University of Glasgow

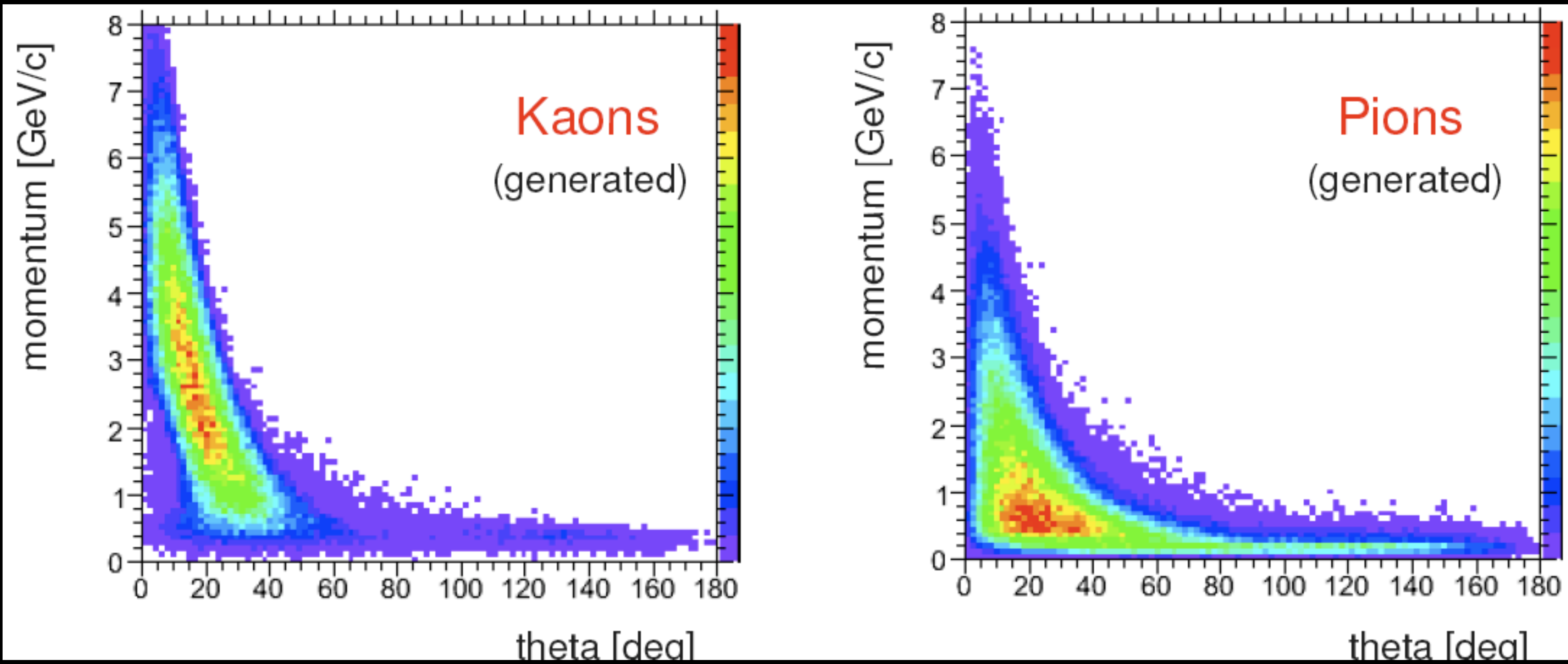
Focussing Disc DIRC Detector for PANDA

STFC Visiting Panel

Royal Institute of British Architects

London, 15/04/2008

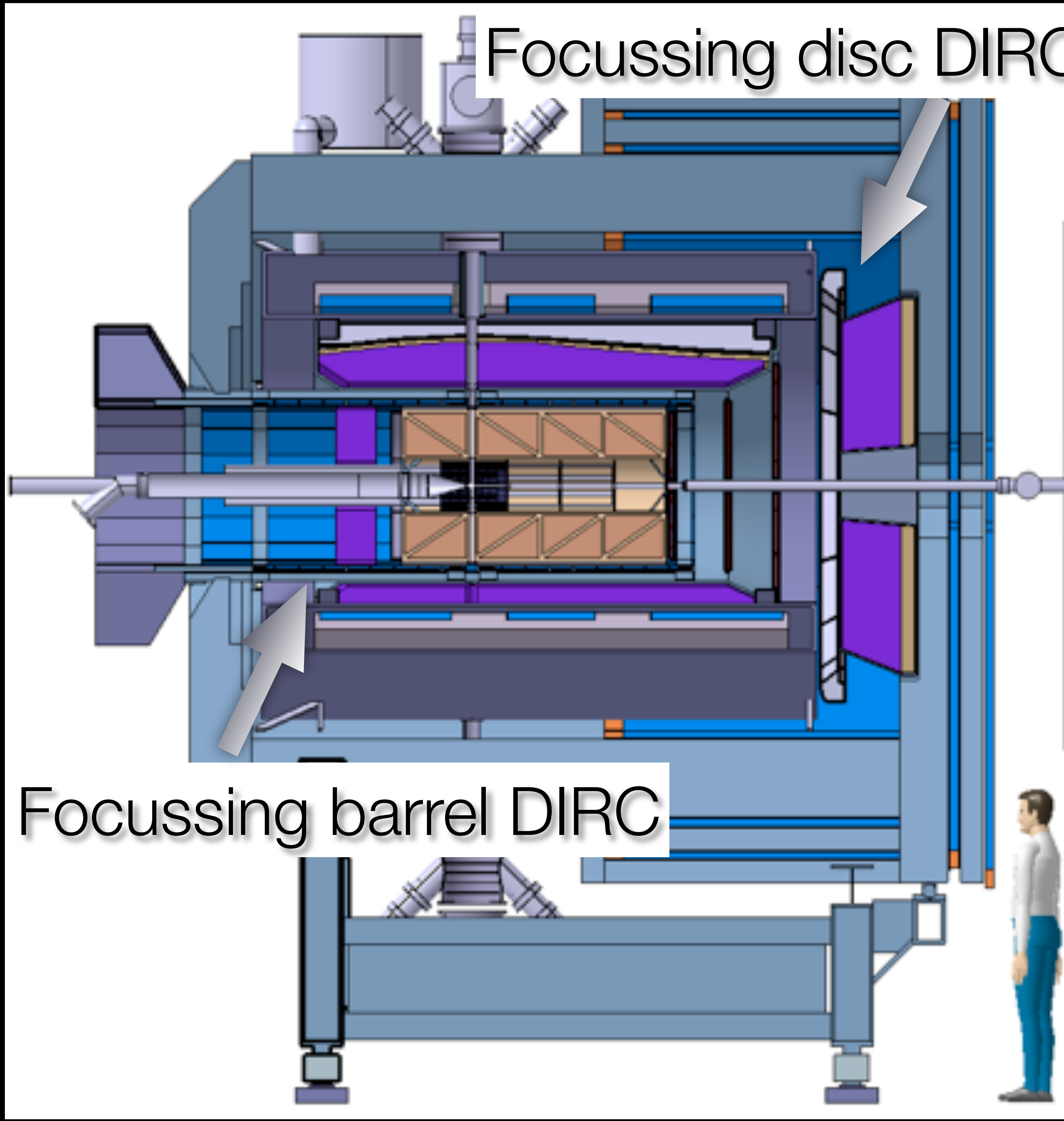
PANDA Physics Requirements



- Expected decays of glueballs and charmed mesons produce π/K with momenta > 6 GeV for θ <25°
- Need particle ID for reconstruction and PWA

The PANDA Experiment

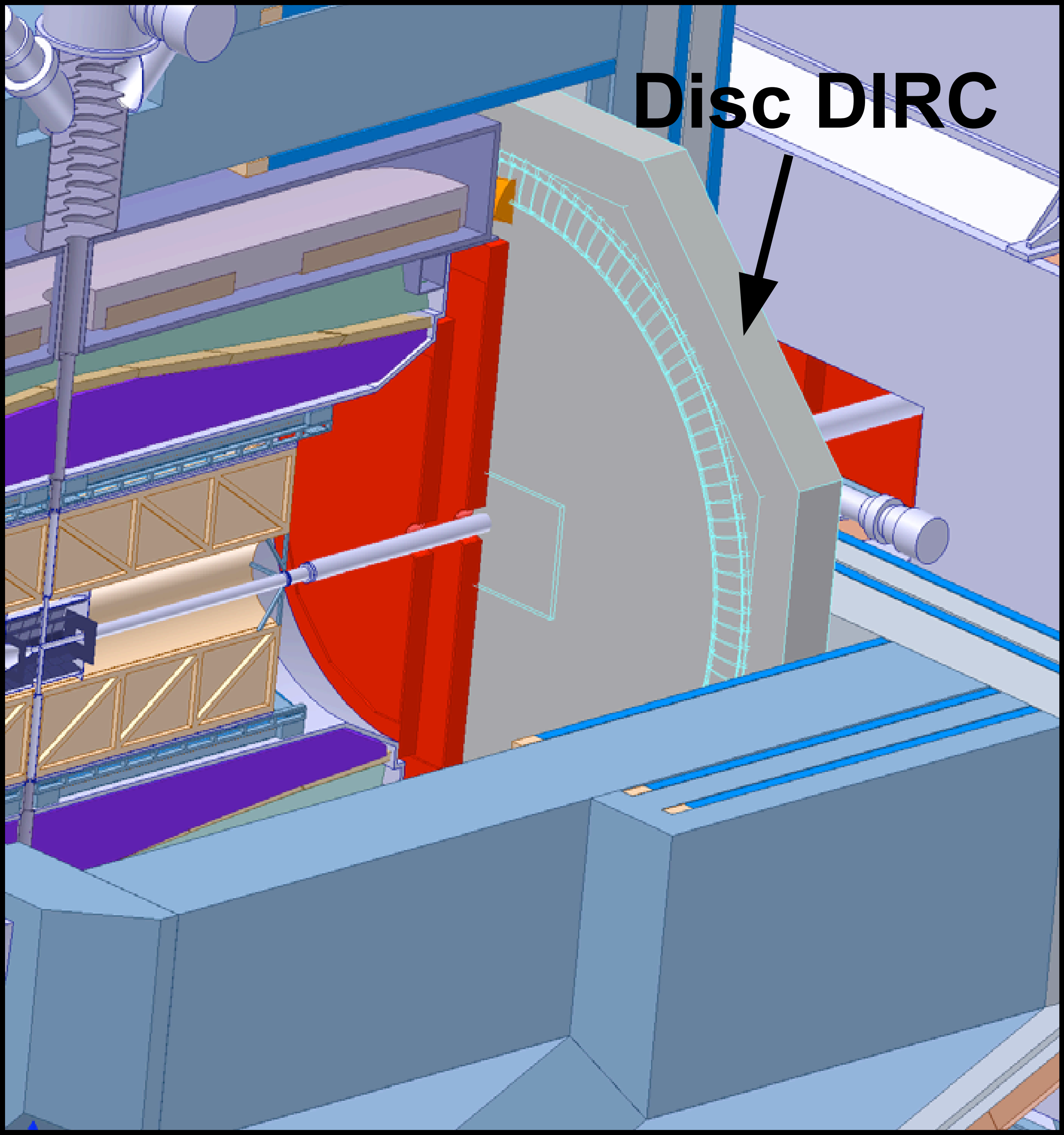
- PANDA is an anti-proton annihilation experiment at $\sqrt{s}$=5.5 GeV/c
- Full angular coverage and very good PID mandatory
- Detector has to stand 20 MHz interaction rates
  - radiation hard (>100krad)
  - high count rates (~1.5 MHz)
  - excellent time resolution (< 300 ps)
- Detector has to work in magnetic field up to 1.4 T
- small radiation length



Note: only target spectrometer shown

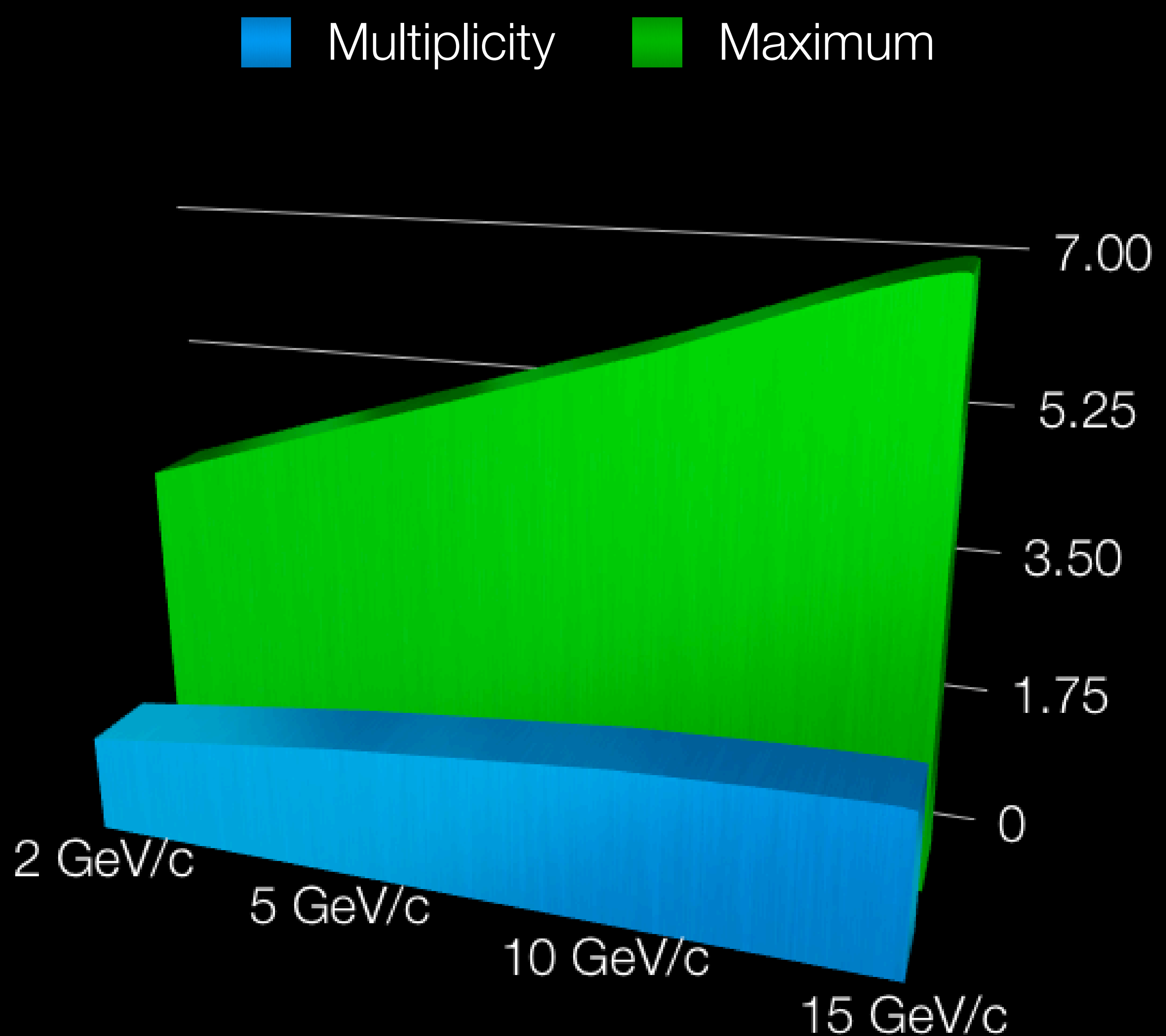
Focussing Disc DIRC

- Detection of Internally Reflected Cherenkov light
- 5° < θ < 25° angular acceptance
- Momentum range: 1 - 6 GeV/c
- Positive identification of π/K/p
- Compact detector: fused silica disc of 20 mm thickness and 1100 mm radius
- 128 focussing light guides
- readout by multipixel MCP PMT
- Dispersion correction by LiF



