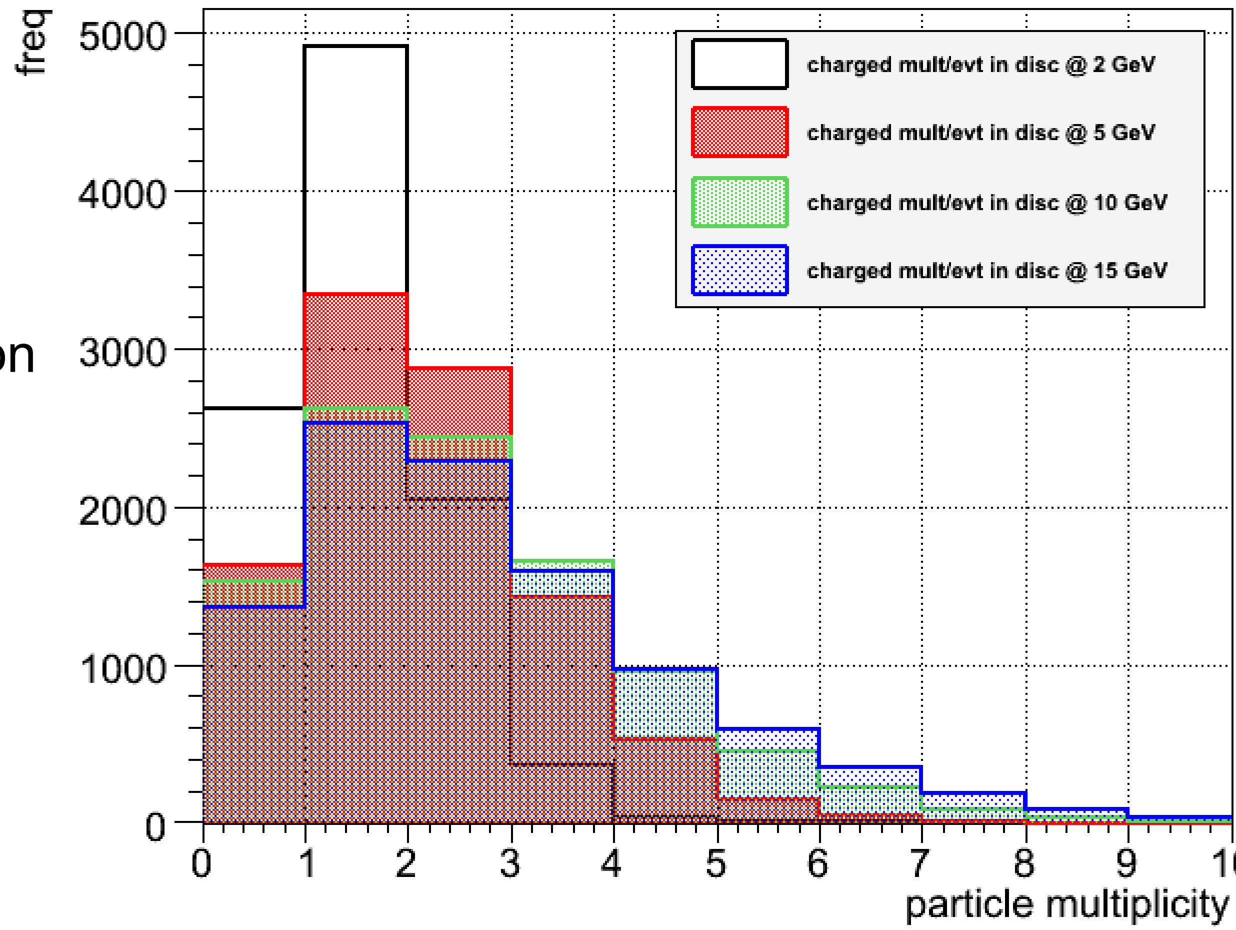


Physics Requirements - Charged Particle Hit Distribution



Physics Requirements - Particle Multiplicities

- Occupancy
  - Readout
    - Granularity
    - Quantities
  - Pattern recognition
- Secondary particles
  - Shower leakage EMC
  - Correlated background



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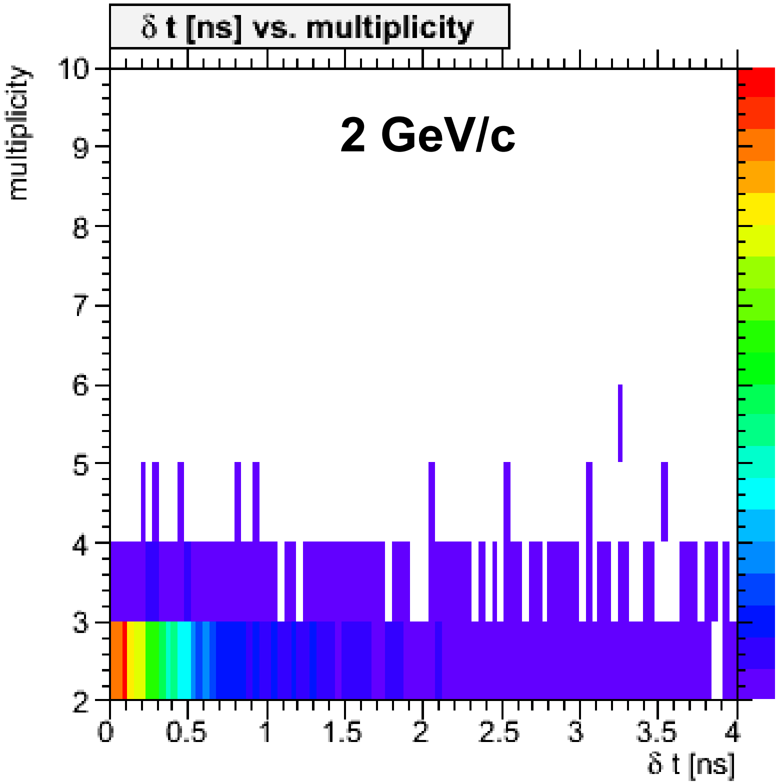

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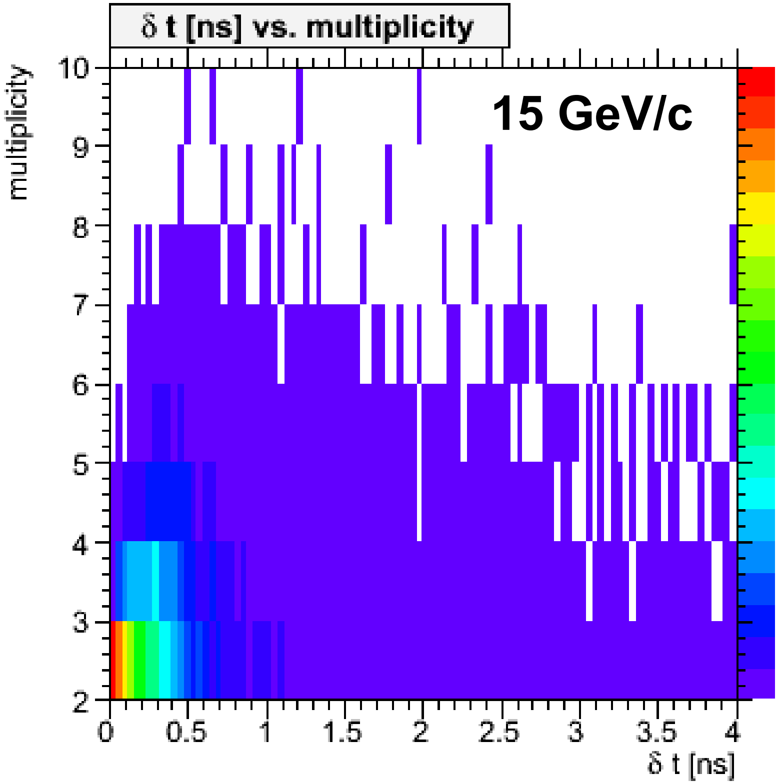
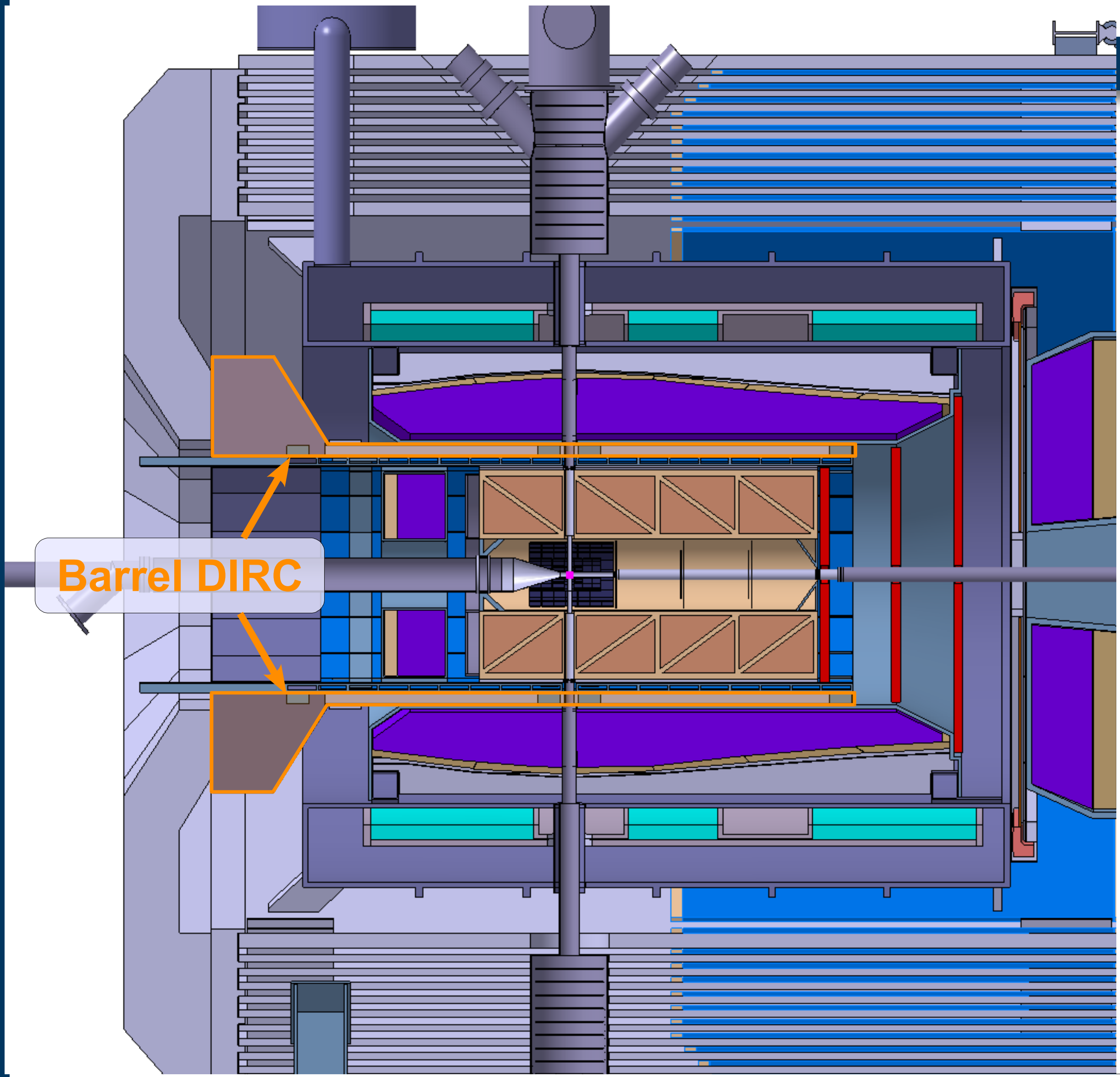