Particle Rates

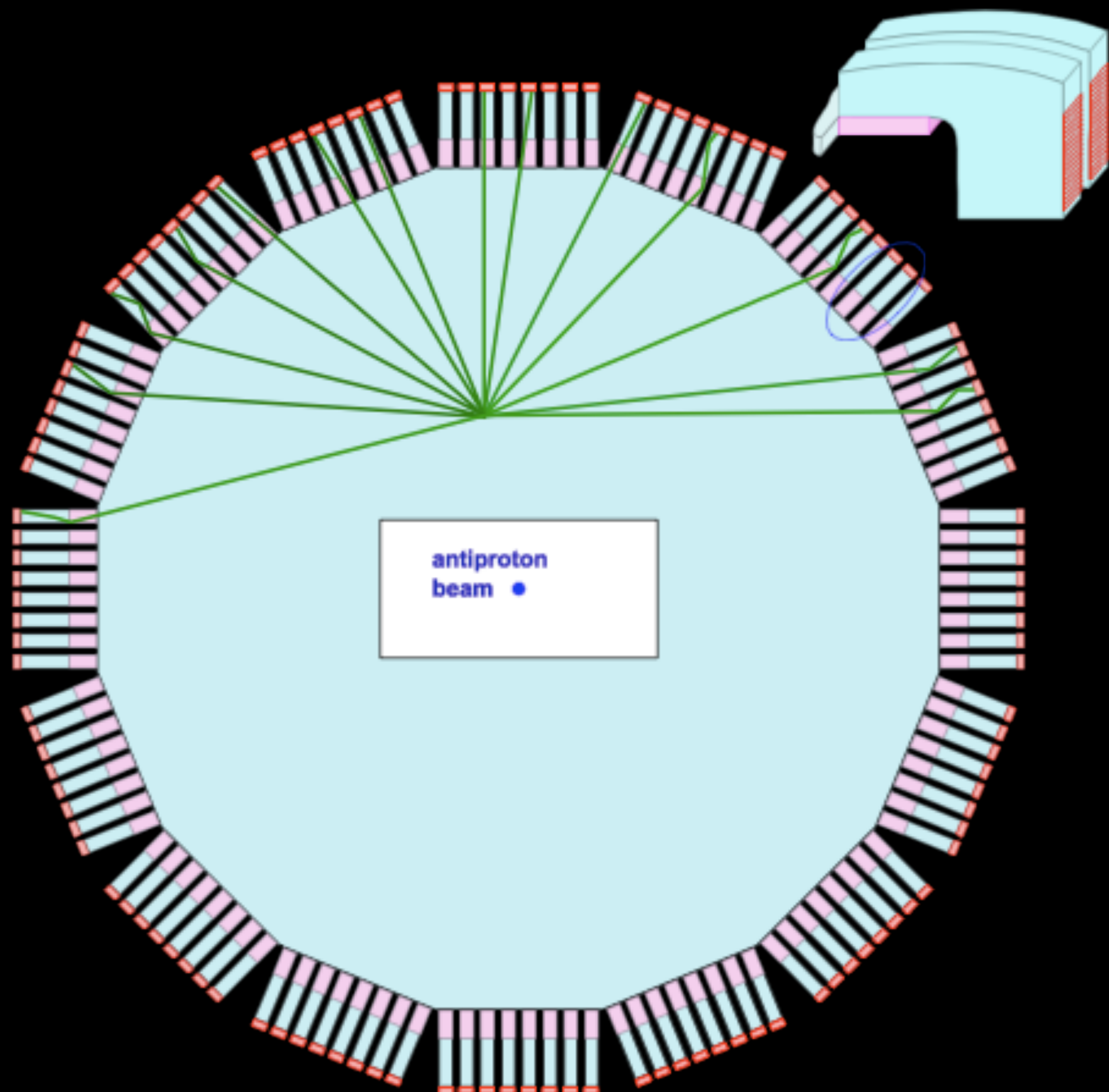
- Multiplicity estimated with *FastSimulation* based on DPM model
- Average multiplicity at full PANDA beam momentum ~2 charged particles/event arriving in < 1ns
- Pile-up probability <10% for 1ns gate
- resolved by fit in time and space



Photon Generation and Transport

Focussing DIRC Design

- Detection of Internally Reflected Cherenkov light allows to build thin radiators
- Focussing disc DIRC:
  20 mm radiator thickness,
  radius < 1100 mm
- Disc to be constructed from 4 + 2 pieces
- Surface roughness < 20 nm
- focussing elements ensure good imaging and compact detection plane (50x50mm^2)



Note: drawing no to scale

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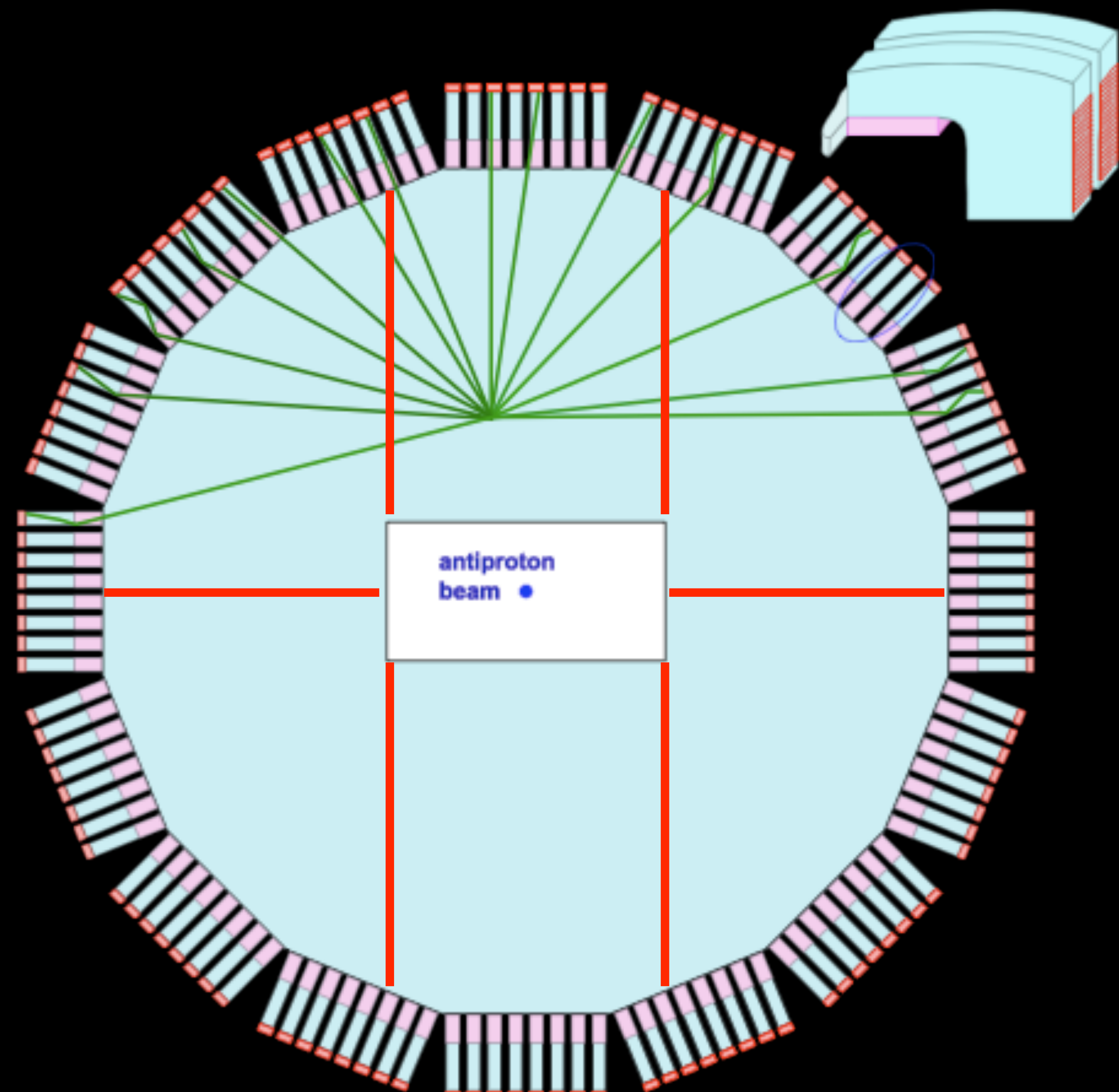

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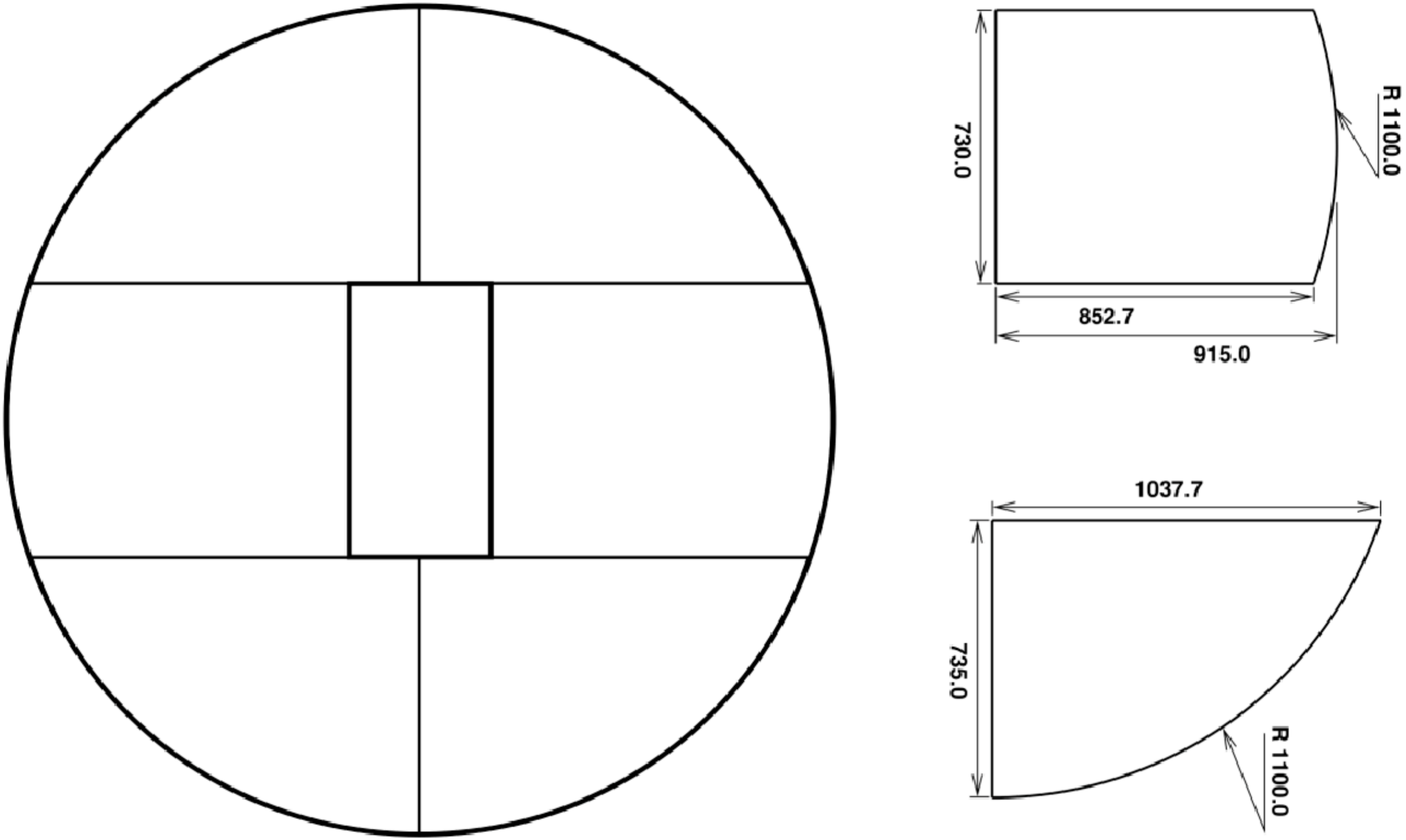
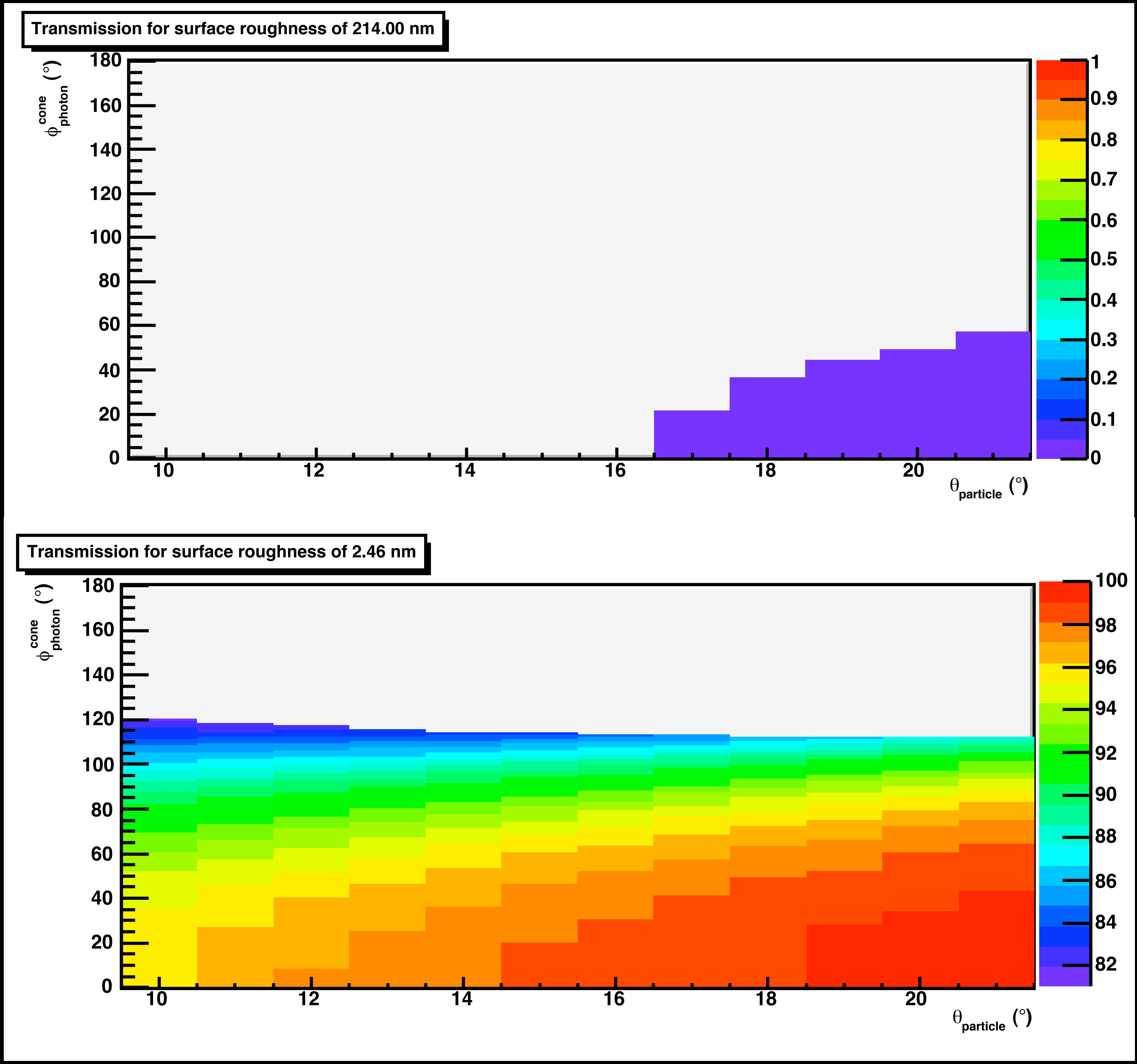
Disc cutting details



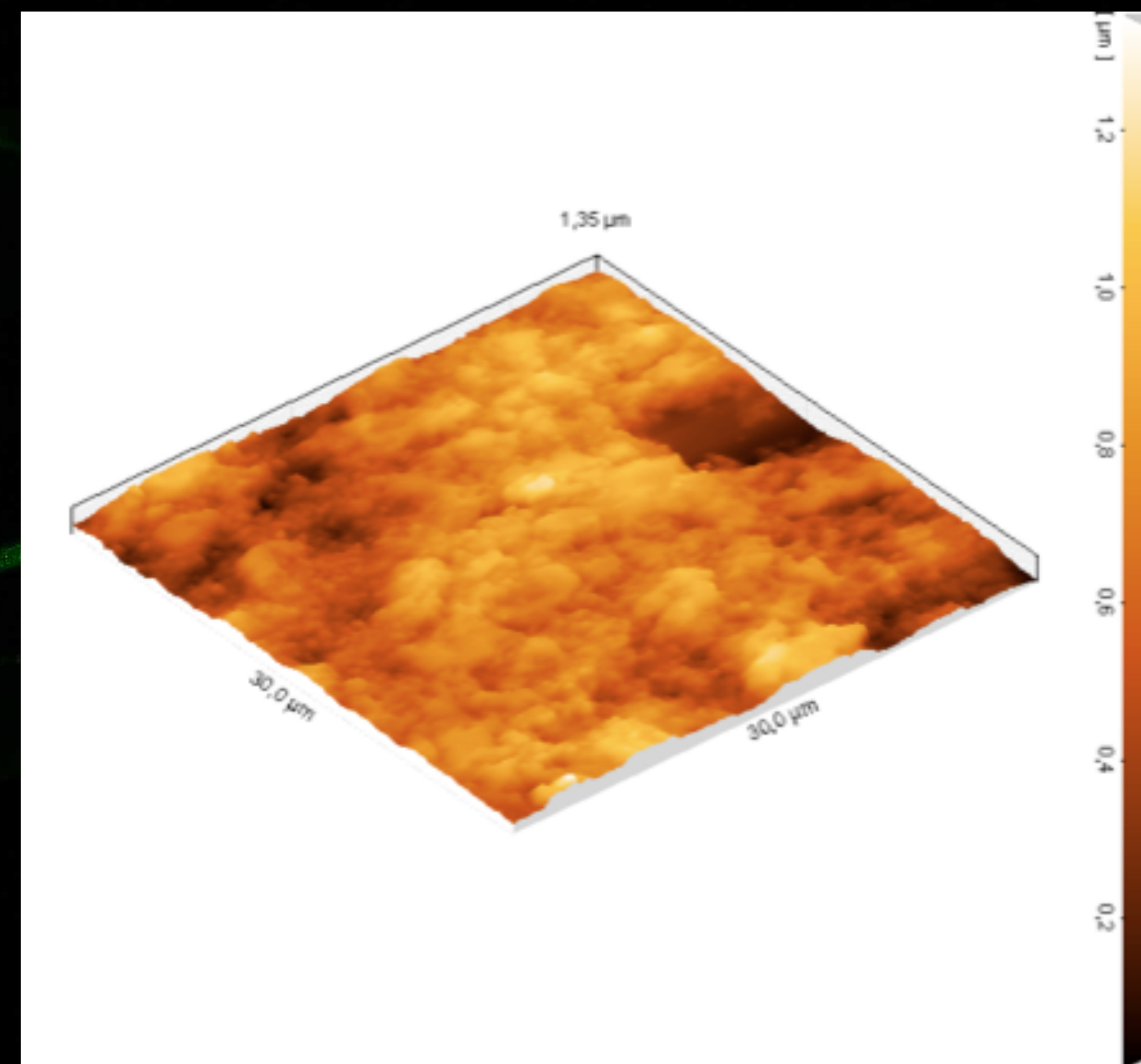
Surface requirements

- Surface quality of industrial fused silica (unpolished) leads to very high losses at each reflection
- Polished surfaces guarantee high light output
- Examples from PANDA polishing tests (INFN Ferrara)



Radiator tests

- High optical quality is mandatory for solid radiators
- Radiator surface polishing is crucial
- Employ different test methods
- Precision on single measurement < 0.1%
- Reproducibility < 0.5%



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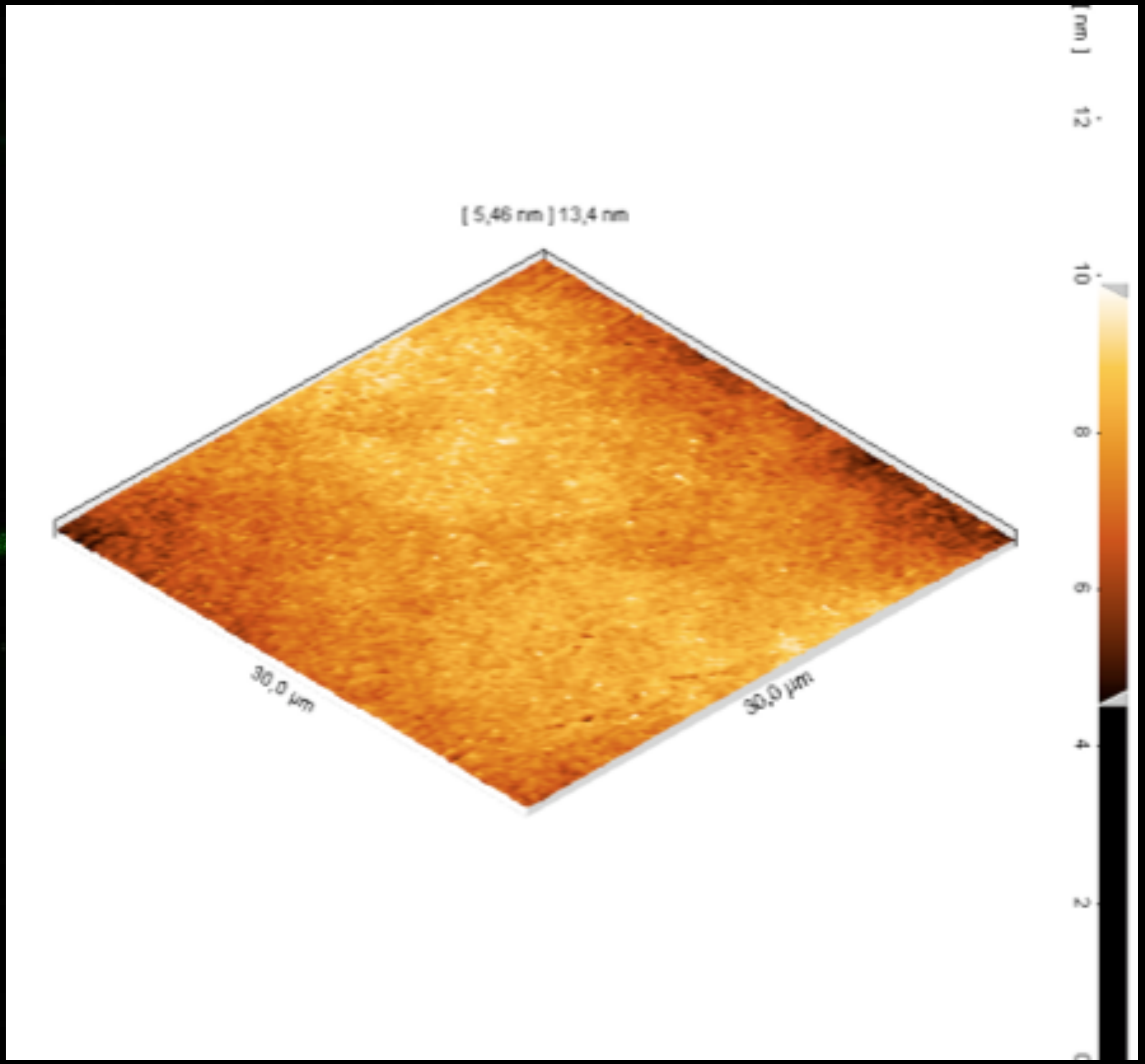
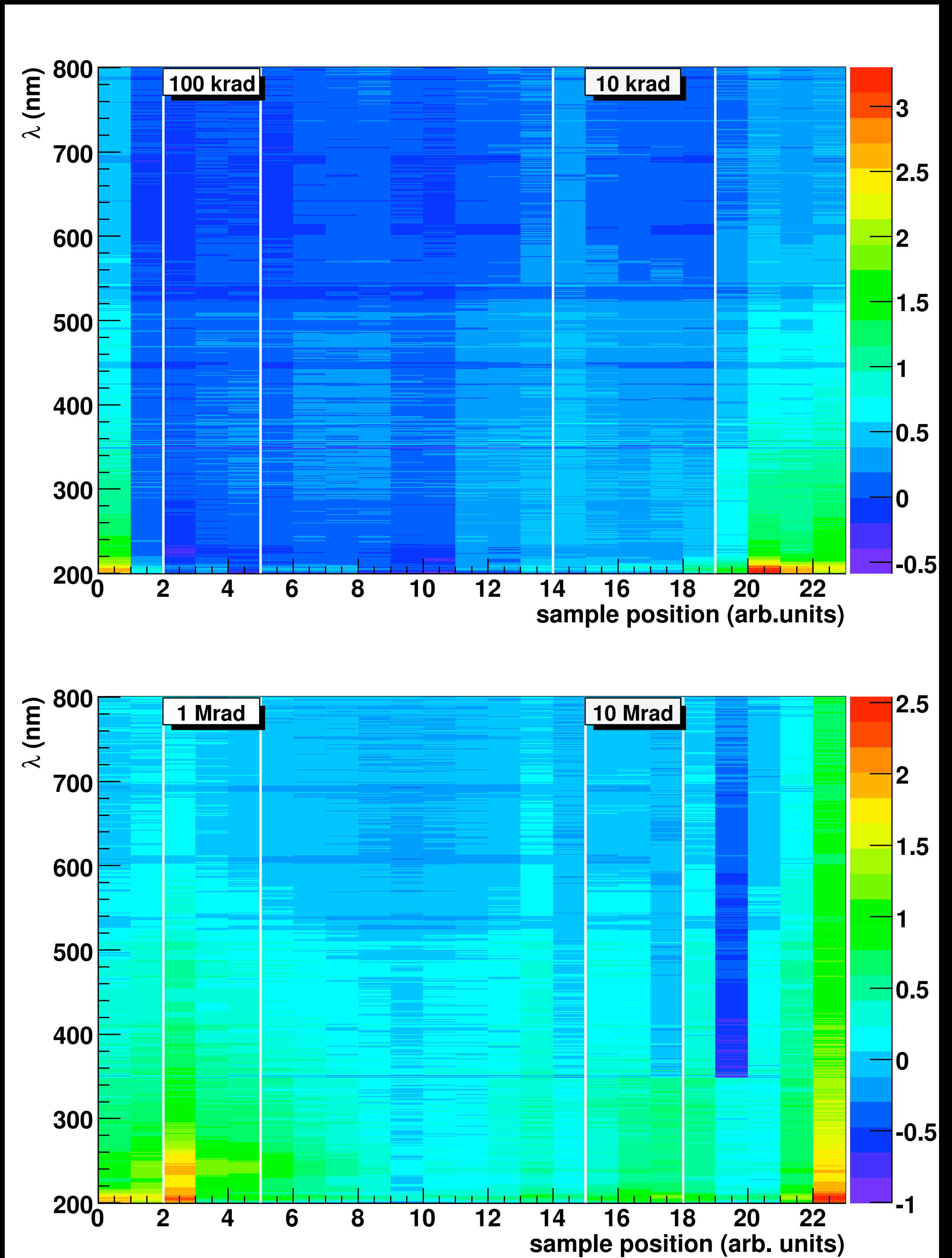


Radiation hardness tests

- Evaluation by CARY 300 photo spectrometer
- Sensitivity better than 1%
- Samples measured before and after irradiation
- Method tested using normal glass susceptible to radiation damage
- Radiation band observed in LiF, no radiation damage seen in all three fused silica samples



Cherenkov Image Reconstruction

Expected Detector Performance

- Cherenkov images will be pattern in θ/ϕ space
- θ will be measured by PMT
- ϕ is given by the light guide width
- Pattern are widely spread in ϕ
- Performance increases with stand-off distance

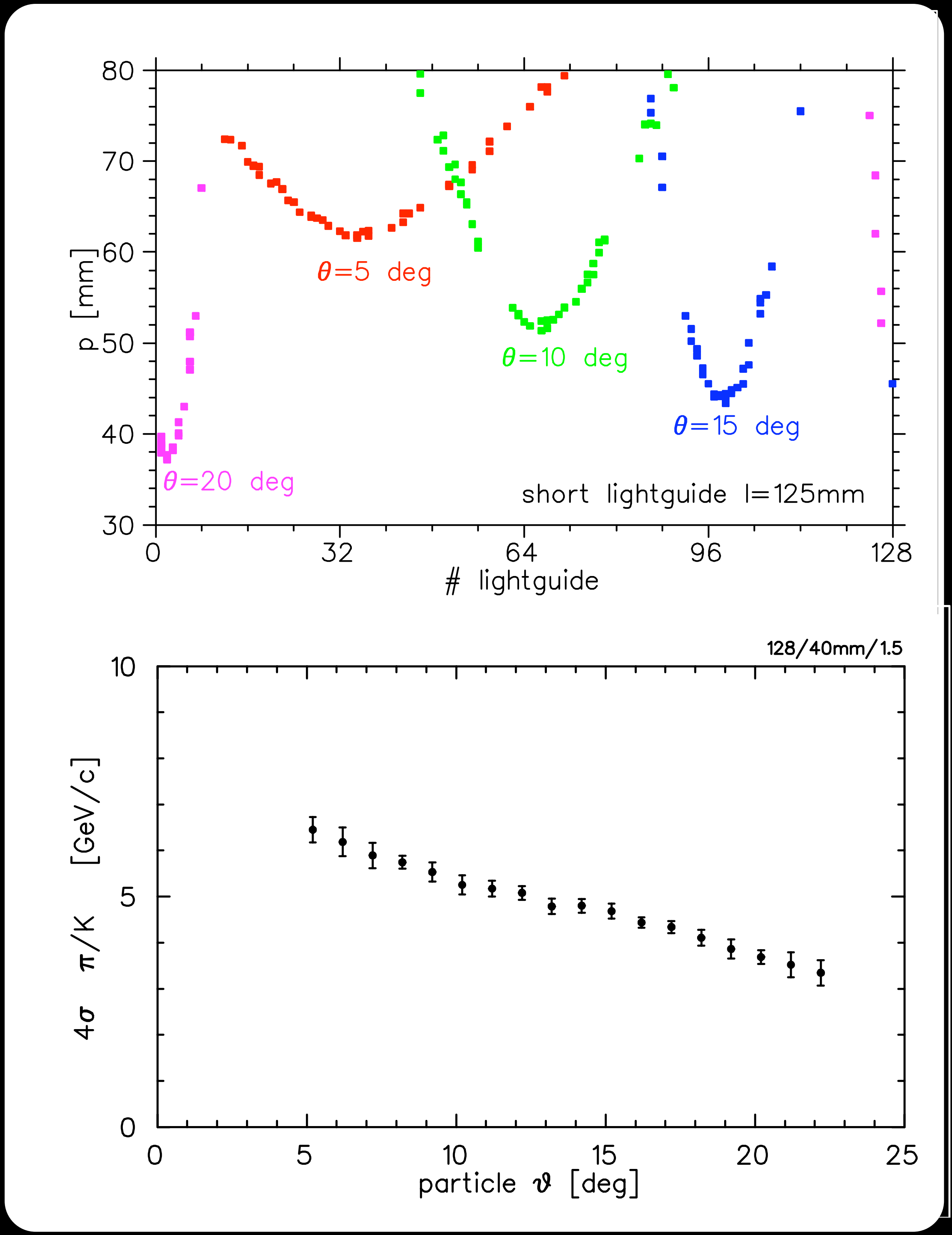
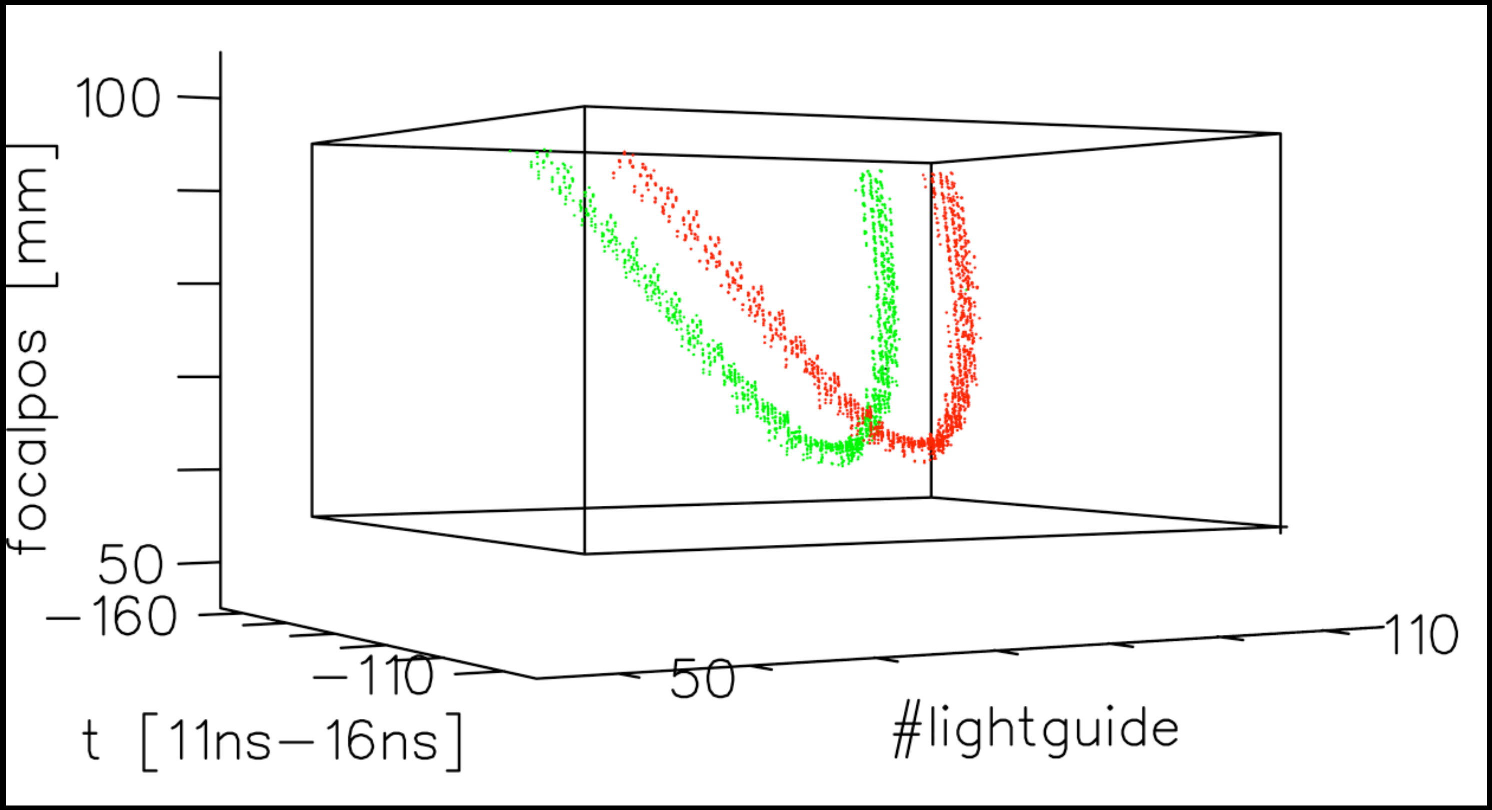