Endcap Cherenkov Detector



- Acceptance
  - 5° < Θ < 22°
- Proximity Imaging
  - Liquid Radiator (e.g. ALICE HMPID)
  - Solid Radiator
    - Dense (e.g CLEO)
    - Aerogel
- DIRC Principle
  - Imaging
  - Time-of-Propagation

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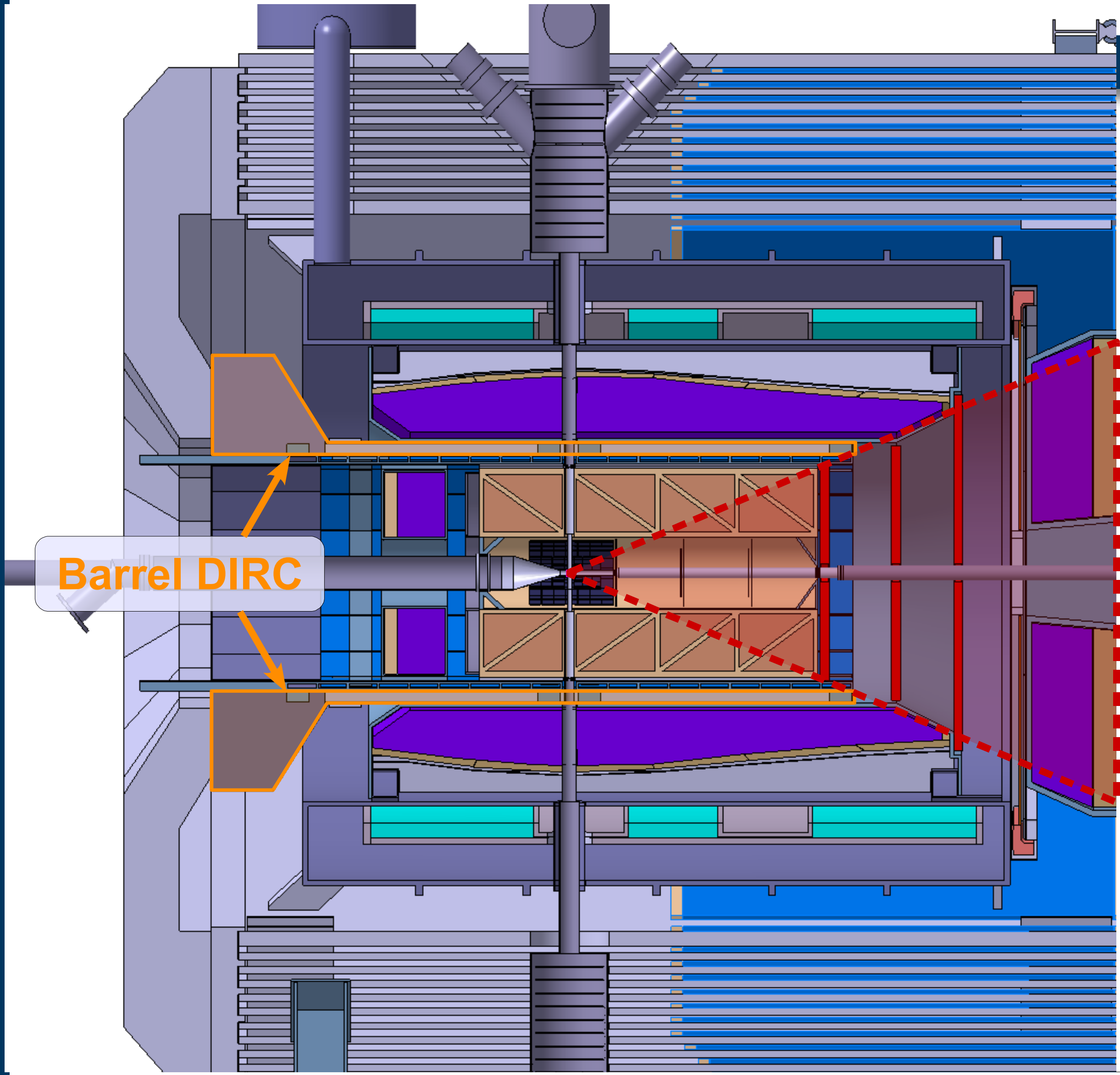

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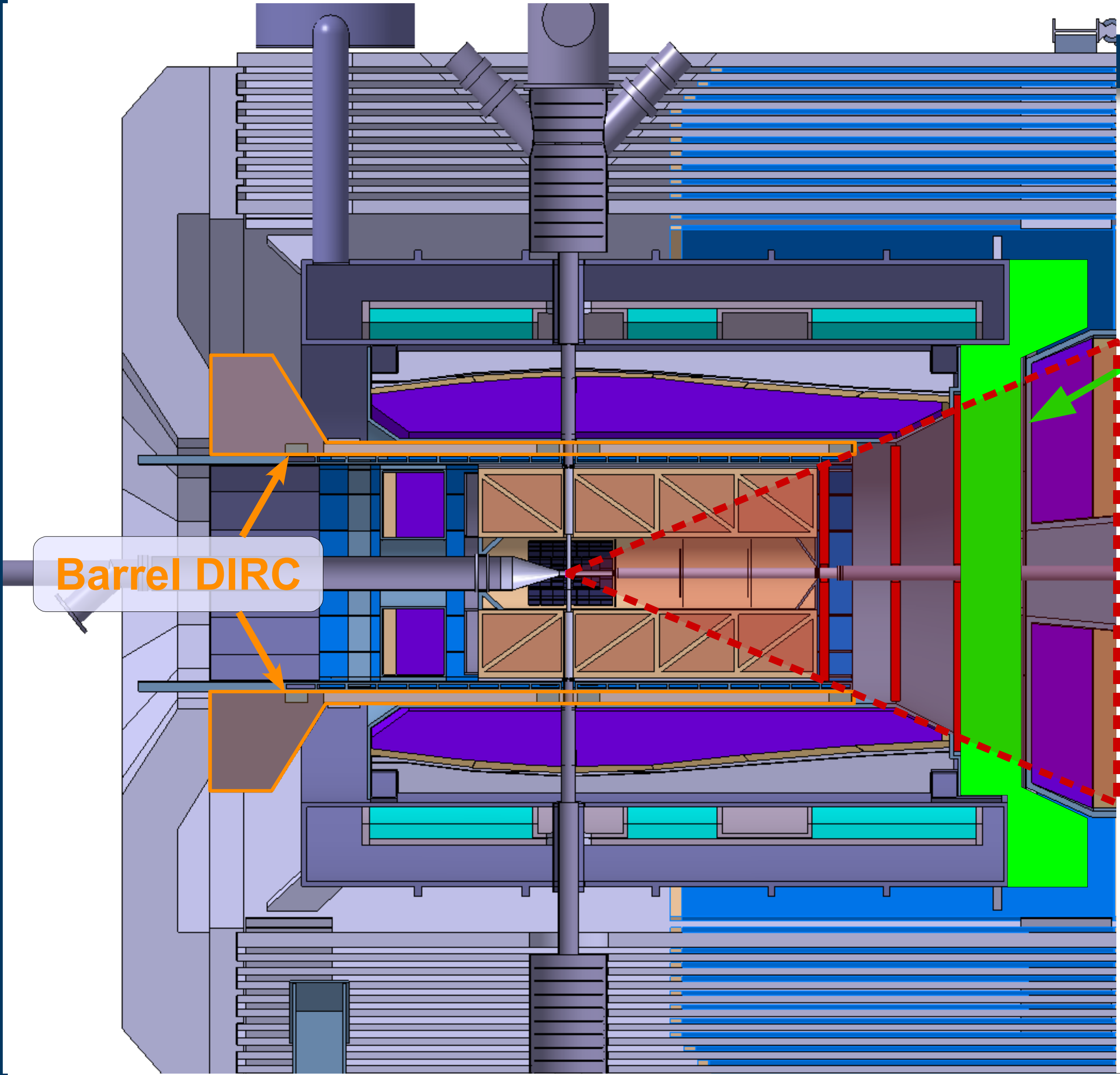

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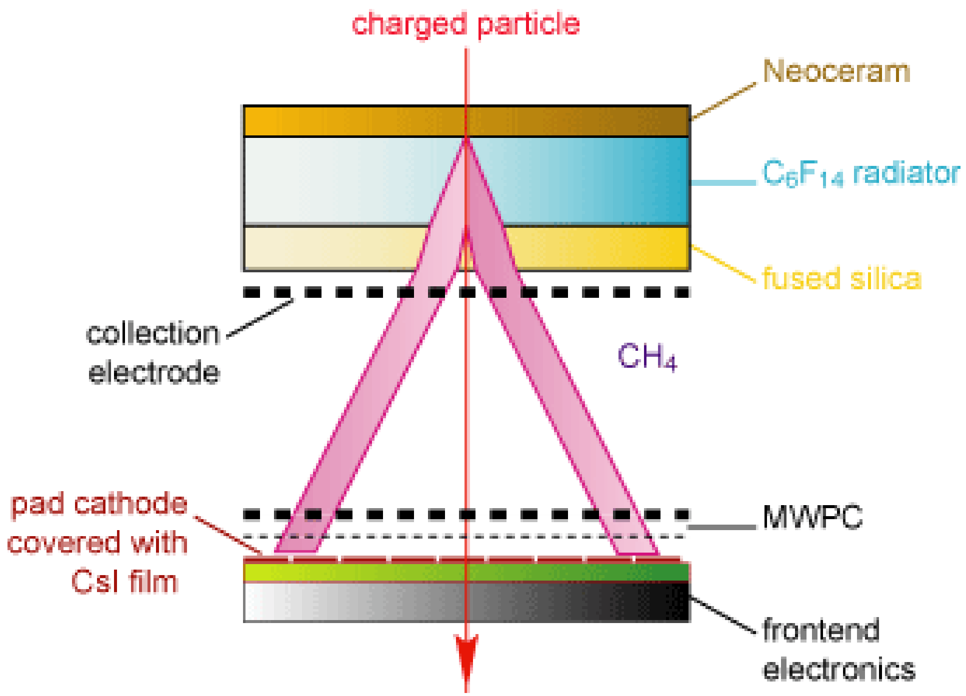
Detector Design - Endcap Cherenkov Choices

- Proximity Focussing Type
  - Liquid Radiator (e.g. ALICE HMPID)
  - Solid Radiator
    - Dense (e.g CLEO)
    - Aerogel (e.g. Belle)
  - Limited stand-off distance
  - Large readout plane
- DIRC Type
  - New compact design
    - Basic design pioneered by T. Kamae (Tokyo) *NIM A382 (1996)*
  - Improved imaging optics
    - High optical quality