Image Reconstrucion

- Define road in 2D+t space for pi/K/p hypothesis based on tracking information
- Timing information resolves ambiguities
- Studies show possible mass reconstruction and resolution



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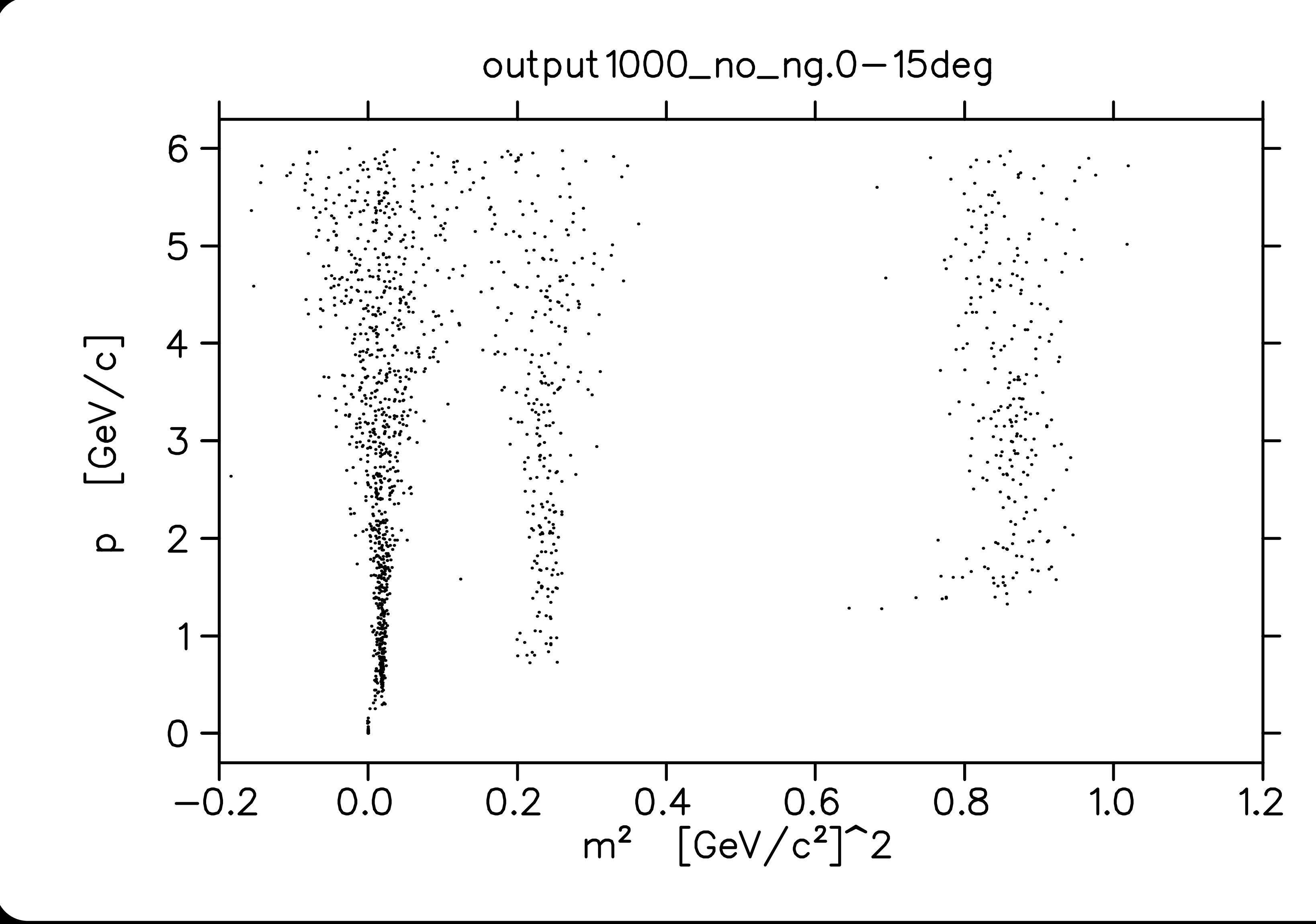
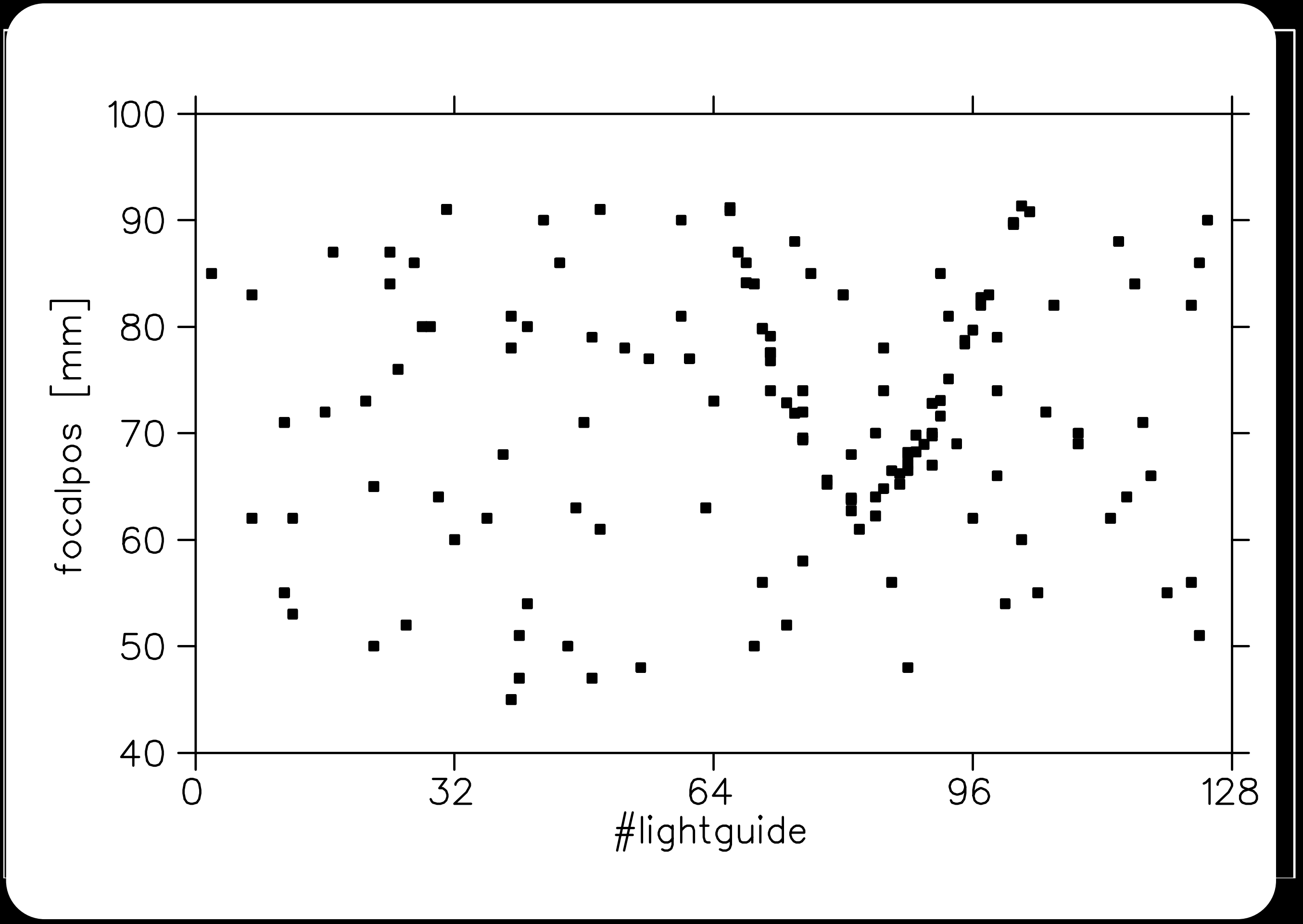


Sensitivity to Noise

- Reconstruction was studied for 3 noise scenarios
  - no noise
  - S/N = 1/1
  - S/N = 1/6
- Fitted mass resolutions agree within errors



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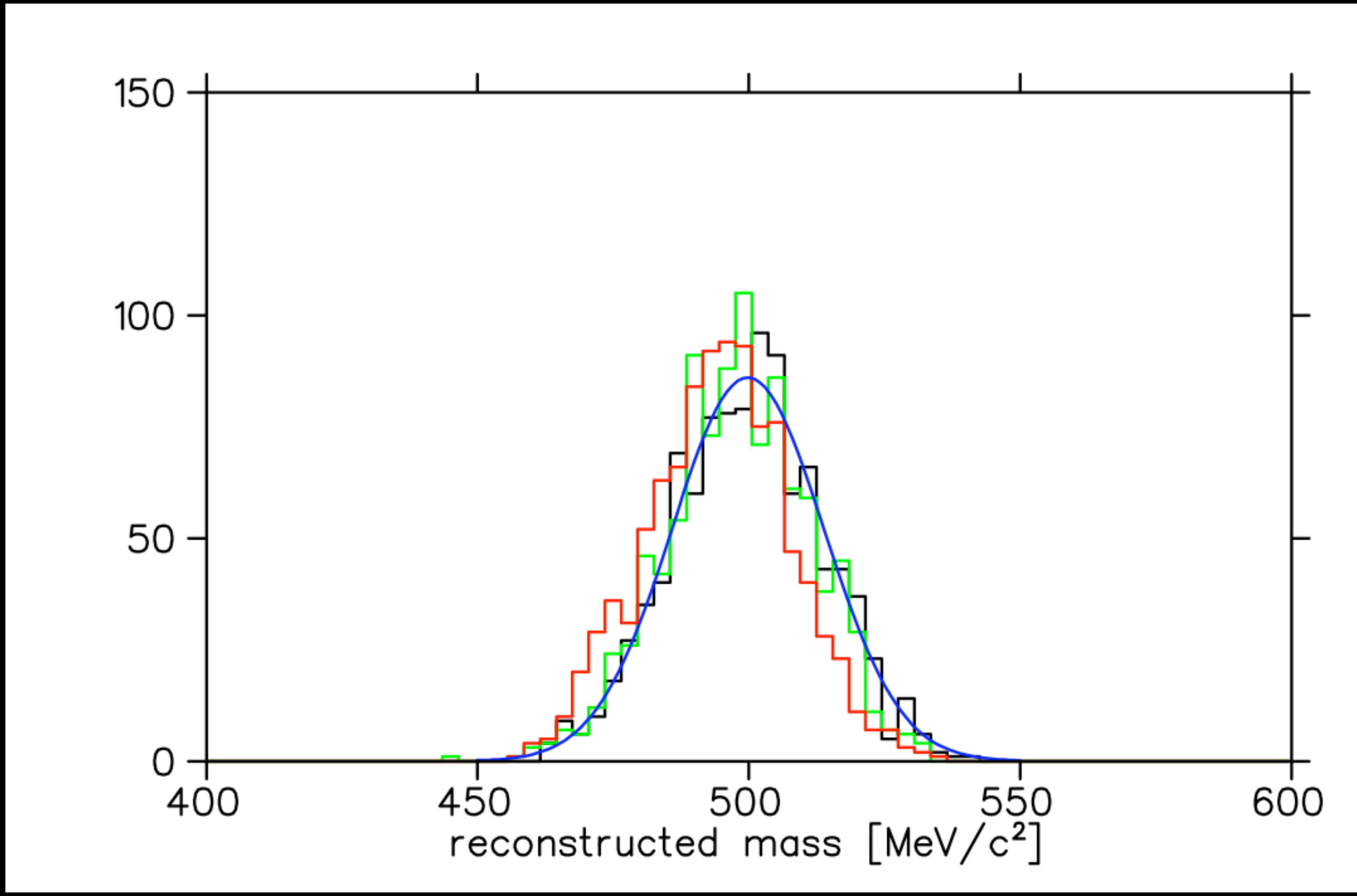
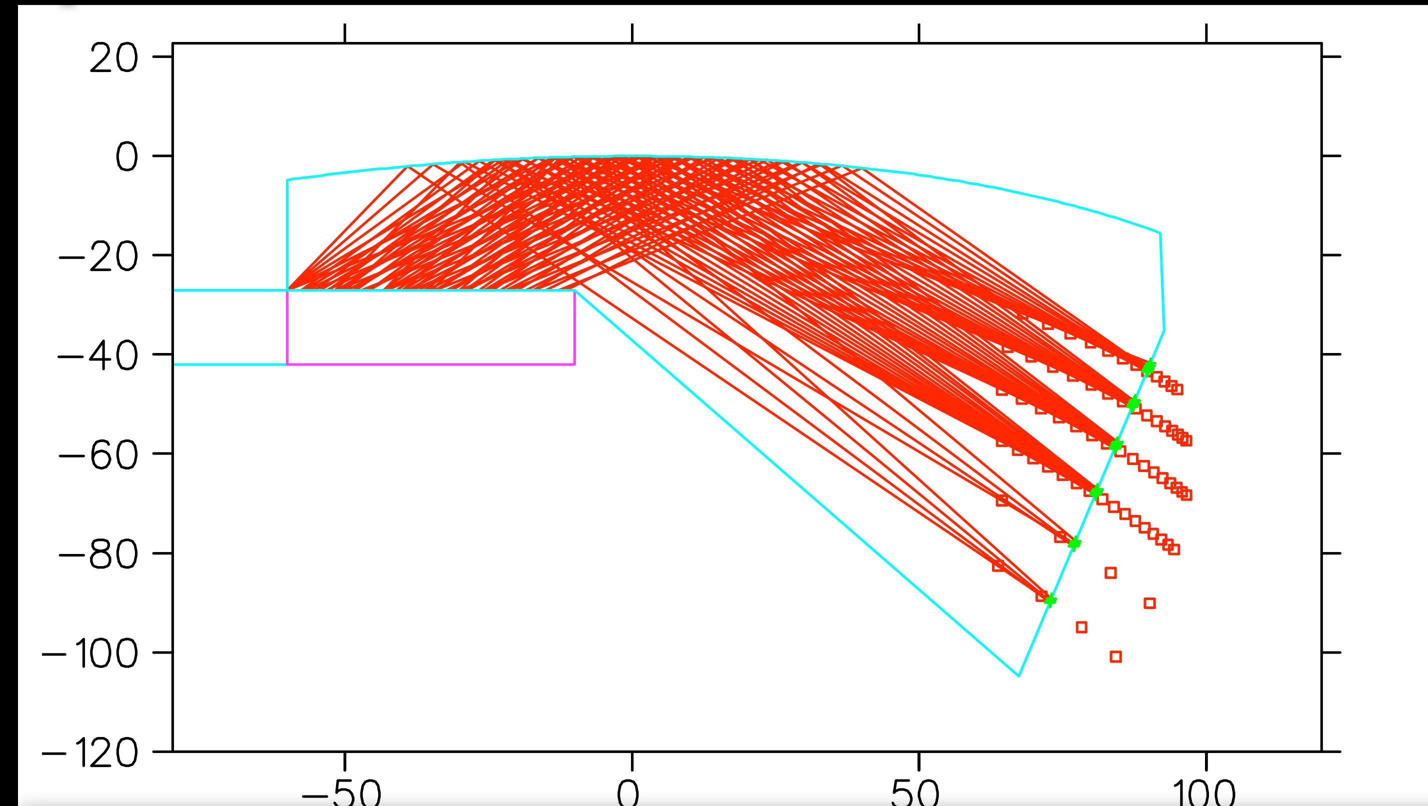
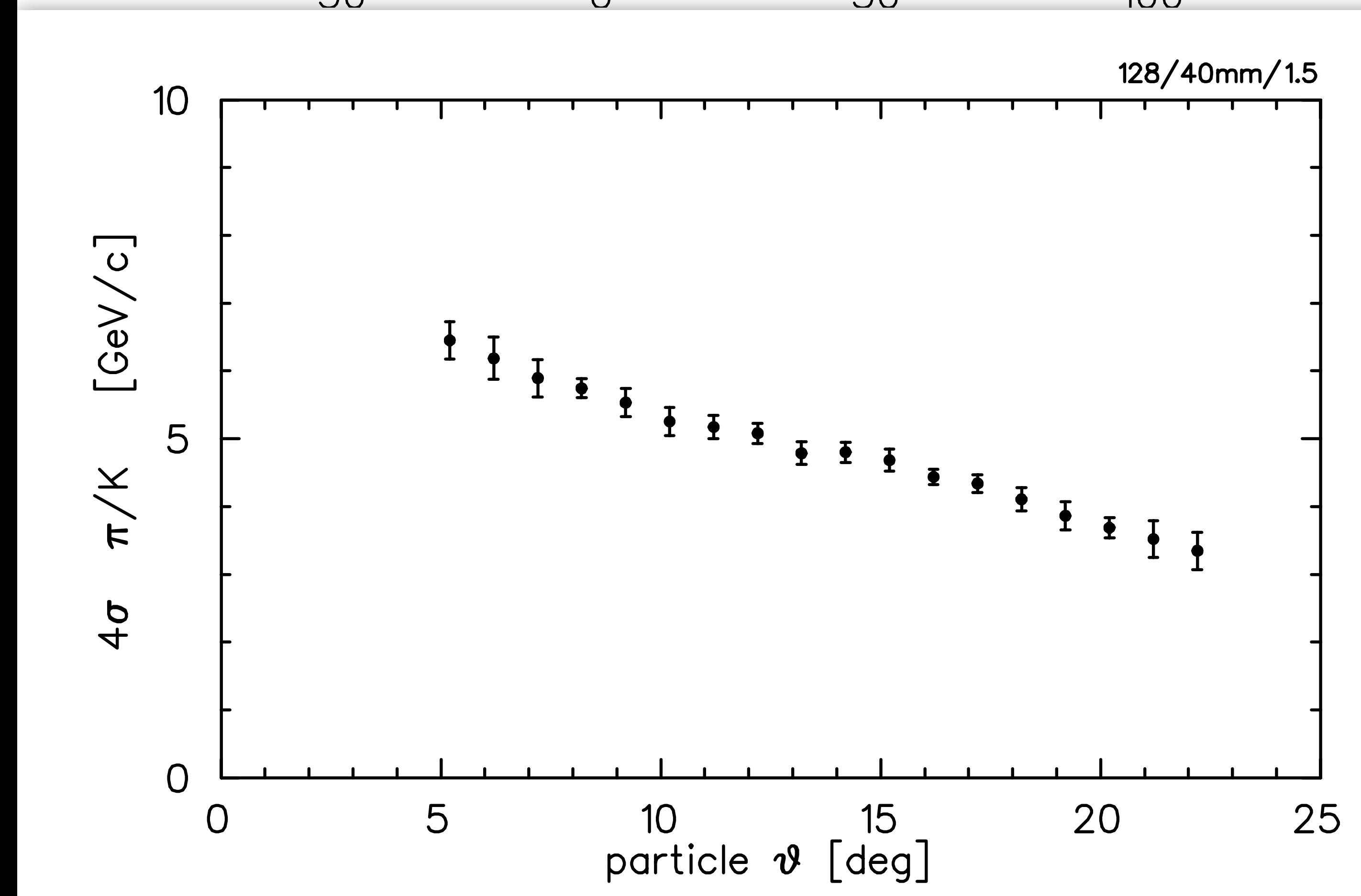


Focussing Optics

- Lightguide design optimised for 50x50mm2 focal plane matching available MCP-PMTs
- Some freedom in orientation of focal plane to optimise performance in magnetic field
- Performance study for 1.5 mm strip pitch and and 3 mm strip pitch
- Include LiF for dispersion correction





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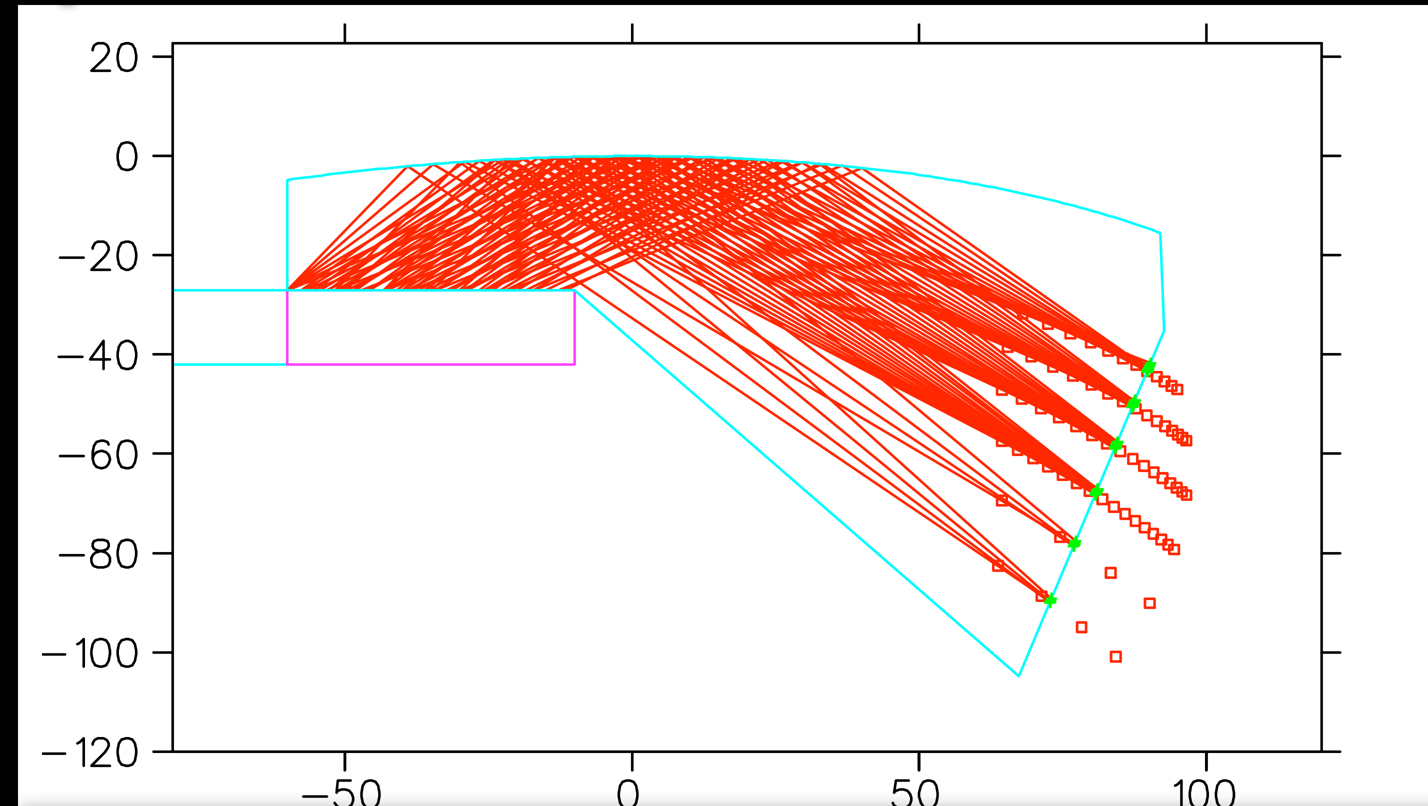
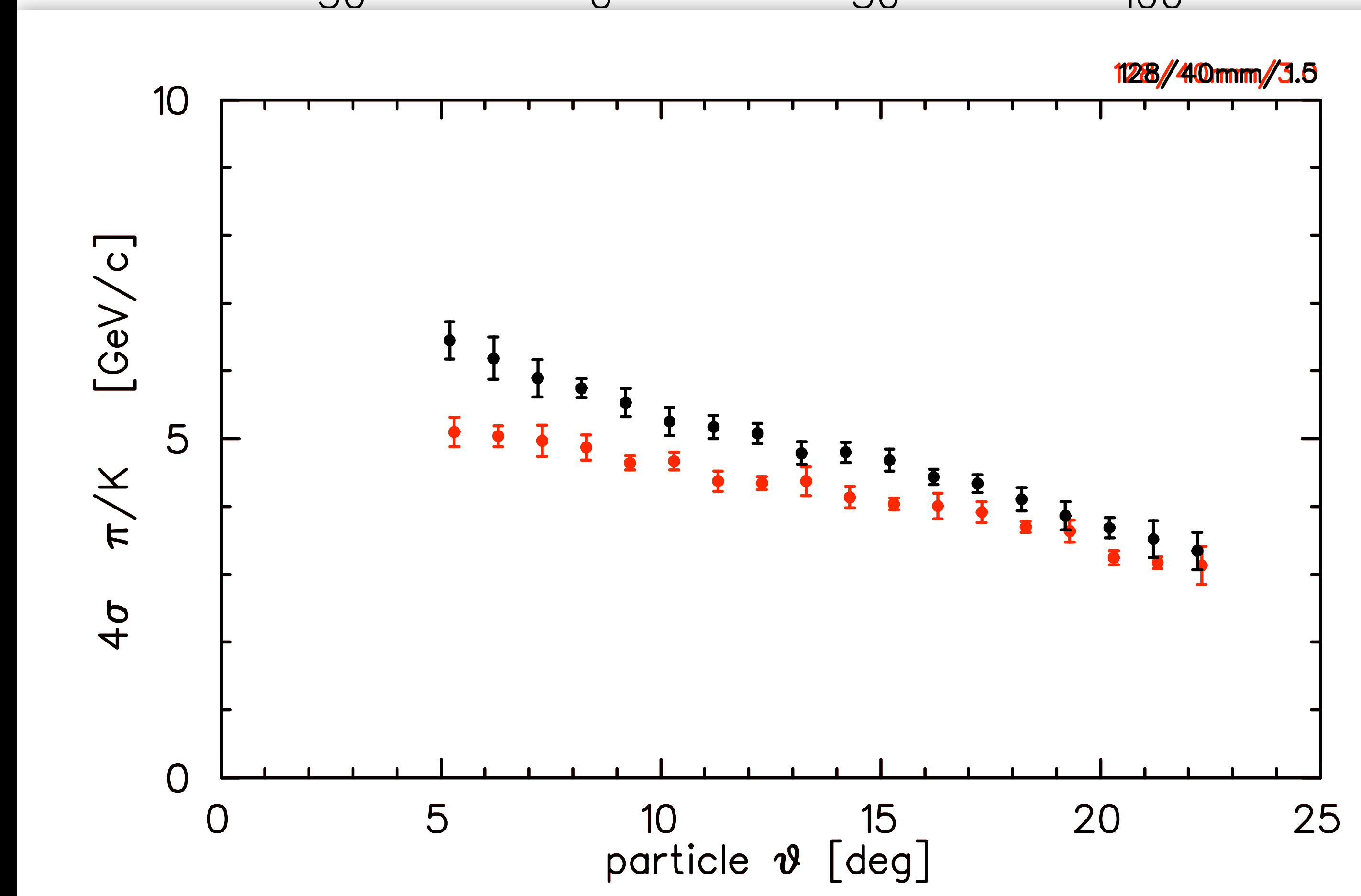
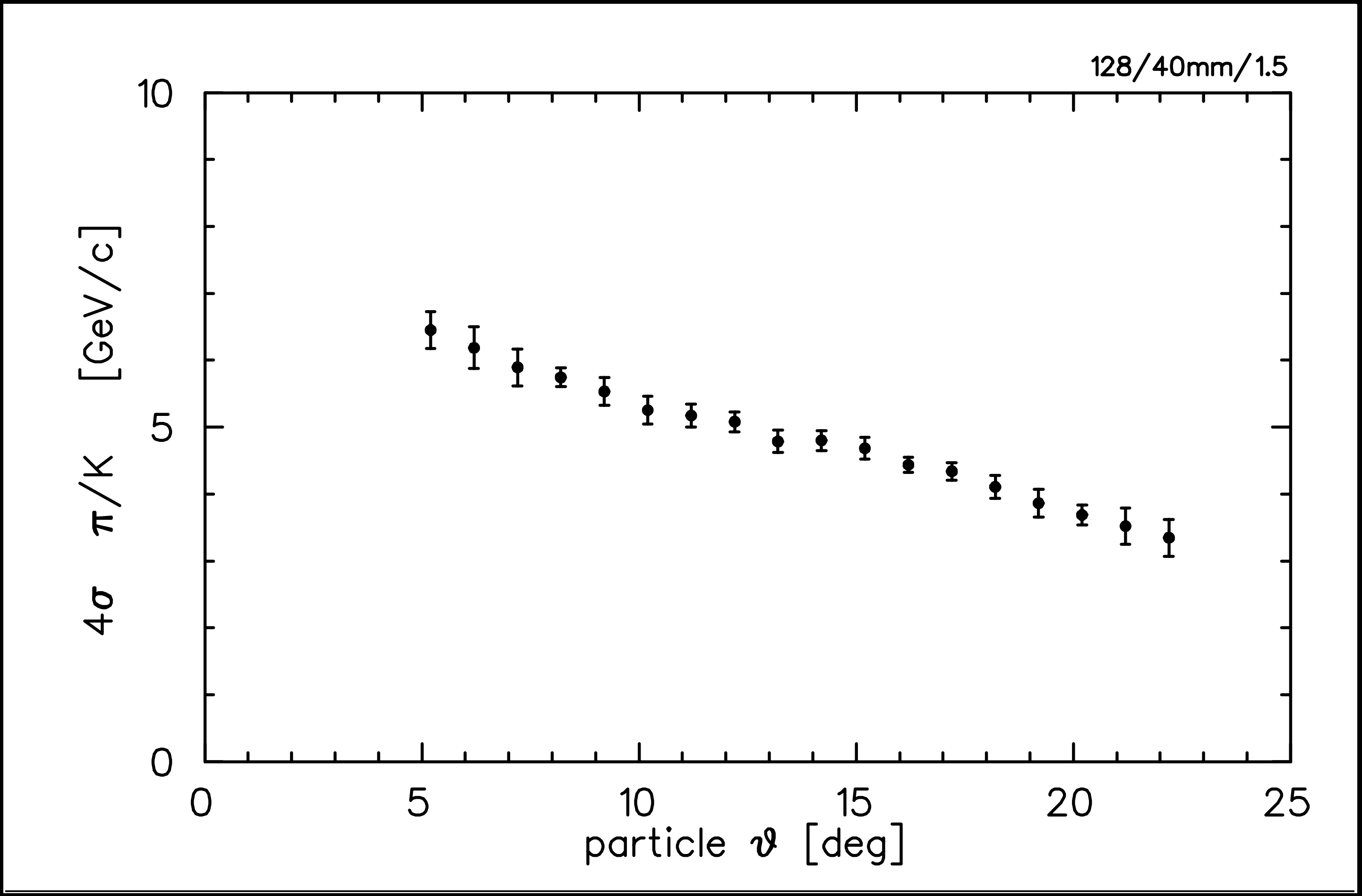




Light guide width

- Studies performed to optimise the width of lightguide
- This is equivalent to resolution in Φ
- studied 128 LG, 64 LG and 256 LG with same pixel size in θ (1.5 mm)
- 128 LG is a compromise between performance and read-out cost



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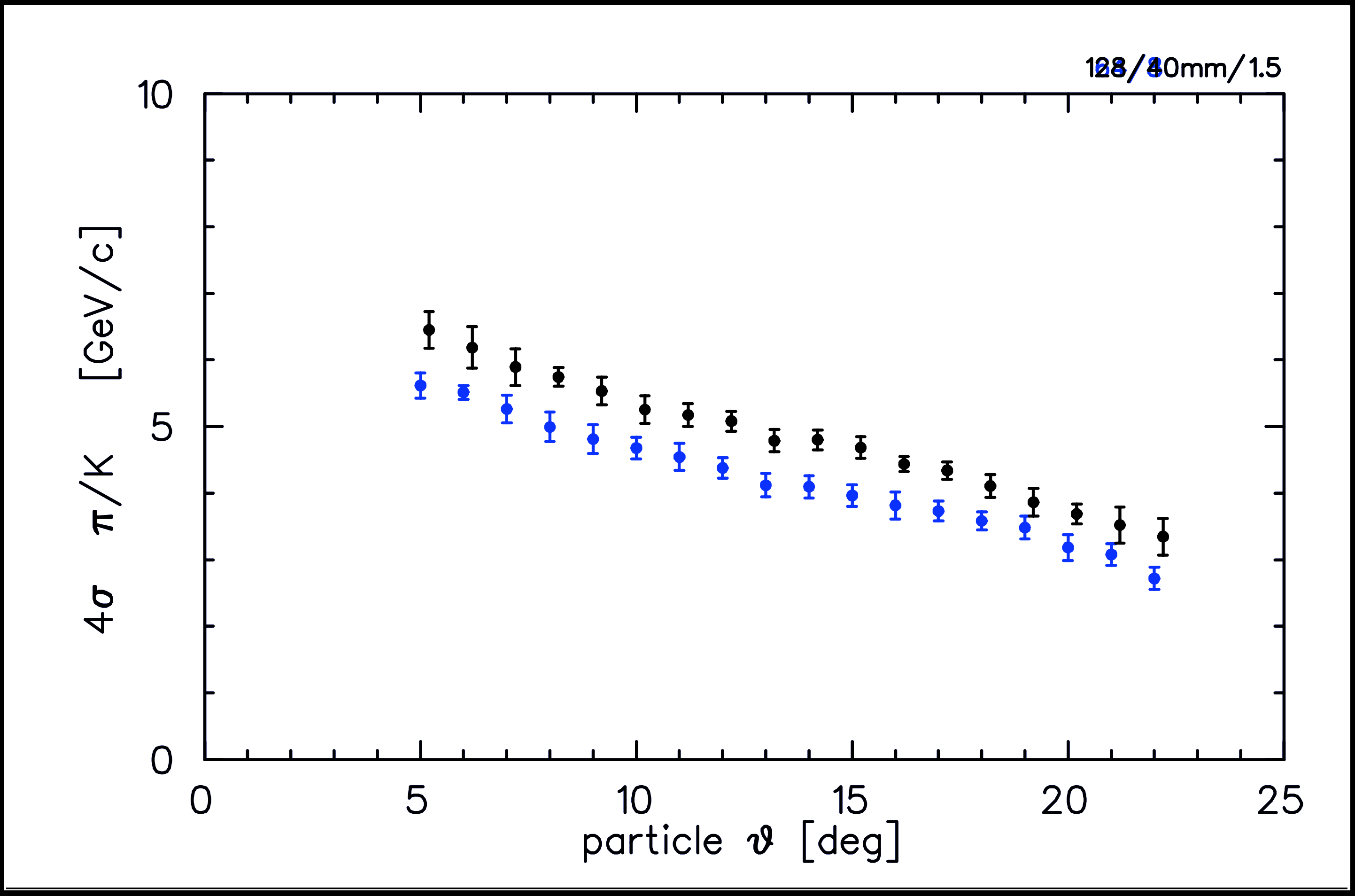