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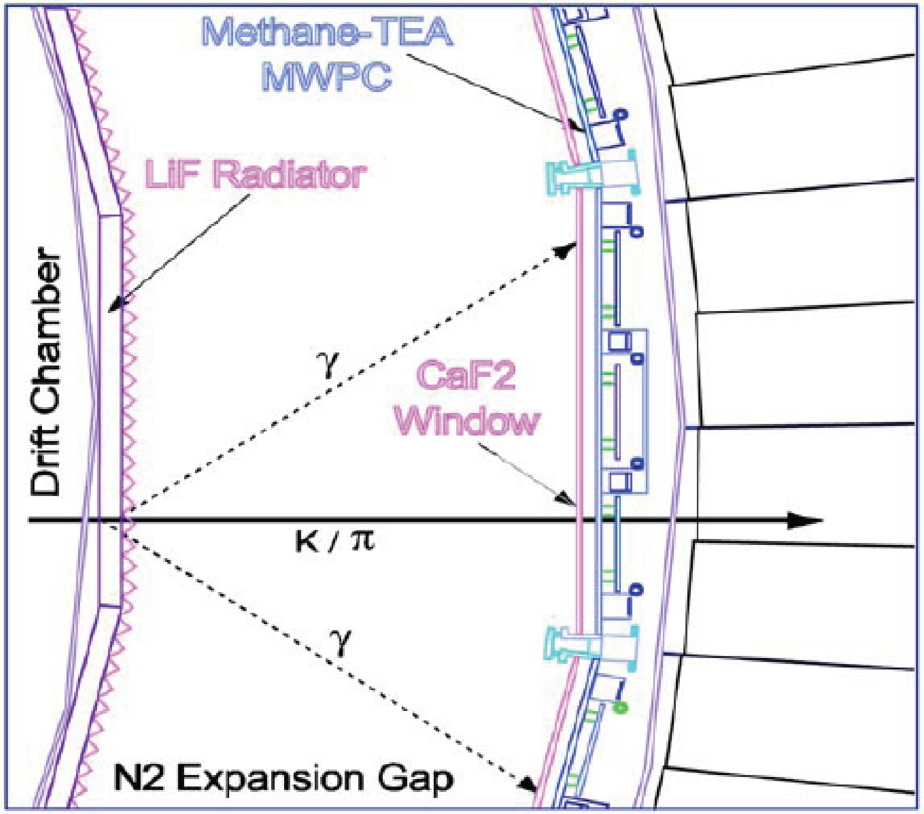

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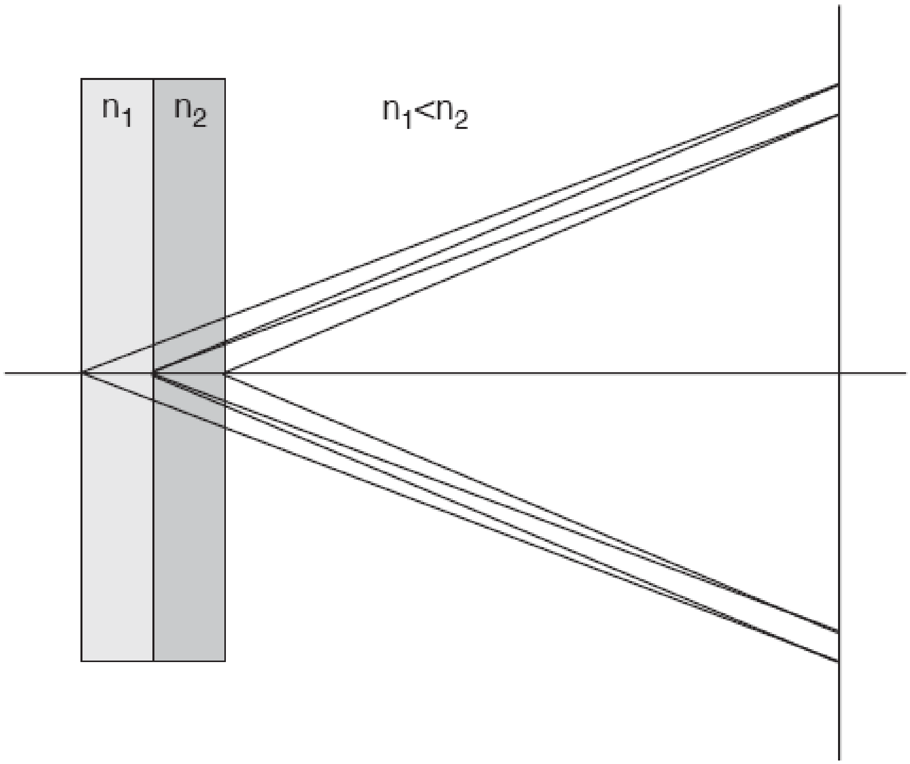

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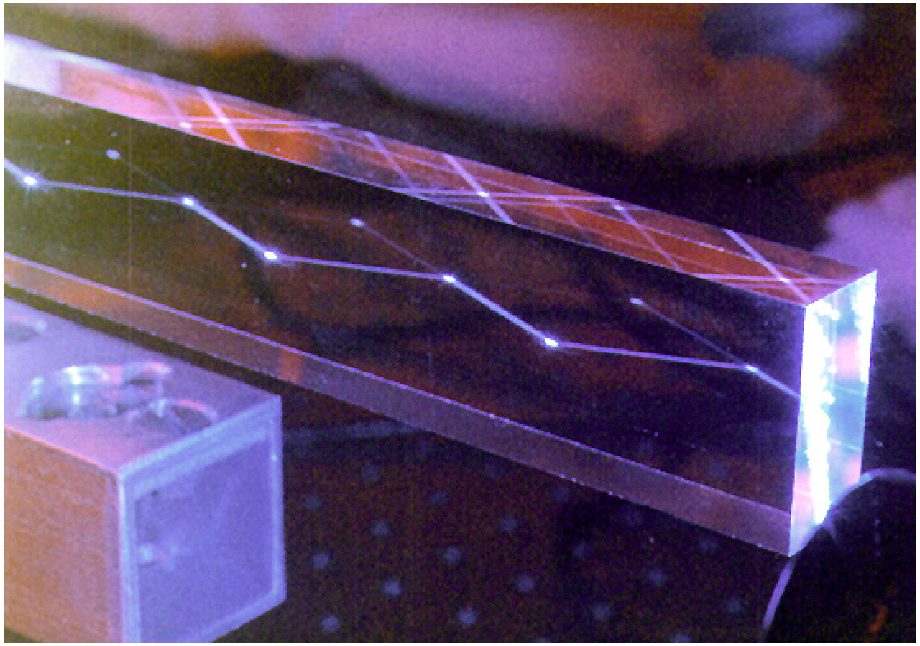

Detector Design - Endcap Cherenkov Choices

	Disc DIRC	Proximity Imaging		
		Liquid Radiator	Solid Radiator	Aerogel
X_0	0.17	0.2	0.24	0.14
N_0 (1/cm)	124	60	57	76
N_{pe}	135	36	68	18
p_{min} (GeV/c)	0.6 (0.2)	0.84	0.56	2.75
p_{max} (GeV/c)	6.5	3.3	2.8	7.5
σ_θ	0.45	4.1	3.9	2.7
Δt	< 500 ps	O(10 ns)	O(10 ns)	O(ns)
Overall length	< 100 mm	~180 mm	~180 mm	~ 250 mm
Photon detection	MCP PMT	CsI GEM	CsI GEM	PMT
spectral range	UV/VIS	VUV	VUV	VIS
pattern	2D + t	2D + t	2D + t	2D + t

see P. Glaessel, NIM A433 (1999)

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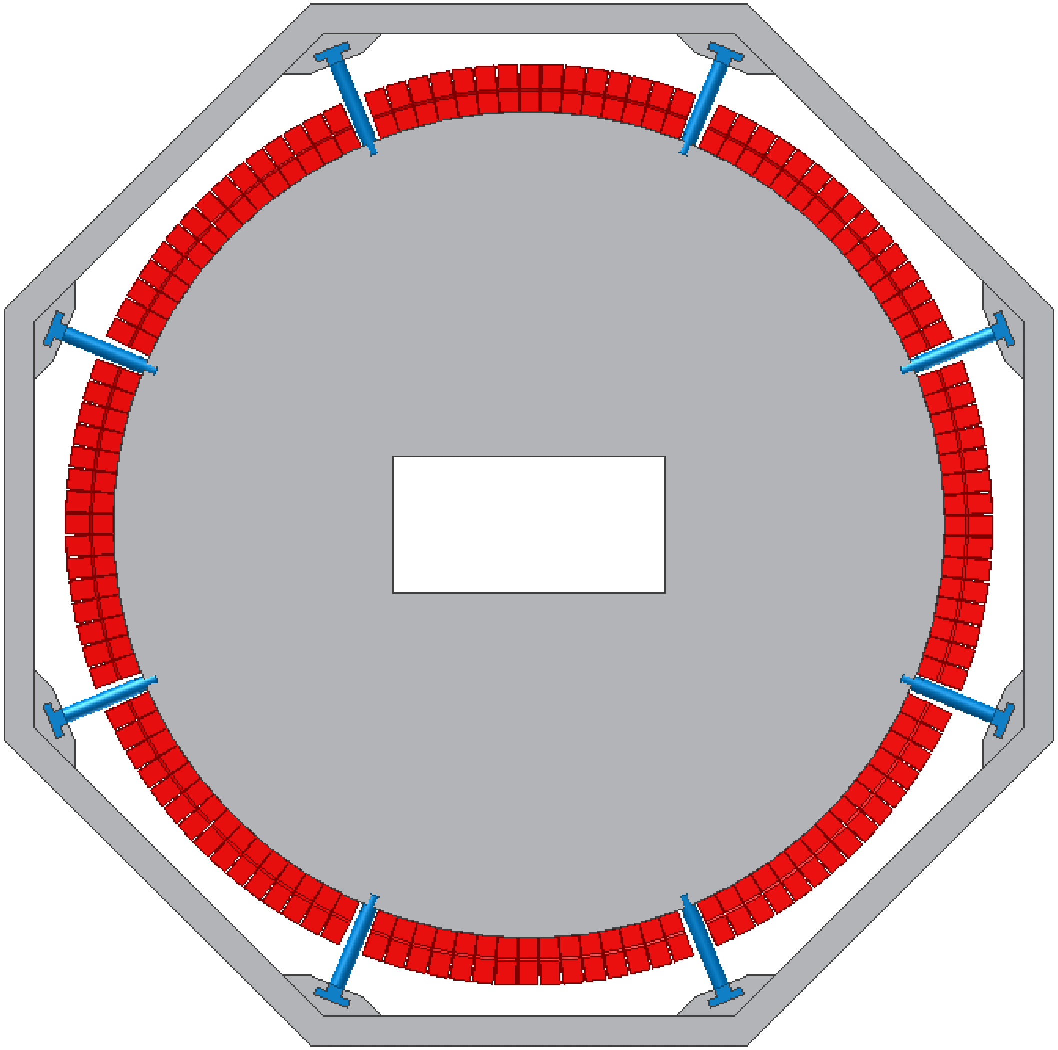
Detector Design - Radiator Disc