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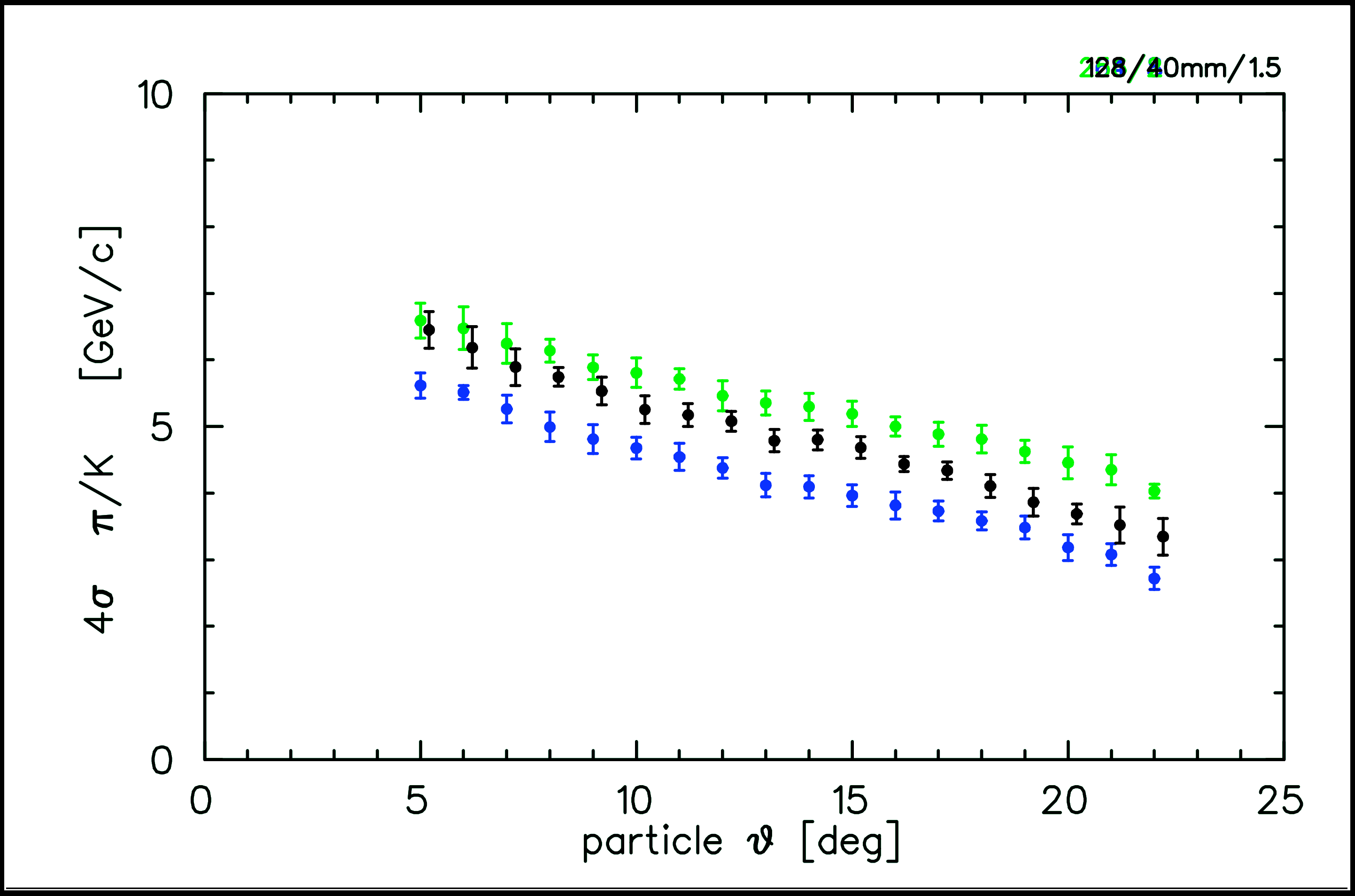
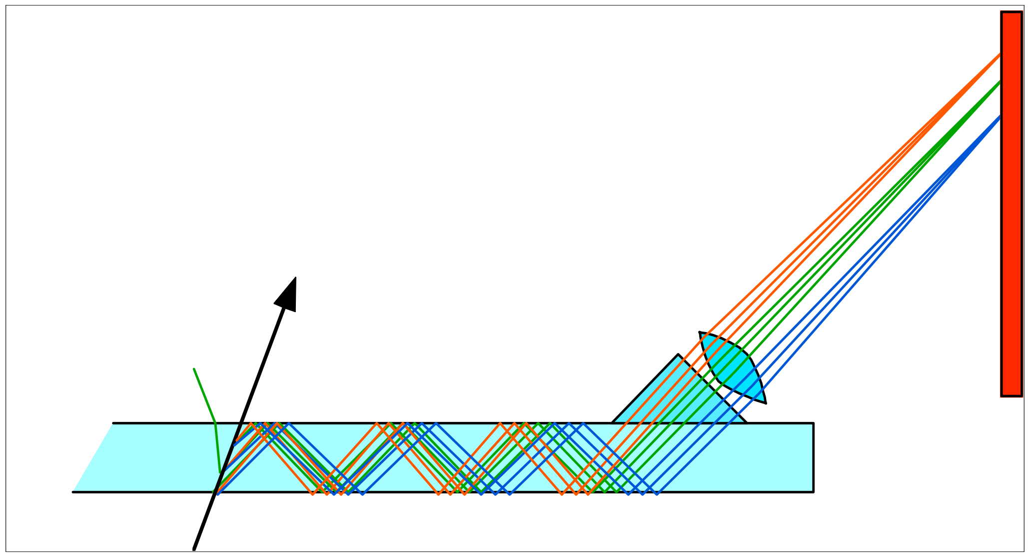


Dispersion correction

- Performance of solid radiators hampered by dispersive effects
- Inserting a material with higher refractive index and different dispersion curve minimises blurring
- Can be incorporated into a focussing design
- We study: fused silica and LiF for dispersion correction



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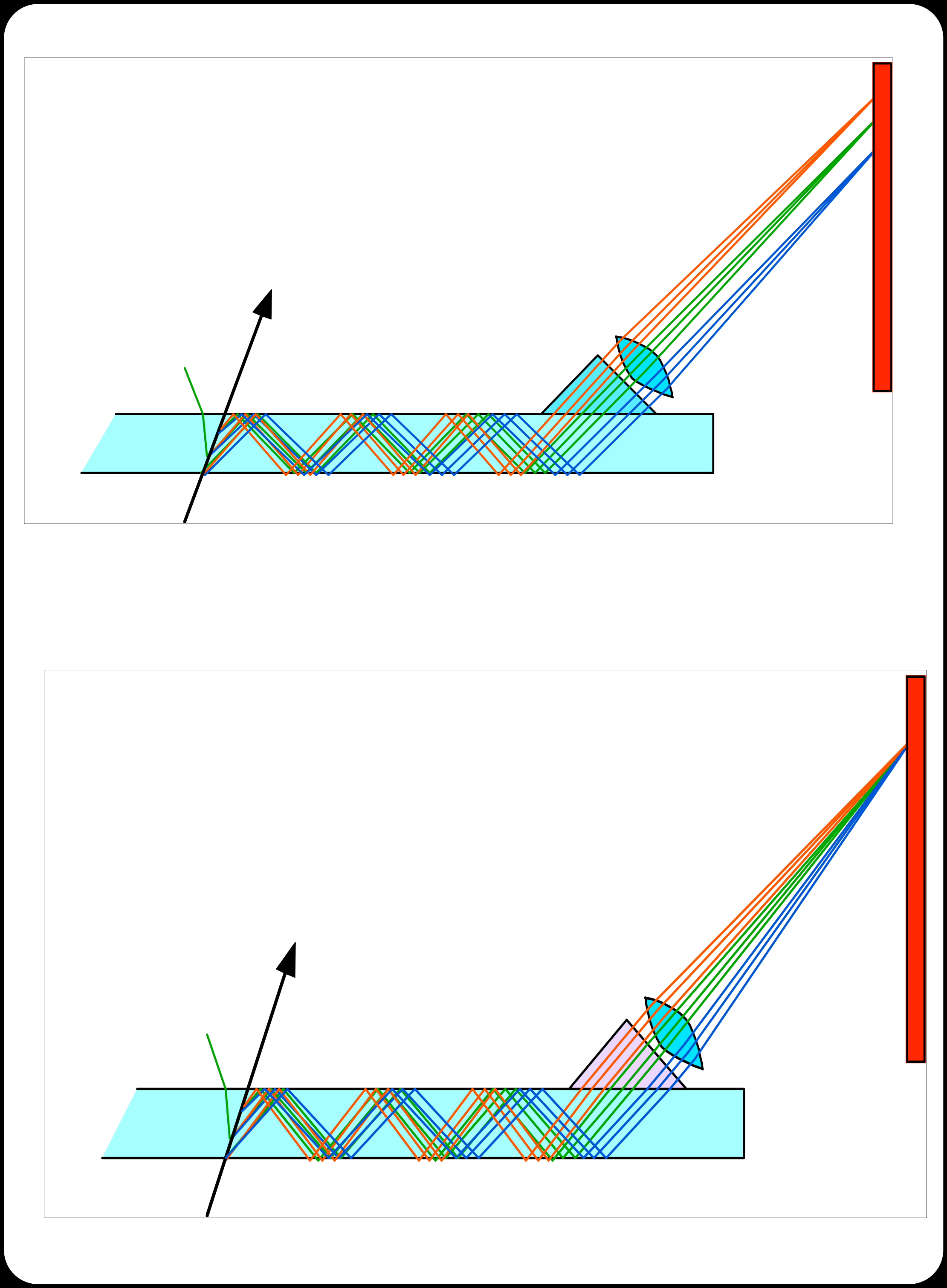

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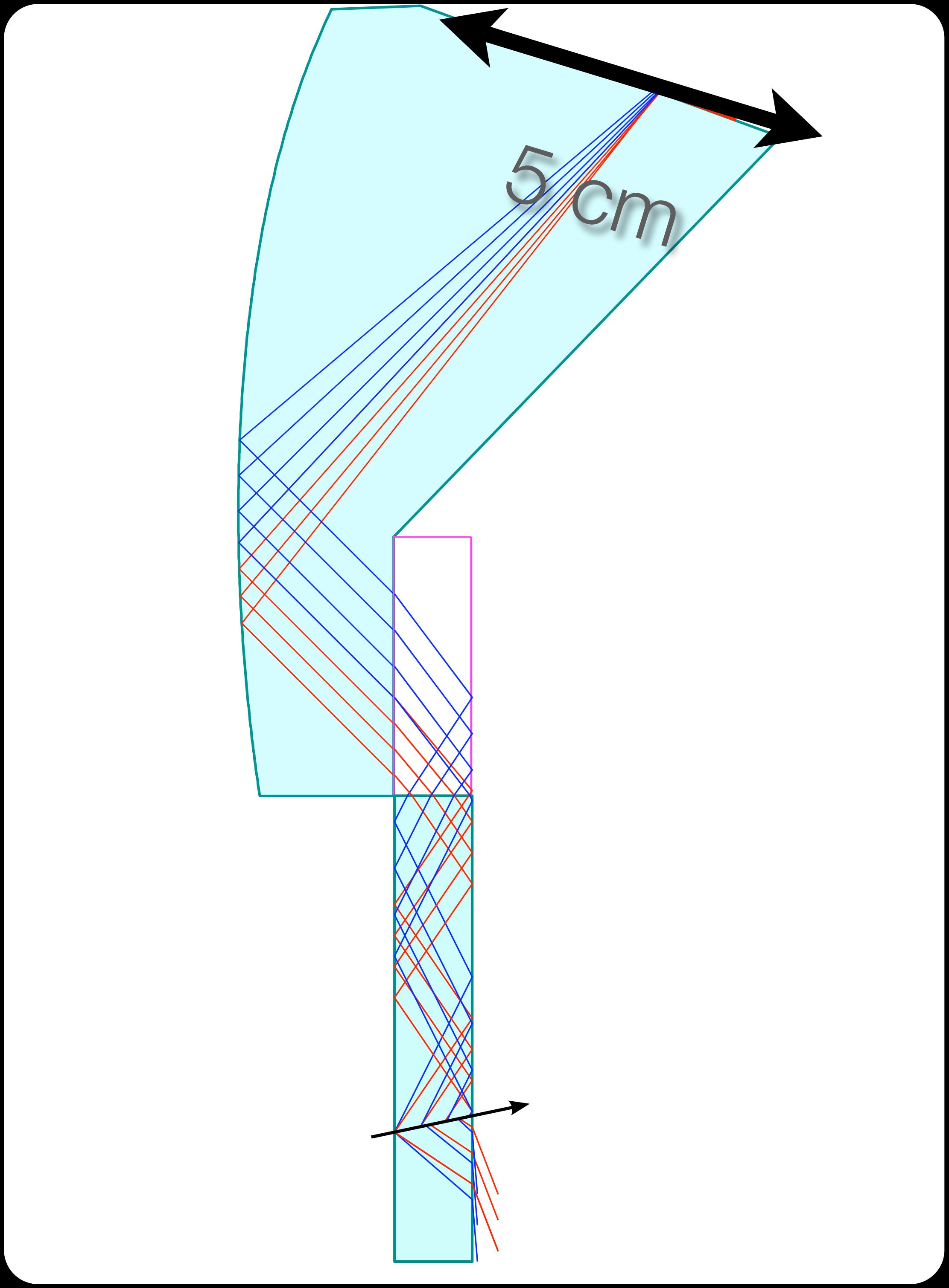
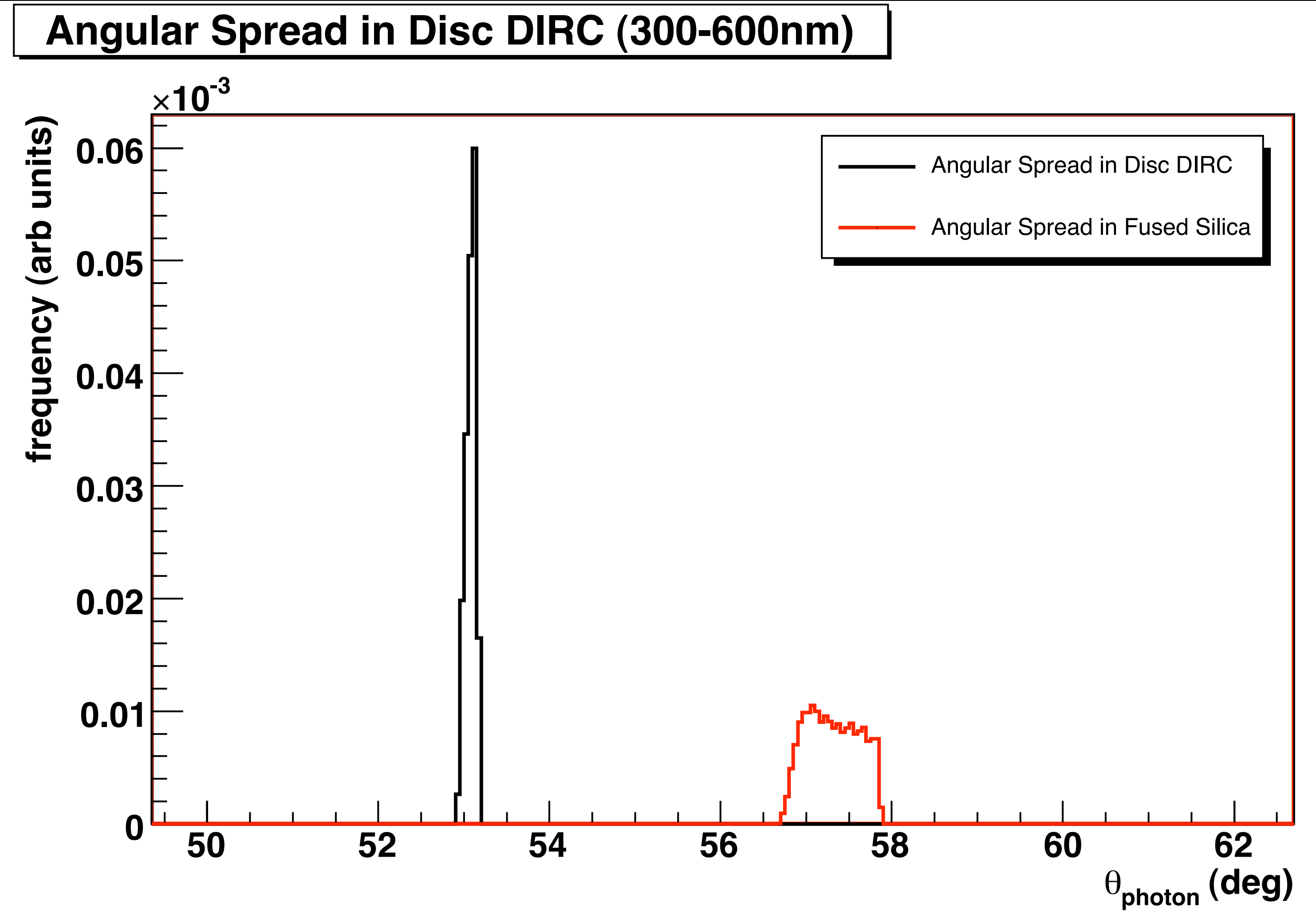