- Radiation Hardness
  - 100 krad estimated lifetime dose
- ➔ Synthetic Fused Silica
  - High optical quality
  - Large refractive index
- No monolithic plate
  - ∅ ~ 2200mm
  - Manufacturer's limit
    - 1200×800mm² (Heraeus Suprasil 1)
  - Optimise tile geometry
  - Investigate glueing options



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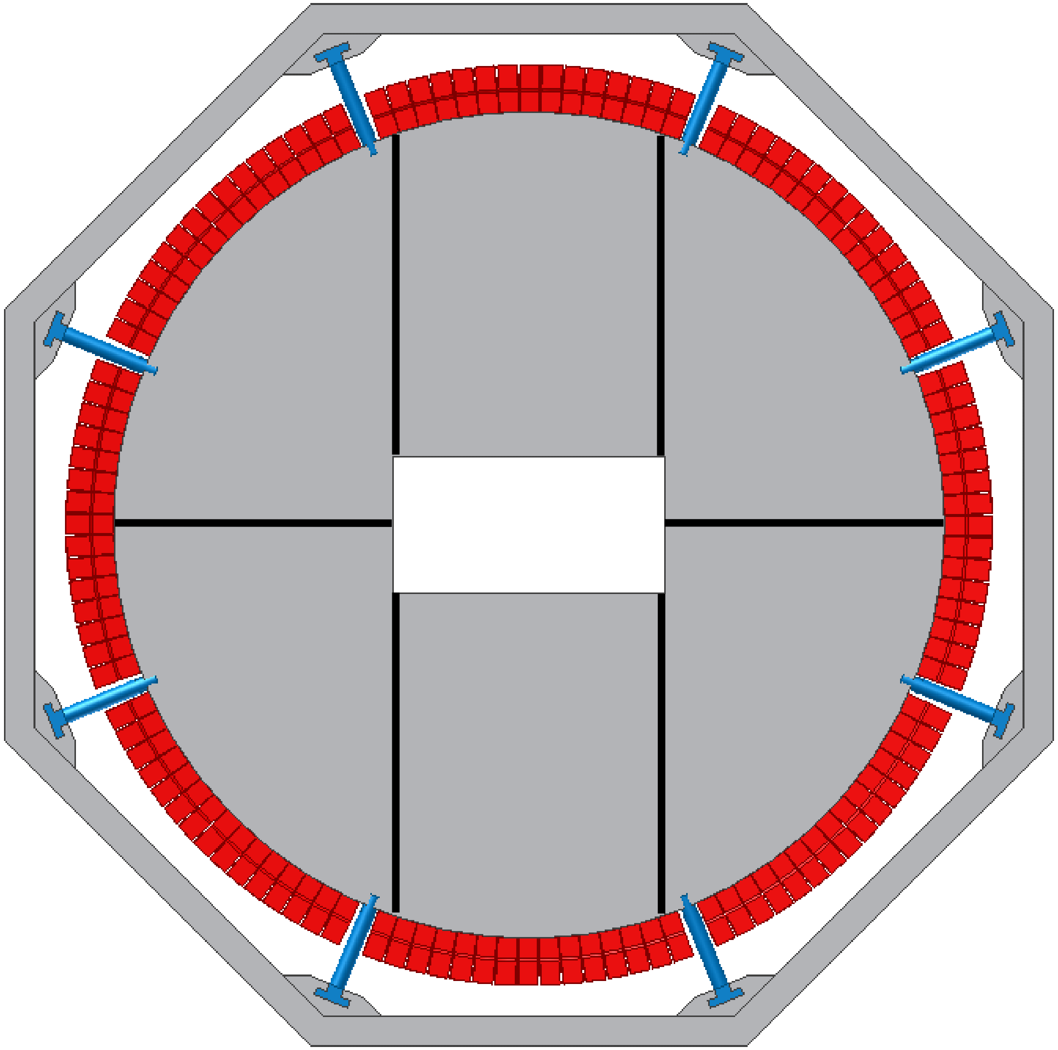

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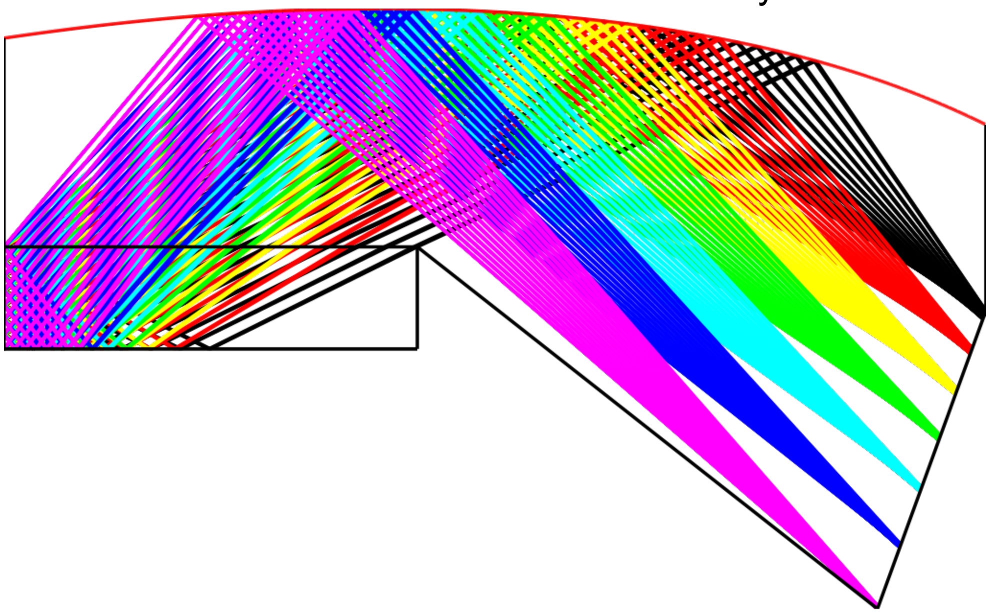
Detector Design - Optical System (Imaging)

Courtesy of T. Keri



- Focussing lightguides placed on rim of the radiator
- Non-spherical surface for best image quality
  - Optimise parameters using ray-tracing methods
  - Take production tolerances into account
- Match image size to photon detector size
- Tilt focal plane according to magnetic field
- Optimise number of units

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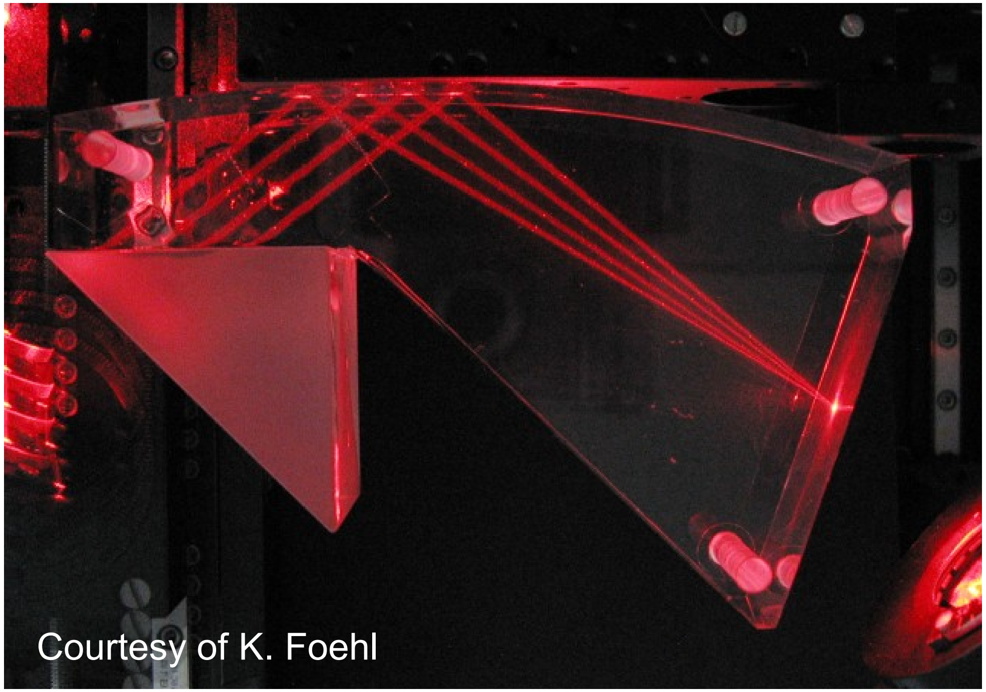

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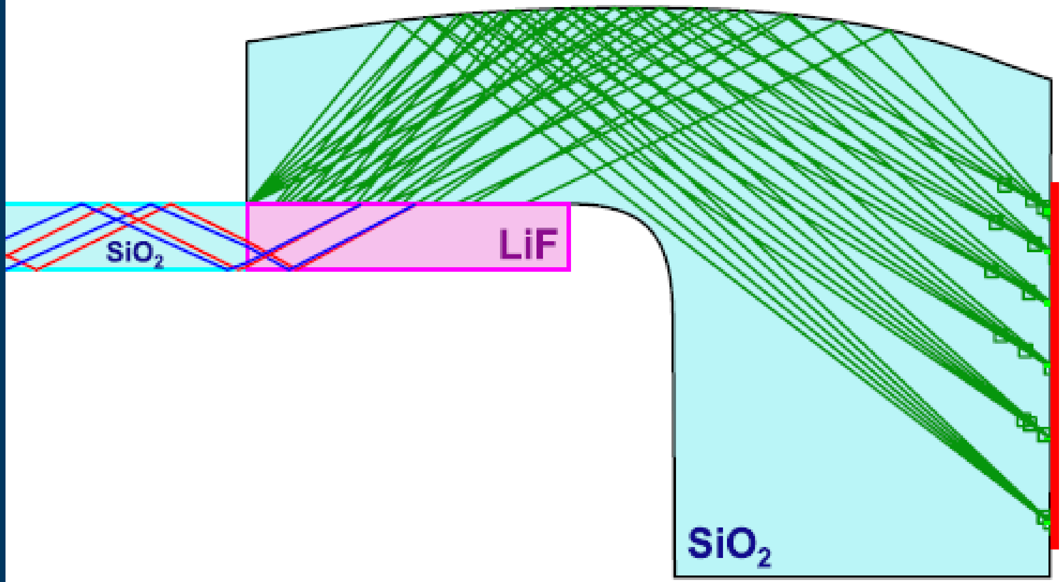
Detector Design - Optical System (Dispersion Correction)

- Focussing optics takes care of radiator thickness
- Compare contributions to Cherenkov angle reconstruction
  - Chromatic dispersion $\sigma_{chr} \sim 5$mrad
  - Multiple scattering $\sigma_{msc} \sim 2$mrad

➔ Mitigate dispersion effects
  - Time-of-Propagation unfeasible ($\sigma < 25$ps)
  - Combine Fused Silica with LiF



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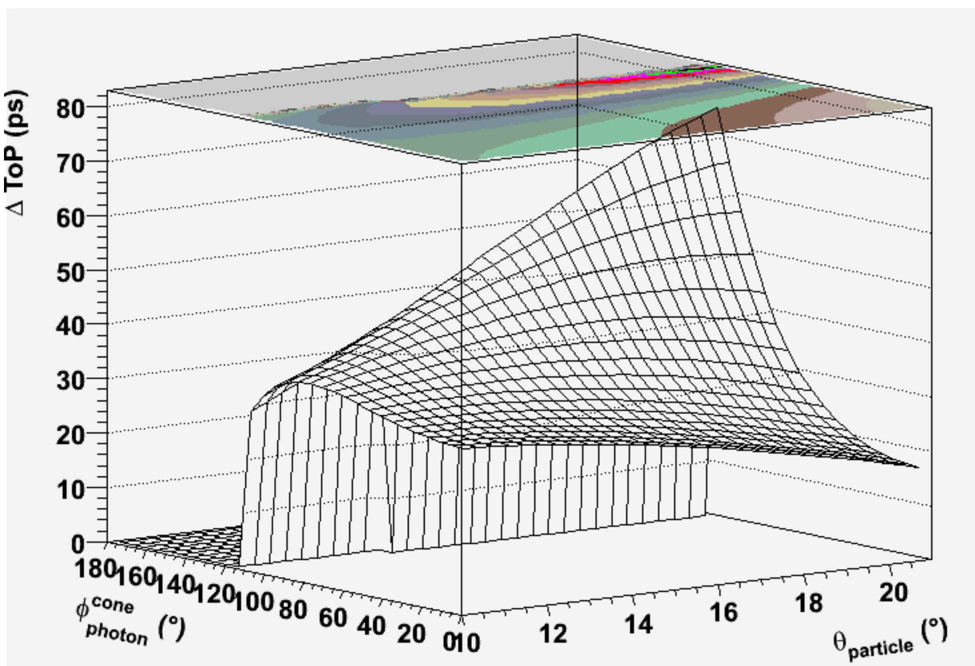

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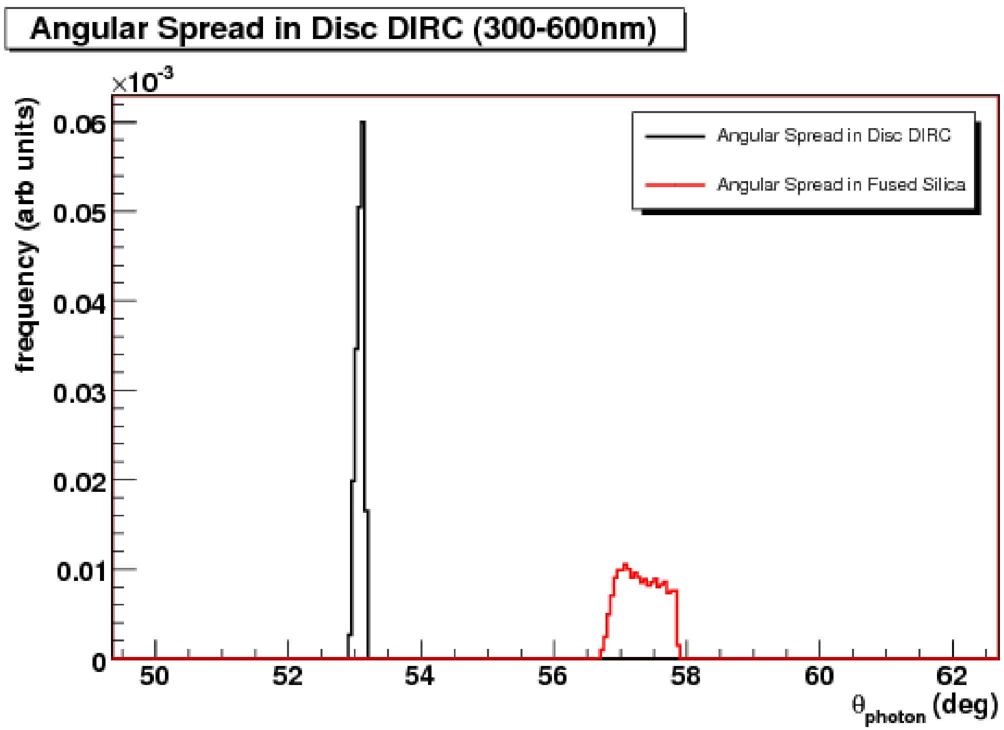
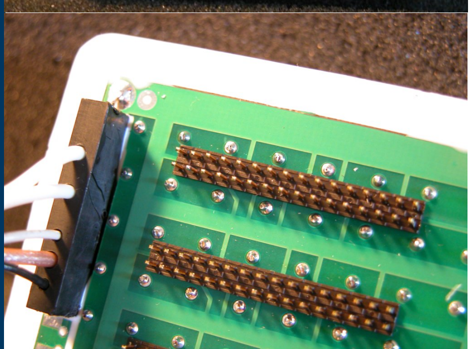


Detector Design - Photon Detection



- Position sensitive
- Response
  - Single photon sensitivity (Gain ~ 5×10^{5})
  - Fast signal response (less than 300ps)
  - High-rate capability (~1MHz per channel)
- Magnetic field operation
  - Inside solenoidal target magnet
  - Field strength up to 1.5T

➔ Multi-anode MCPs

- Custom electronics required
  - Hit pattern + TDC (digital)
  - ADC for performance monitoring & comissioning (analog)

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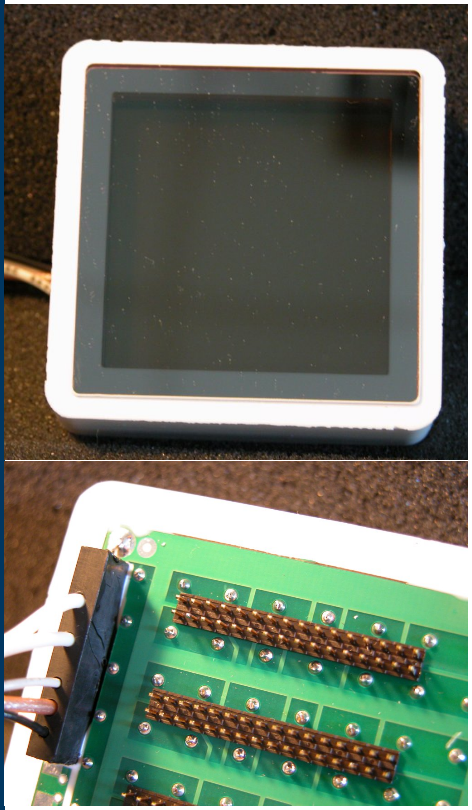

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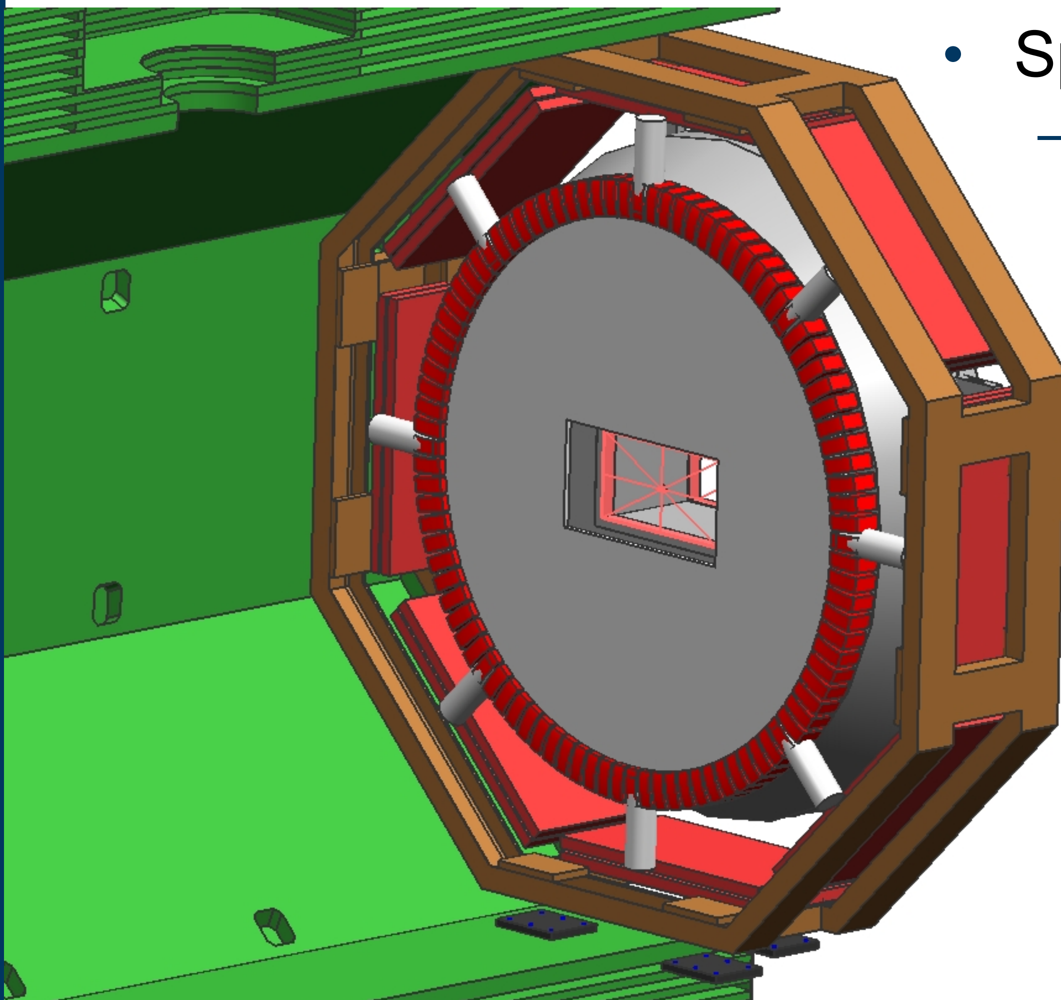
MCPs – A. Lehmann, Mon 17:40
FEE – T. Keri, Wed 12:10