Dispersion Correction

- Transition from fused silica to LiF and back has two-fold prism effect
- Angular spread is diminished
- Centre moves, has to be taken into account in imaging optics and reconstruction



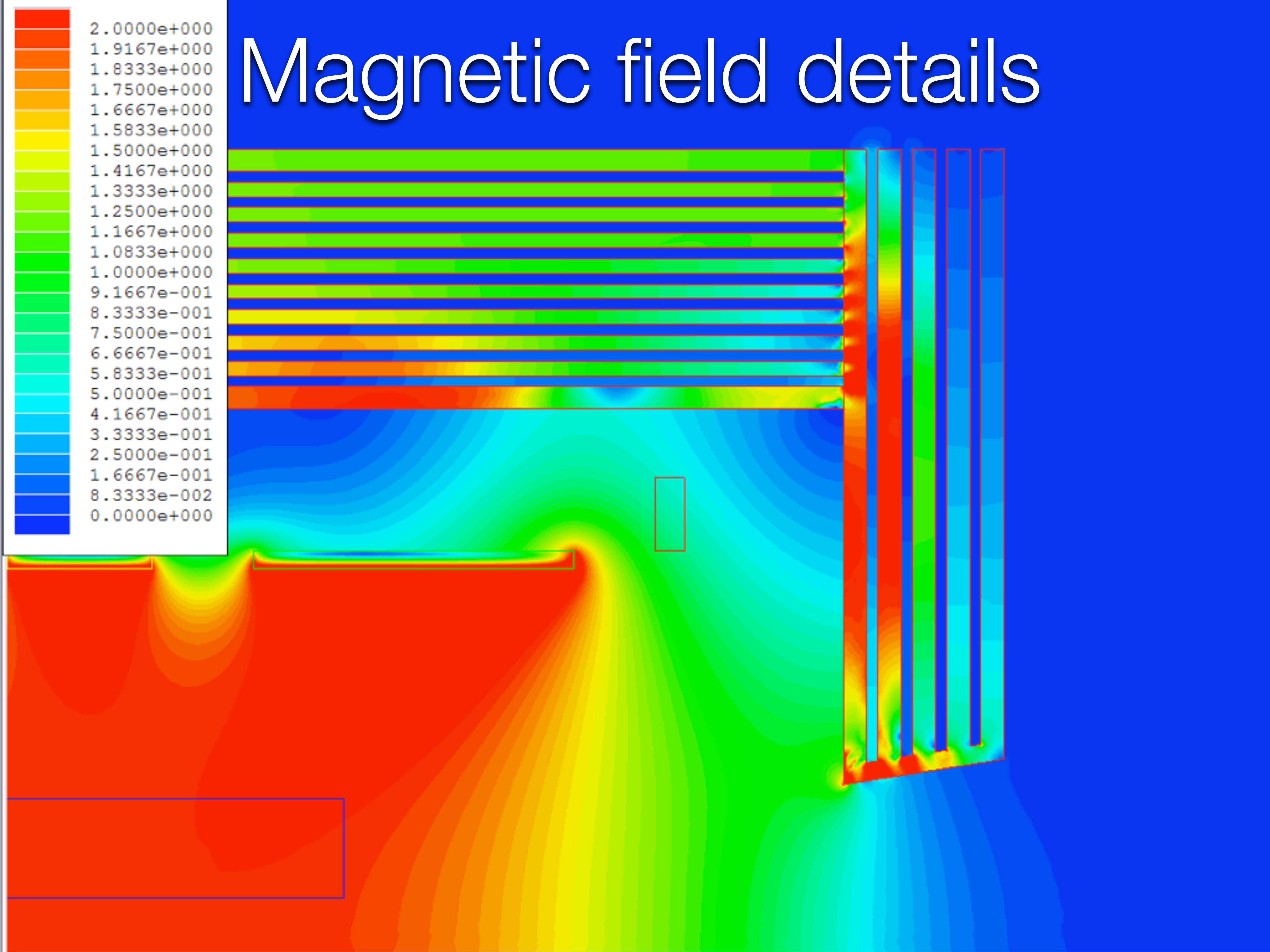
Photon Detection System

Multi-Pixel MCP-PMT

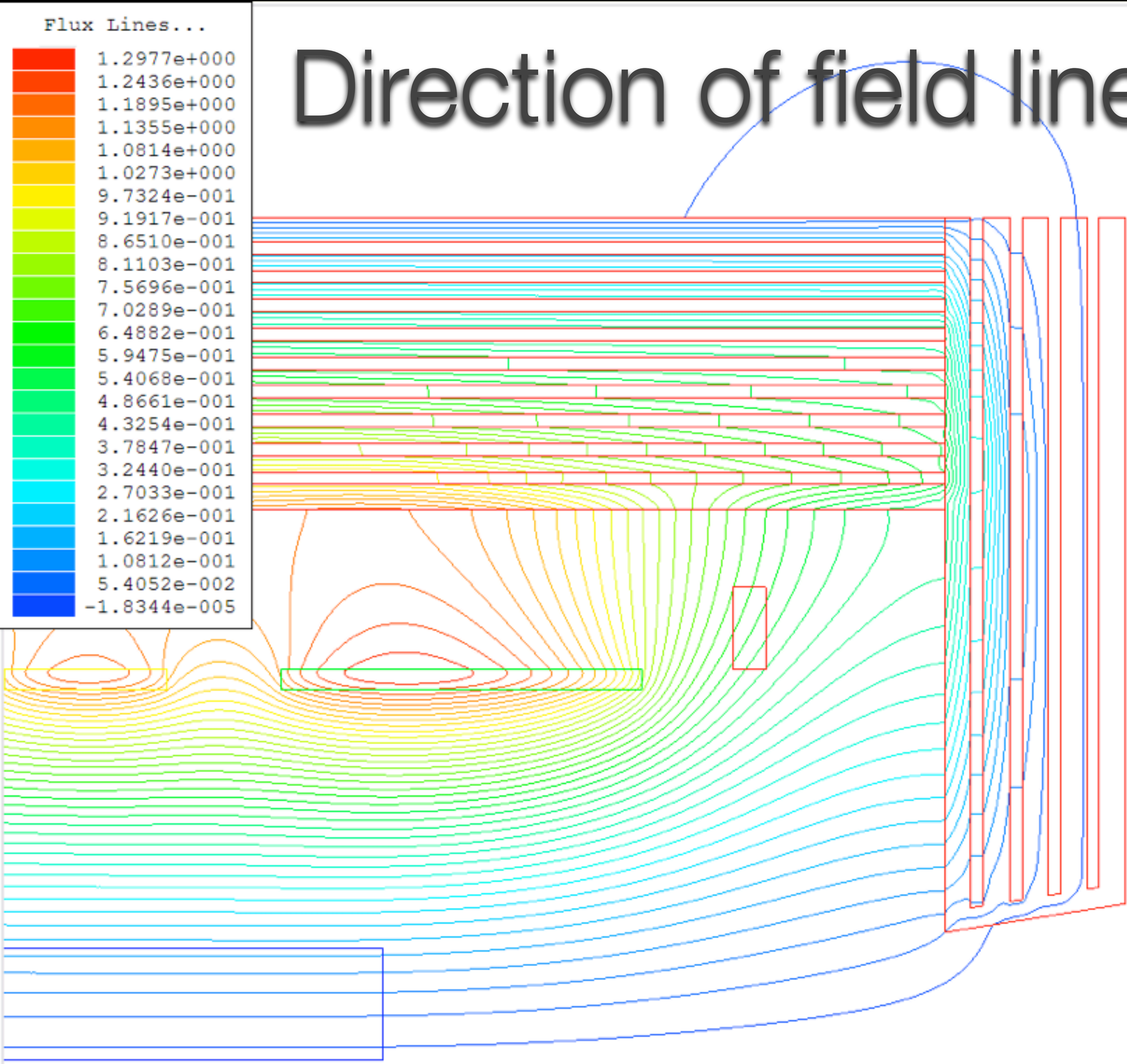
- Need multi-pixel PMT for position reconstruction and high geometrical filling factor
- Photon detector has to work in magnetic fields of < 1.4 T
- Excellent time resolution an advantage
- For tests: 8 x 8 channel
  51 x 51 mm^2 active area
  5.9 x 5.9 mm^2 pixels
- Test Burle 85011 with 25 um and Burle prototype 10 um pore diameter

Work in collaboration with A Lehmann, University of Erlangen , cf. RICH 2007

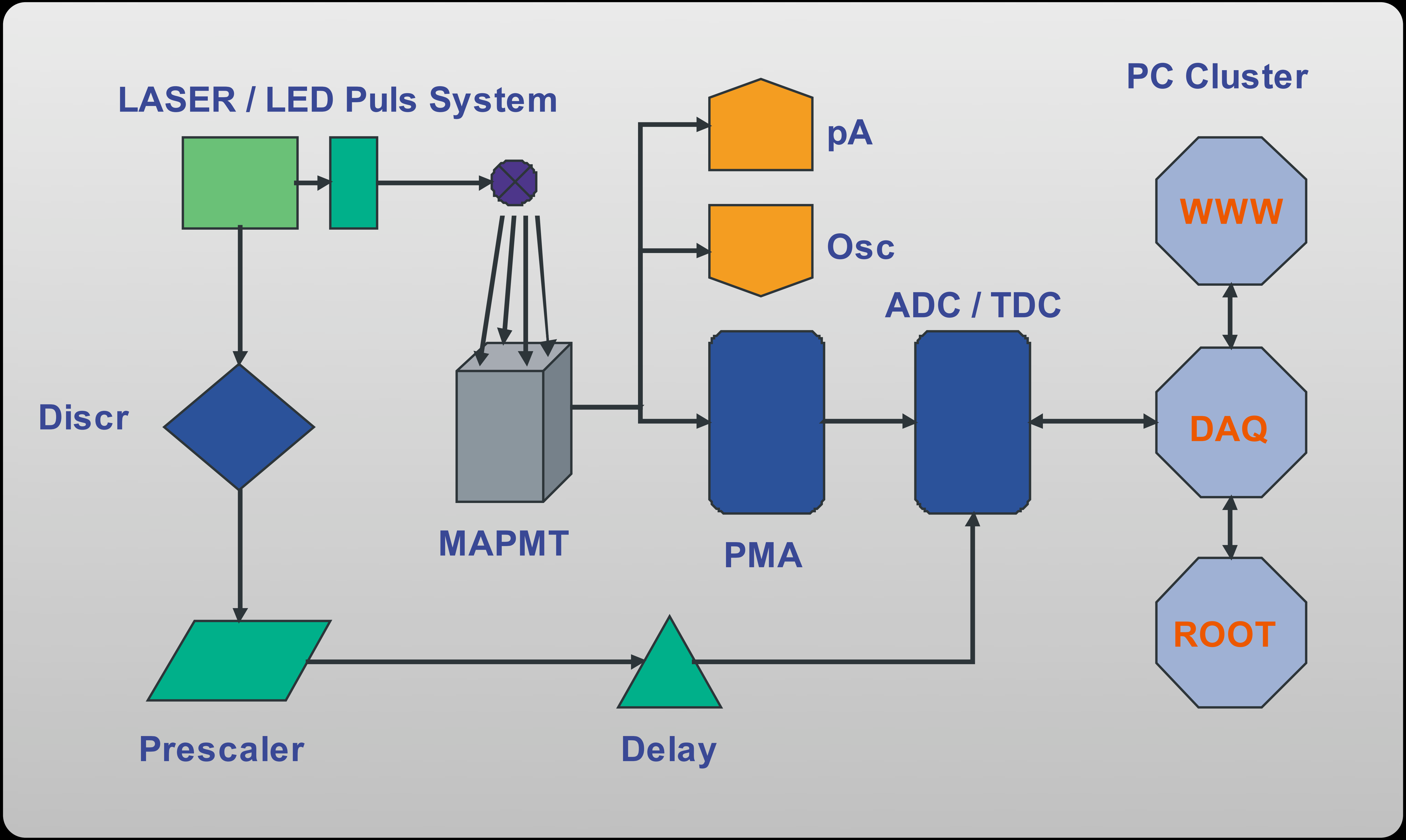
Magnetic field details



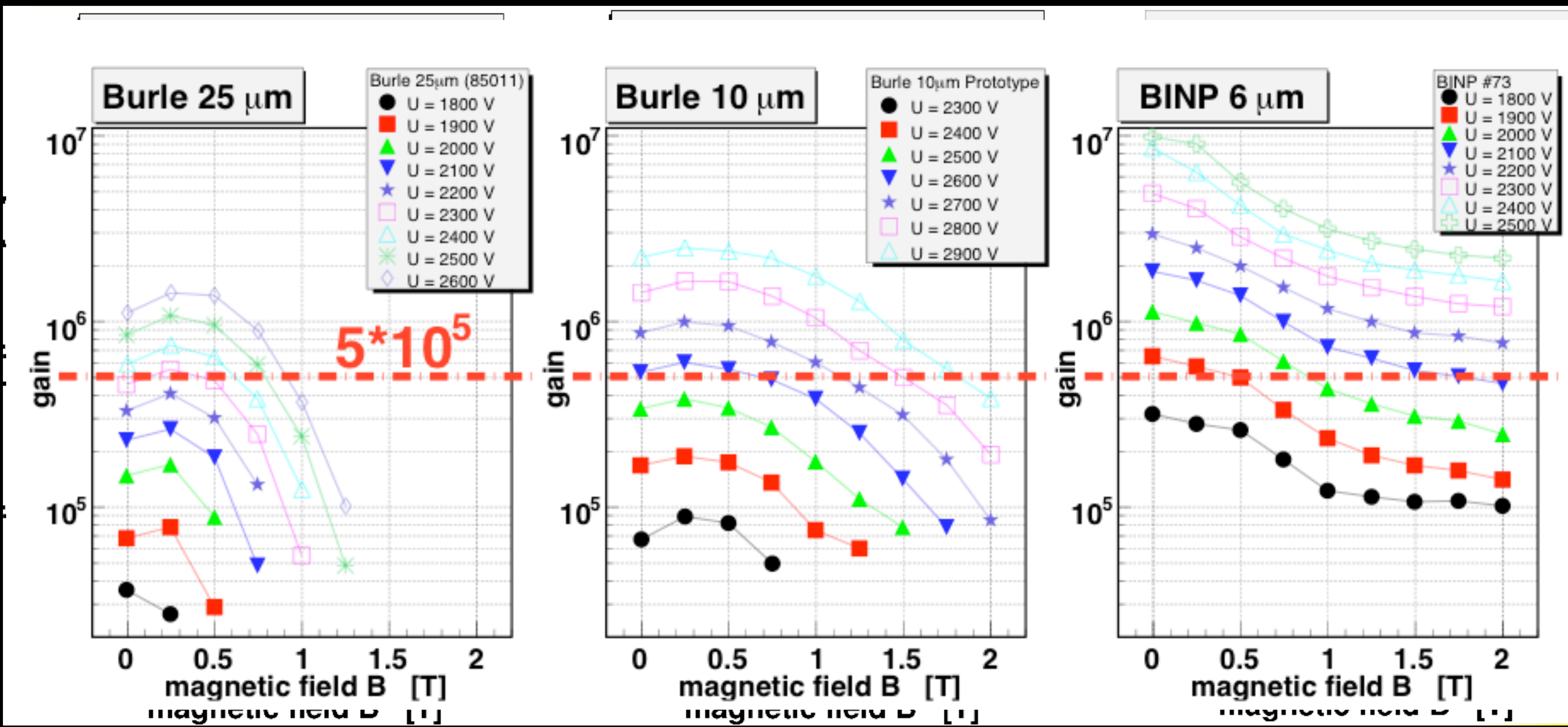
Direction of field lines



PMT Tests


LASER / LED Puls System
pA
Osc
PC Cluster
WWW
ADC / TDC
Discr
DAQ
MAPMT
PMA
ROOT
Prescaler
Delay