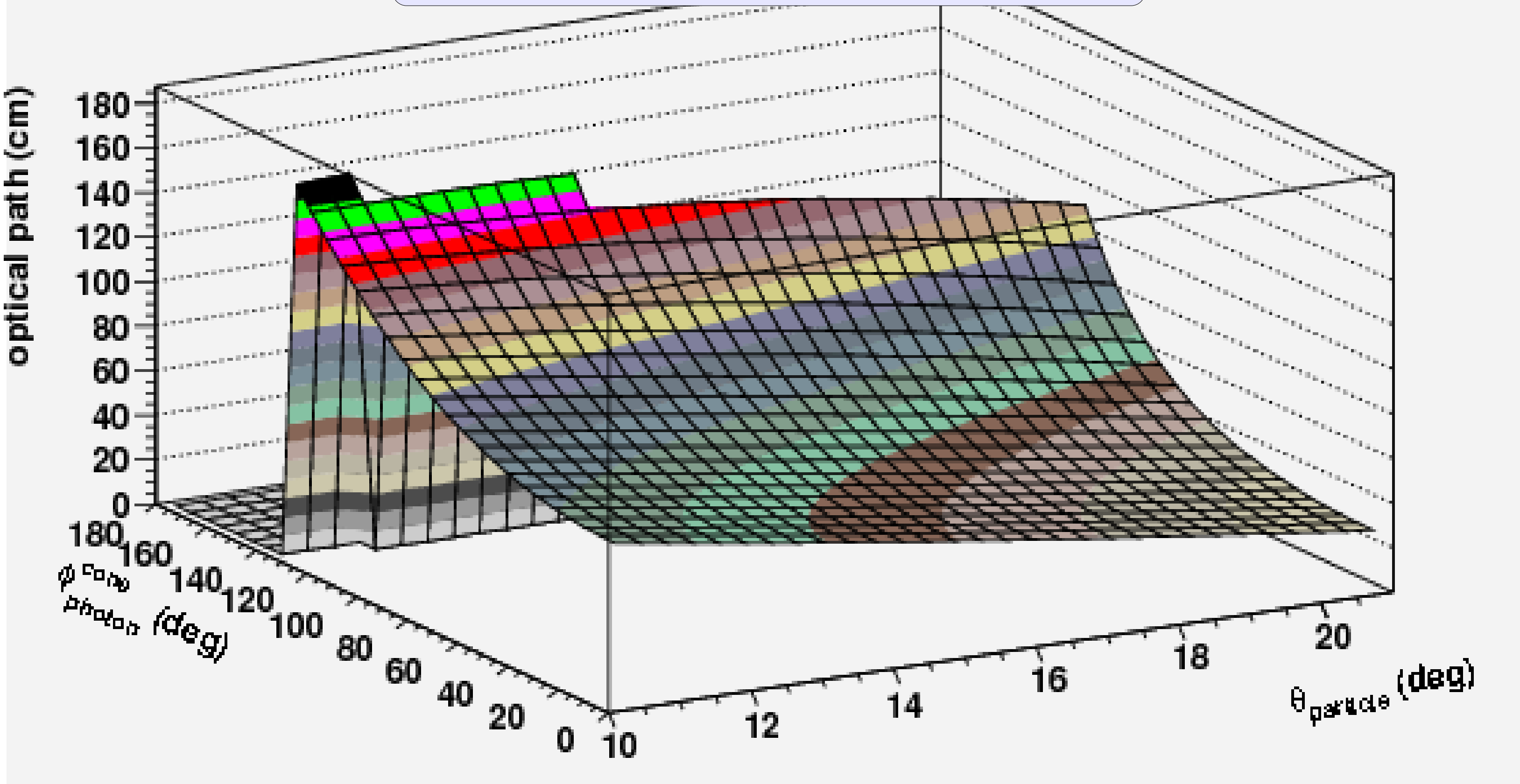
Detector Design – Mechanical Integration



- Space requirements
  - < 100mm in central area
  - Housing
    - Detector weight ~ 1000kg
    - Cooling
    - Environmental control (N_2 atmosphere)
  - Support
    - Attach to rim
    - Allow flexing
    - Share EMC mount points

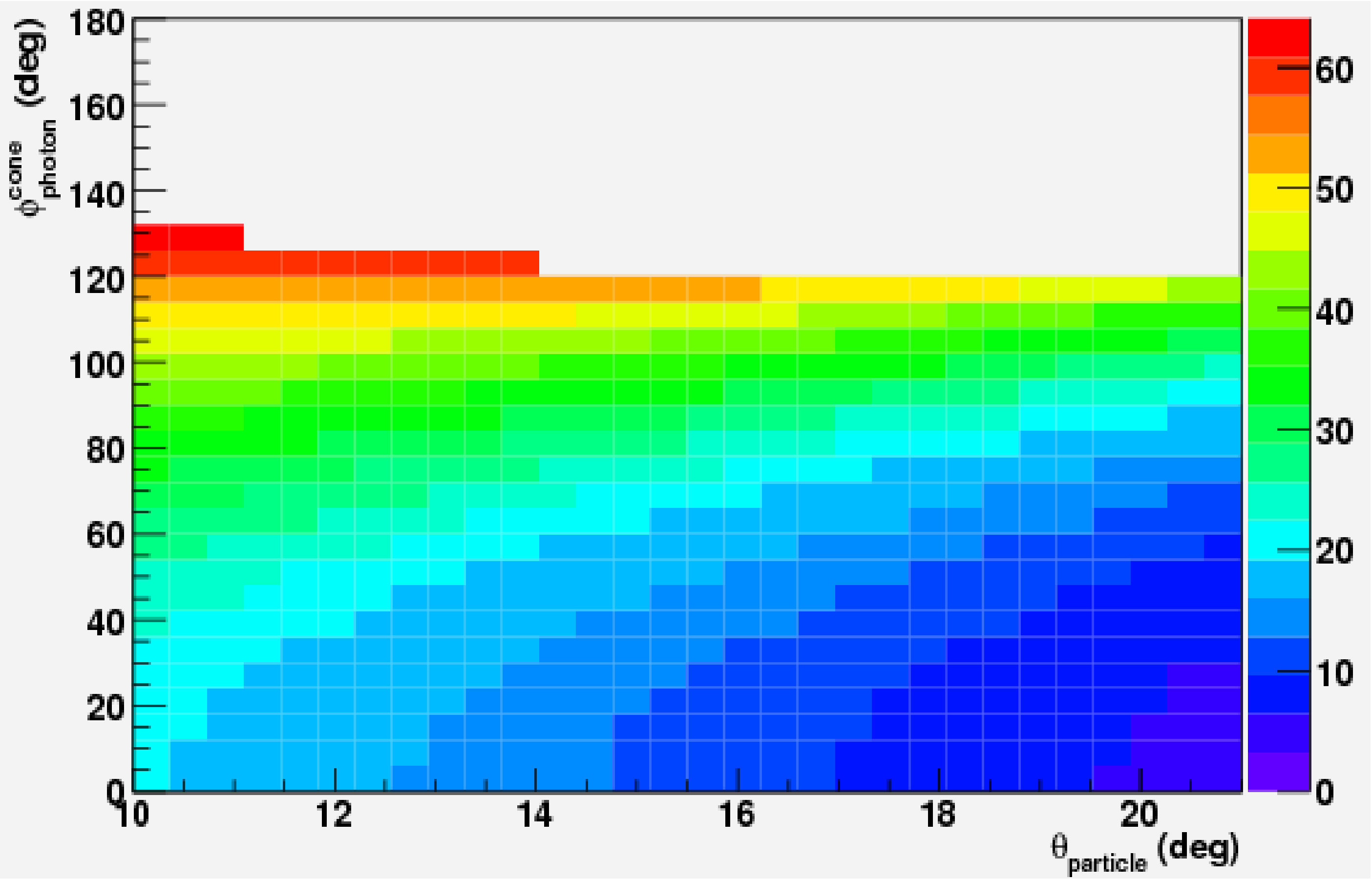
Performance Estimation - Cherenkov Photon Characteristics

Average Photon Pathlength



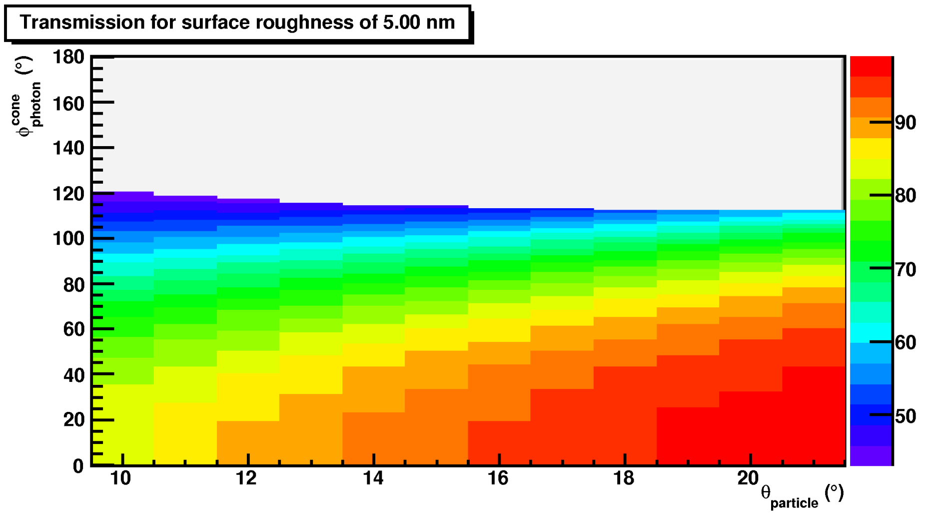
Performance Estimation - Cherenkov Photon Characteristics

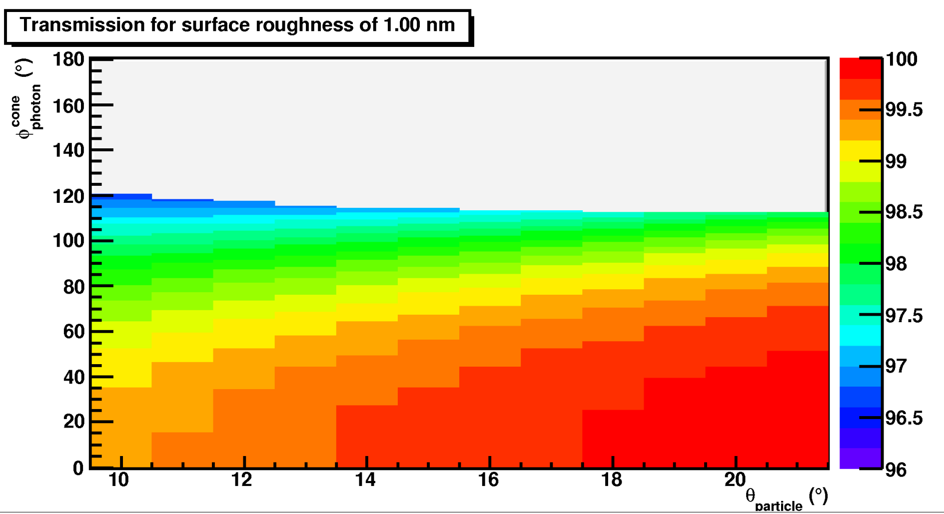
Average Number of Reflections



Performance Estimation - Cherenkov Photon Characteristics

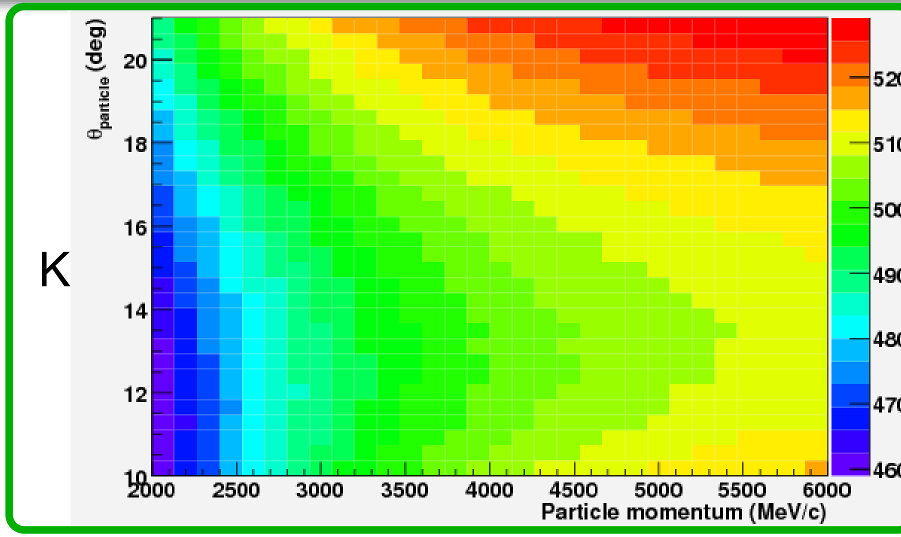
- Moderate photon path lengths (< 1.5m)
- Number of reflections is small (< 60)
  - Less tight conditions for surface
  - Surface roughness better than 1nm RMS
- BaBar DIRC
  - 200-400 reflections
  - Surface roughness 0.5nm RMS

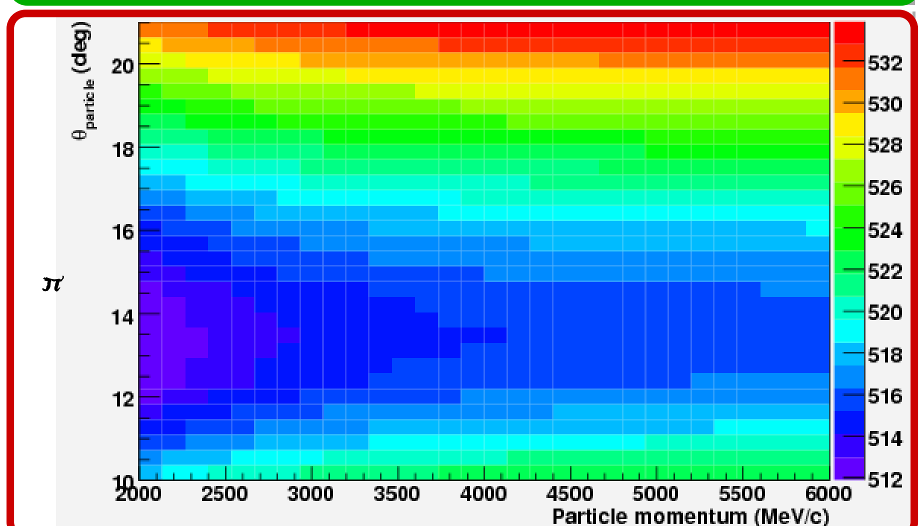




Performance Estimation - Cherenkov Photon Light Yield

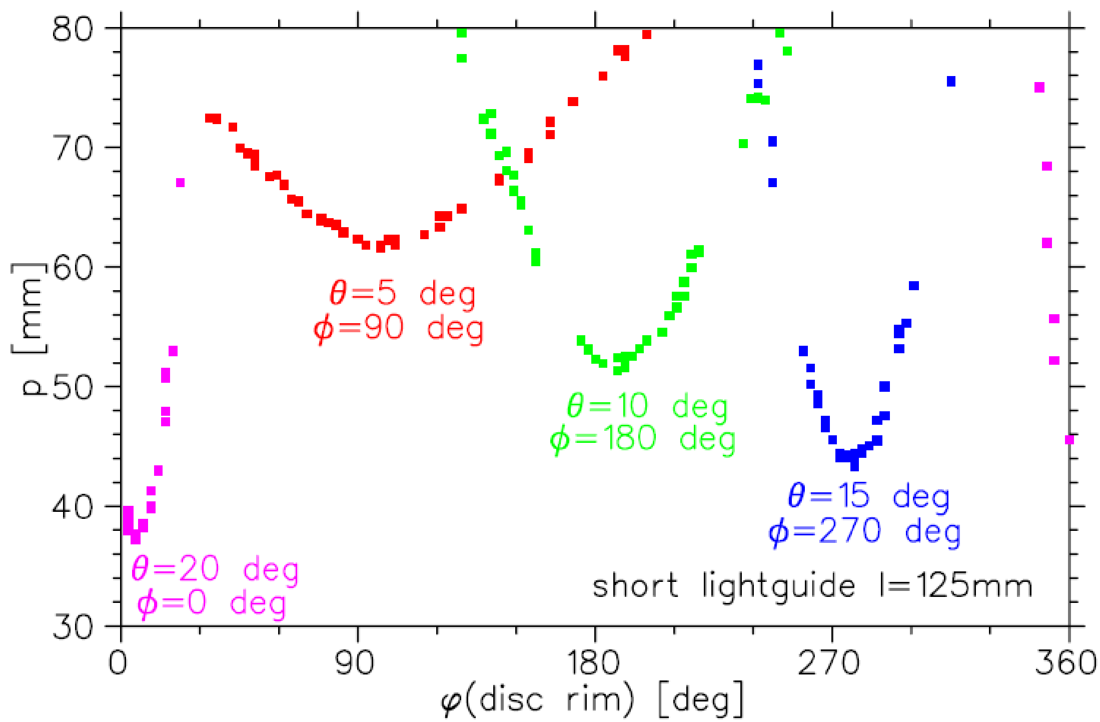
- Function of
  - Radiator thickness
  - Particle velocity
  - Particle polar angle Θ
    - Trapping fraction
- No of detected photons
  - QE of PMT
  - Absorption losses
    - Bulk absorption
    - Reflection loss





Performance Estimation - Cherenkov Cone Patterns

- Expected hit pattern
  - Hyperbolic shape
  - Apex most important
- Required
  - 2D hit pattern
- Timing information
  - Additional coordinate
  - Clean up pattern space



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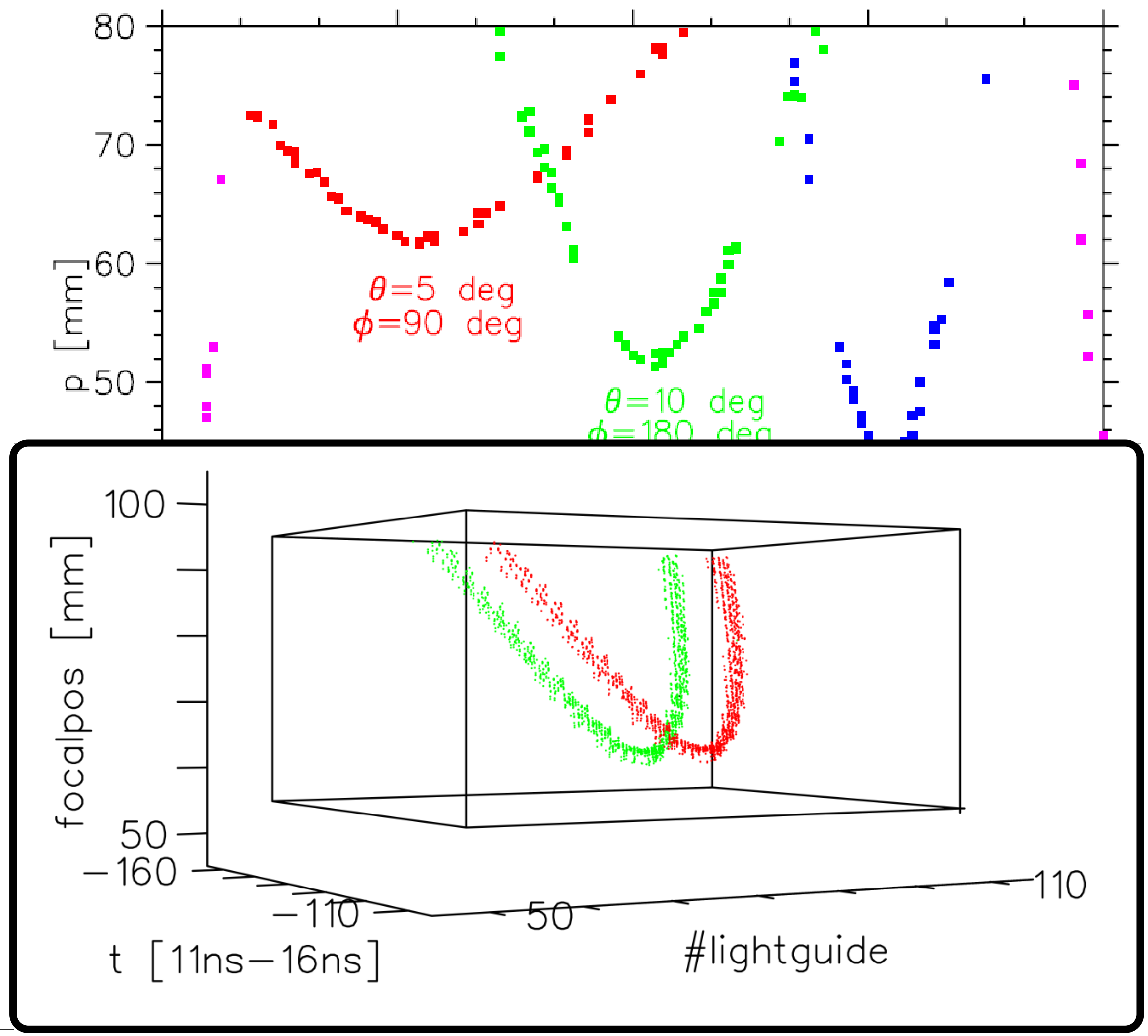

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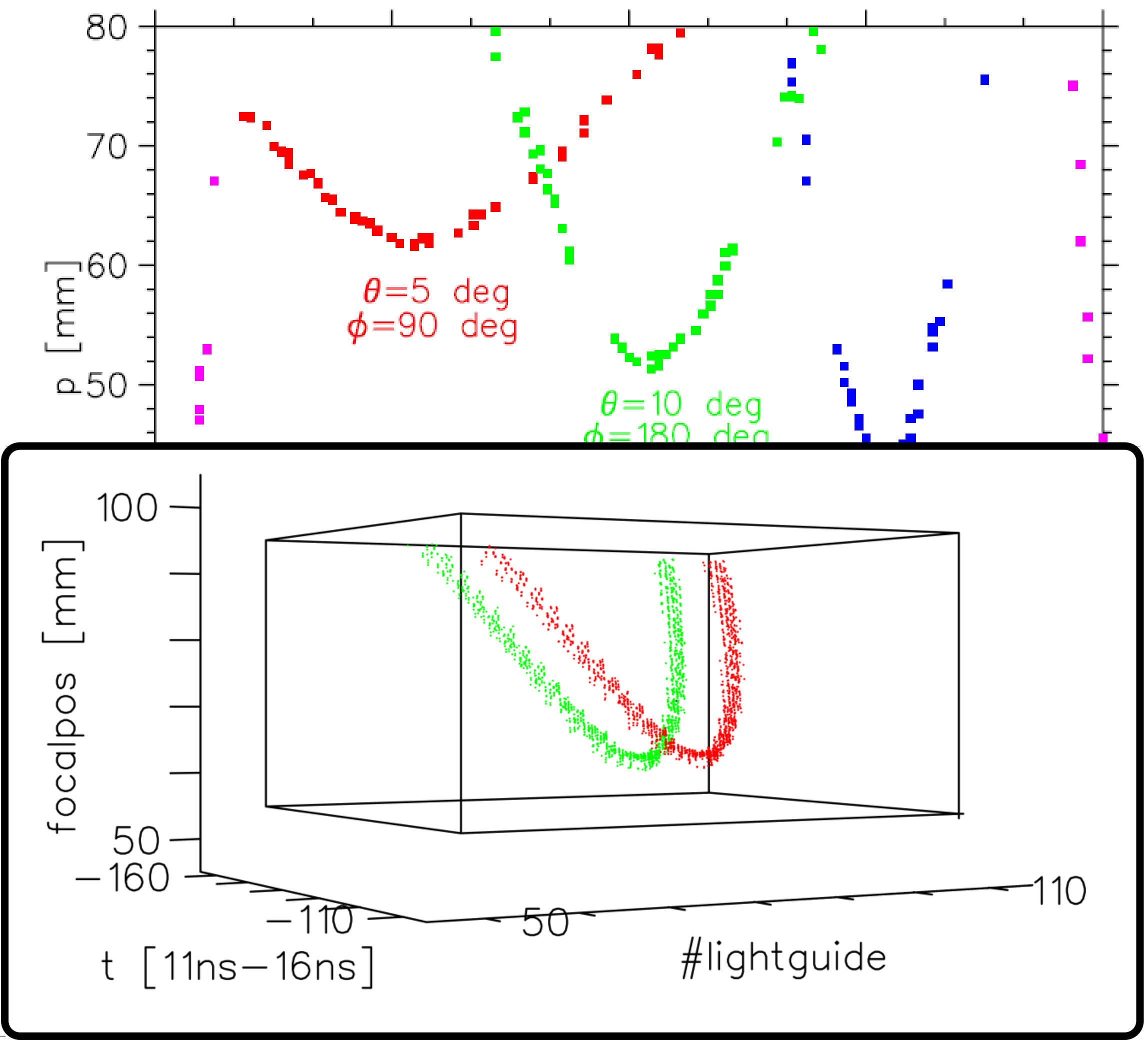

See Gordon Hill's talk, Wed 14:00

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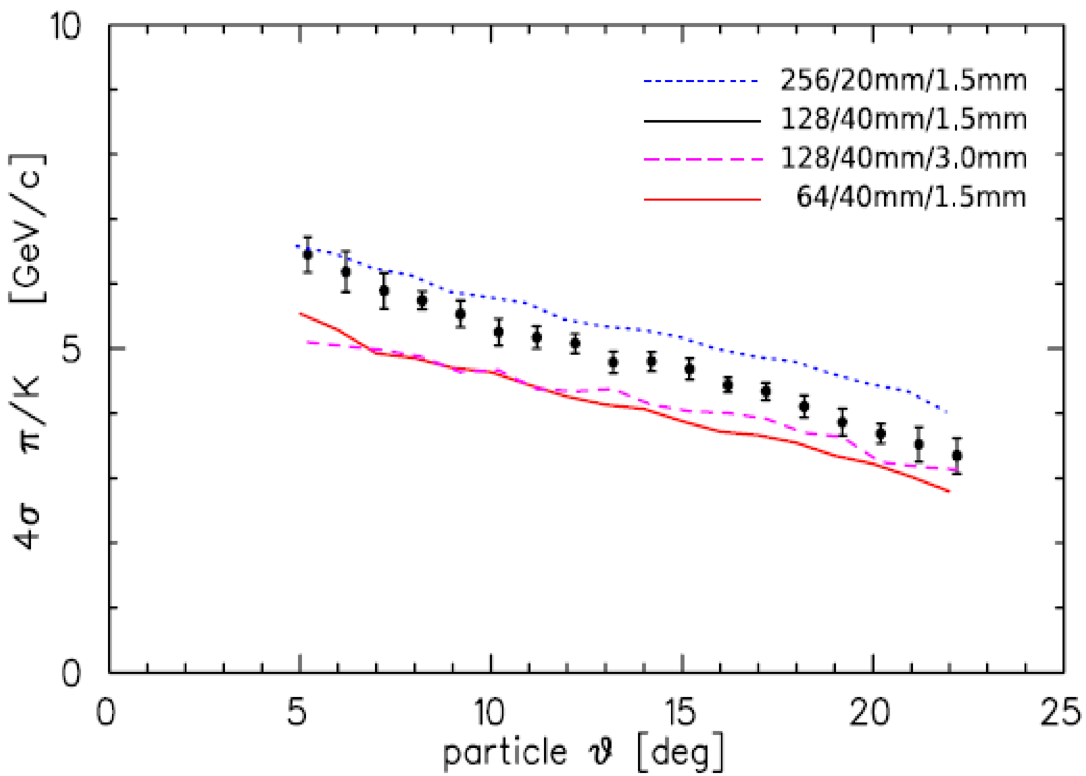
Performance Estimation - PID Performance (π -K Separation)

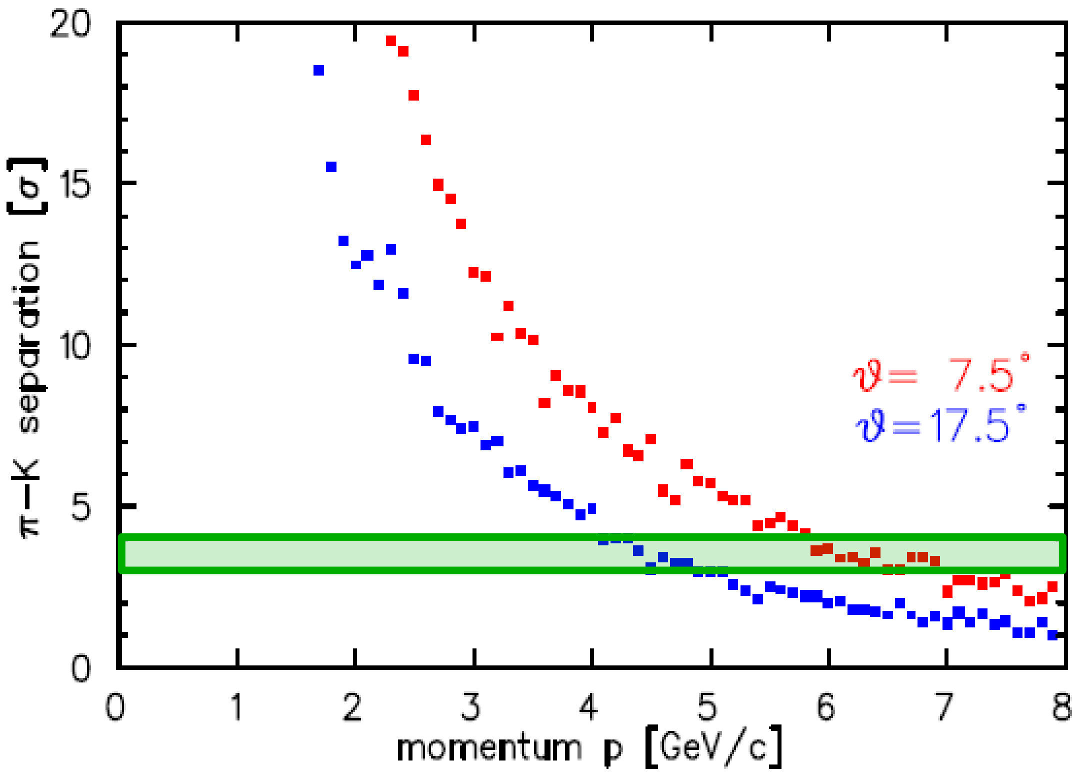


- Performance depends on
  - Number of Focussing Lightguides (φ-resolution)
  - Strip pitch (θ-resolution)
- Current Base Design
  - 128 Lightguides
  - 1.5mm strip pitch
  - 4096 readout channel

➔ > 3σ π-K separation at 4-5GeV/c

University of Glasgow

Performance Estimation - PID Performance (π-K Separation)

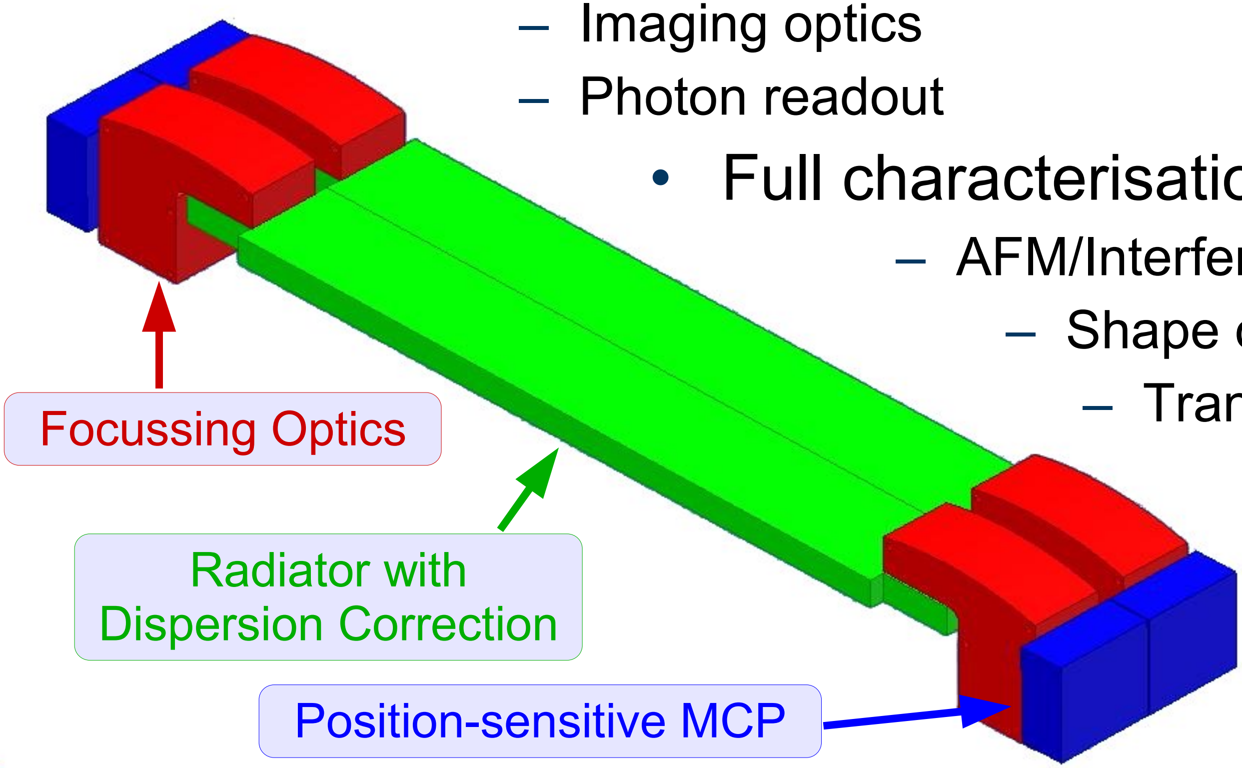


- Performance depends on
  - Number of Focussing Lightguides (φ-resolution)
  - Strip pitch (θ-resolution)
- Current Base Design
  - 128 Lightguides
  - 1.5mm strip pitch
  - 4096 readout channel

➔ > 3σ π-K separation at 4-5GeV/c

Outlook - Prototype Design

- Test core features of Focussing Design
  - Dispersion correction
  - Glue joints
  - Imaging optics
  - Photon readout
- Full characterisation of components
  - AFM/Interferometer on surfaces
  - Shape of radiator bars (CMM)
  - Transmission
- Test Experiments
  - Mixed hadron beams (GSI)
  - Electrons (Glasgow)



Conclusions

- Design
  - Using DIRC principle with new geometry
  - Dispersion corrction with optical elements
  - Spatial hit information plus timing (2D + t)
- R&D Efforts
  - Radiator materials
  - Photon readout in high magnetic fields
  - Fast FEE
- Constructing prototype
  - Confirm design performance by 2011