Response in Magnetic Field



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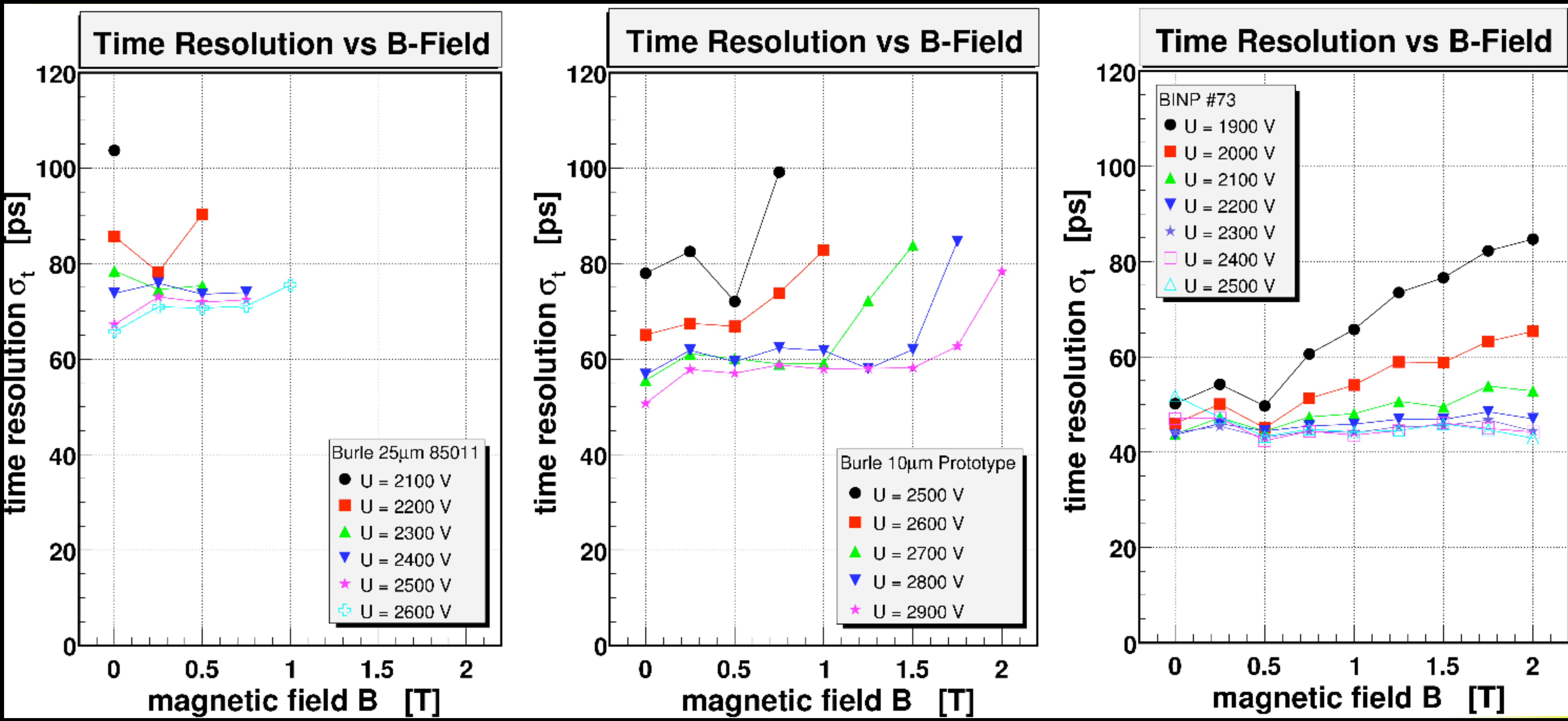

MCP-PMT lifetime

- MCP-PMTs have a reputation for bad lifetime due to ion-feedback affecting the the photo-cathode
- Novosibirsk suggest thin Al_2O_3 foil to protect cathode, also tested by Hamamatsu
- Photonis Burle suggest different production mechanism for MCP
- Estimate without HV adjustment, but after improvement

$$\tau = \frac{\mathsf{Q} \times \mathsf{N}_{\mathsf{PMT}}}{\mathsf{e} \times \mathsf{N}_{\mathsf{p}} \times \mathsf{N}_{\gamma} \times \mathsf{N}_{\mathsf{i}} \times \mathsf{G}}$$

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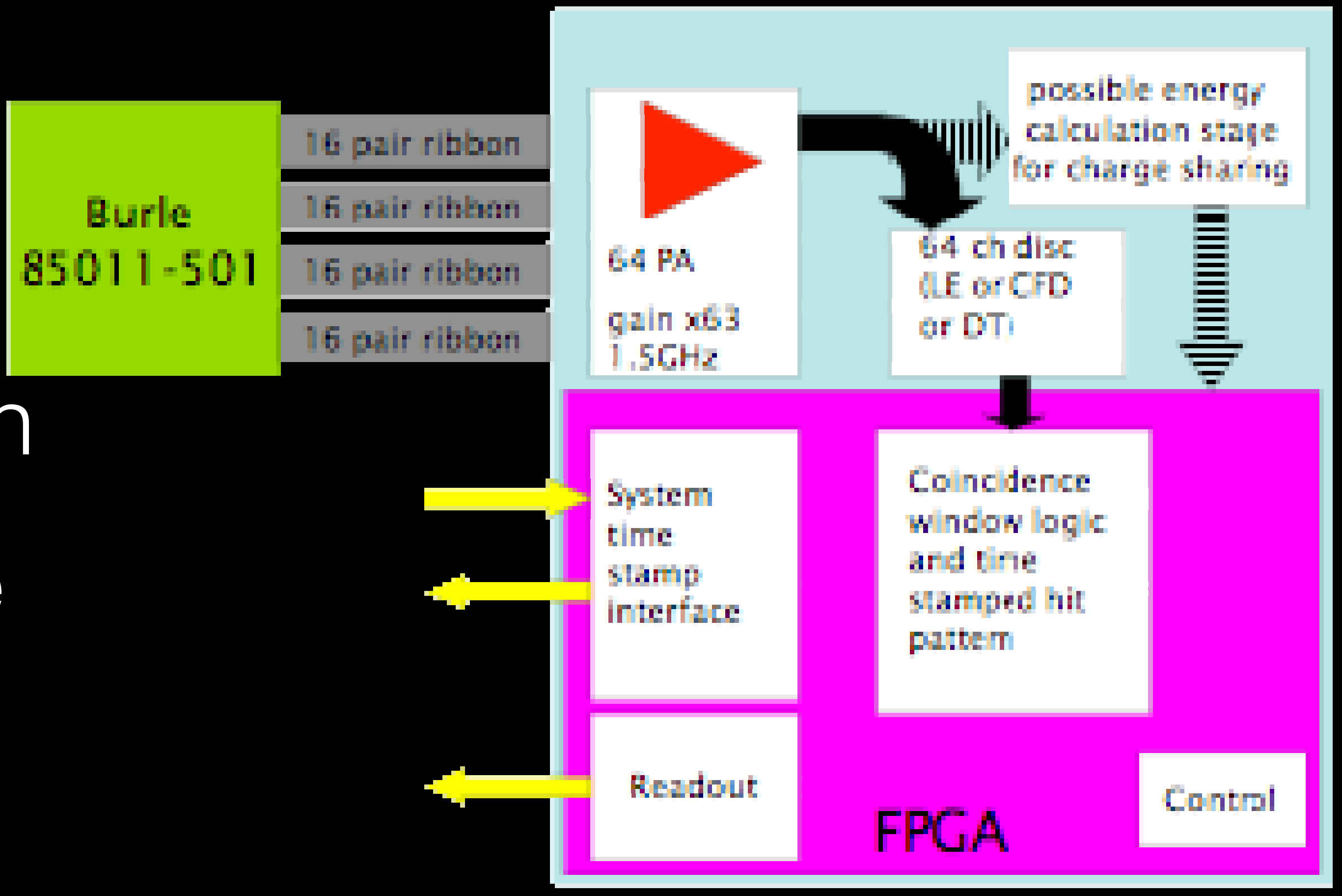
$$\tau = \frac{300\mathrm{C} \times 128}{\mathrm{e} \times 3 \times 80 \times 2 \cdot 10^7 \mathrm{s}^{-1} \times 5 \cdot 10^5} \approx 3\mathrm{y}$$

Electronics

- 4096 read out channels (128 PMTs with 32 channels each)
- need to preserve MCP-PMTs good timing properties ($\Delta t \sim 120$ ps)
- Average rage ~ 1.46 MHz/chn
- Self-triggering, deliver precise time stamp
- No ASIC foreseen, analogue preamp and discriminator favoured
- Properties mimic successfully tested commercial electronics

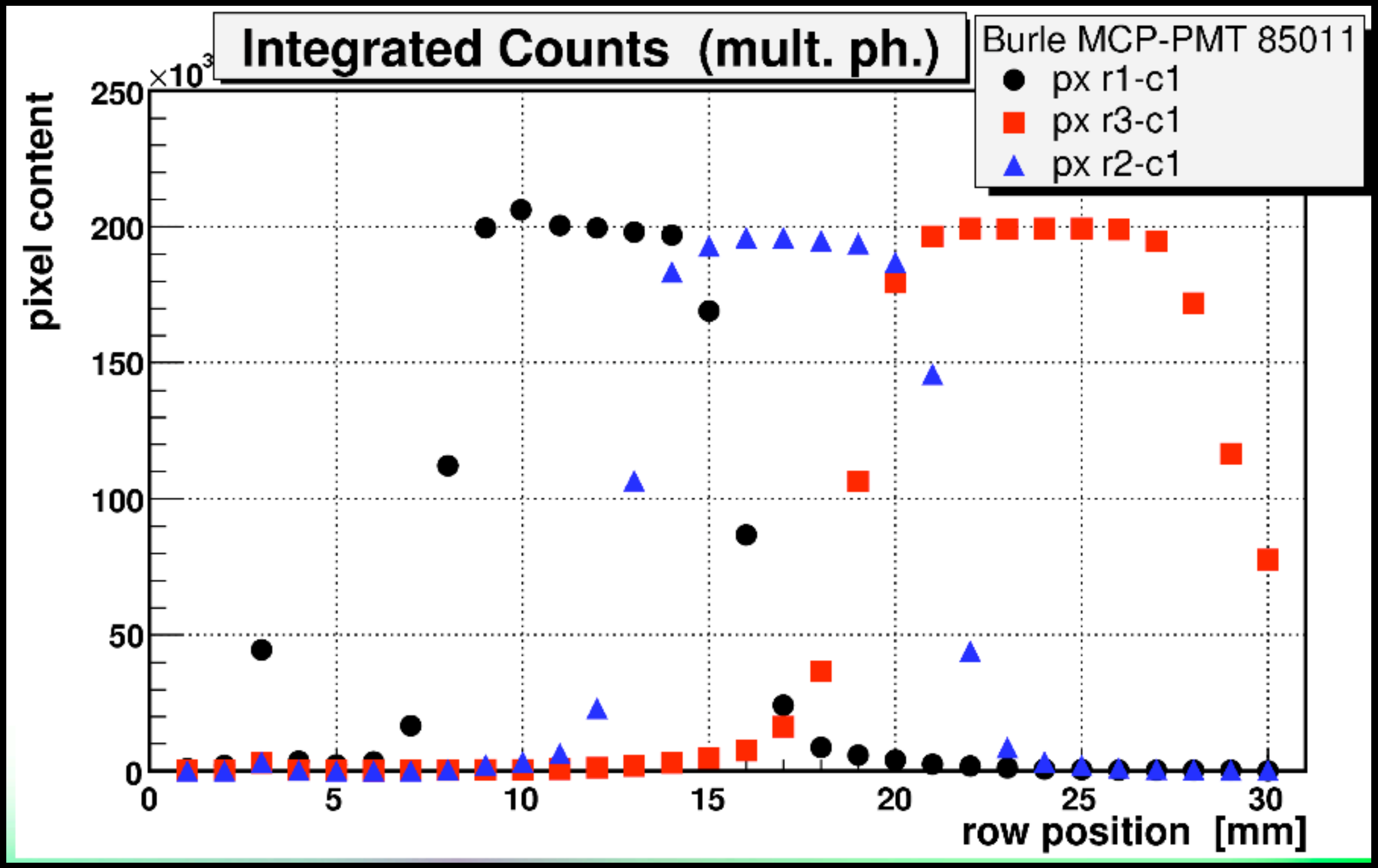


Collaboration with STFC Daresbury

Next Steps

Continue PMT testing

- Single anode multi-pixel PMTs are prone to optical and electrical cross talk
- Move small light source across surface and measure signal in adjacent pixels
- Test lifetime with updated MCP PMTs Q4/2008



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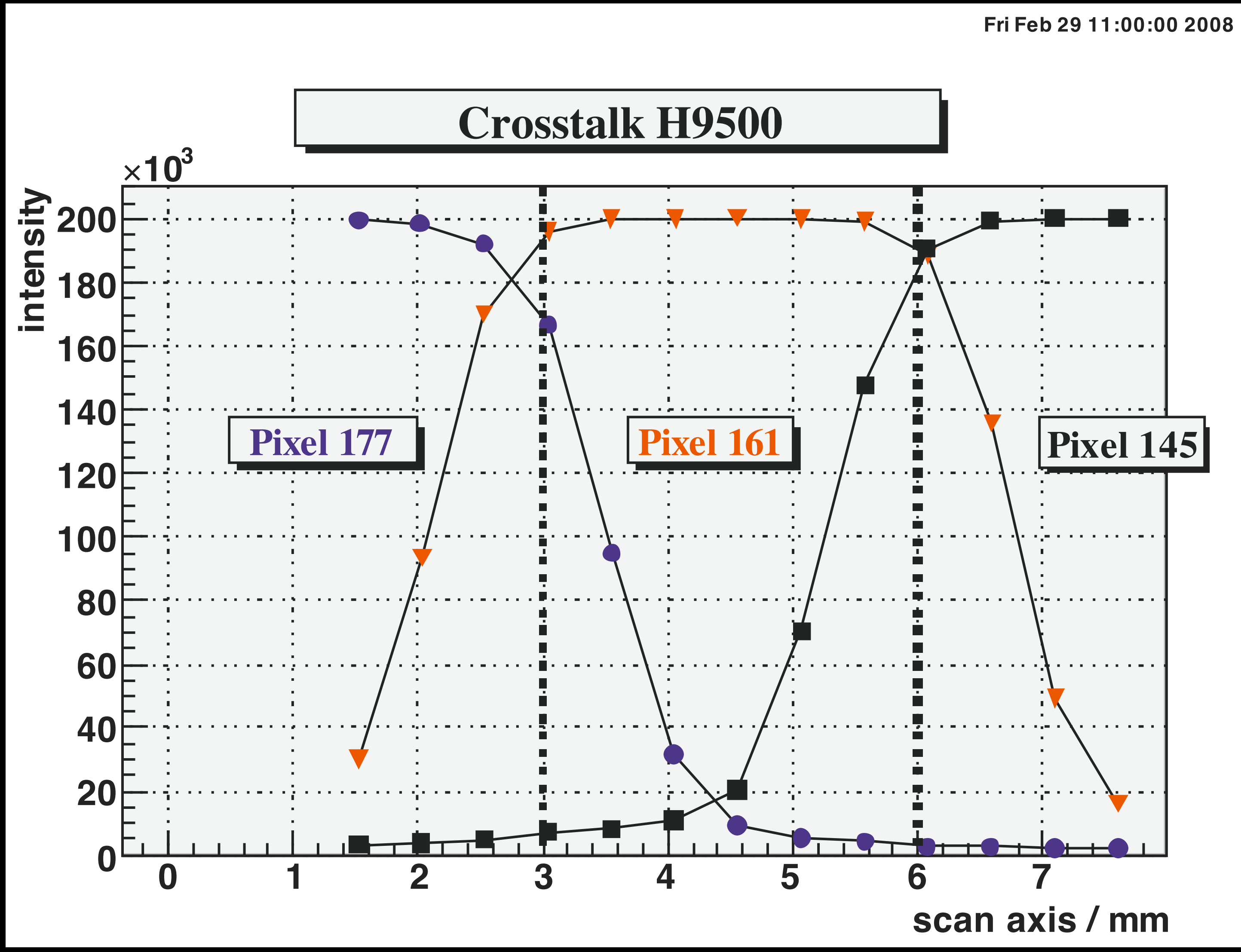
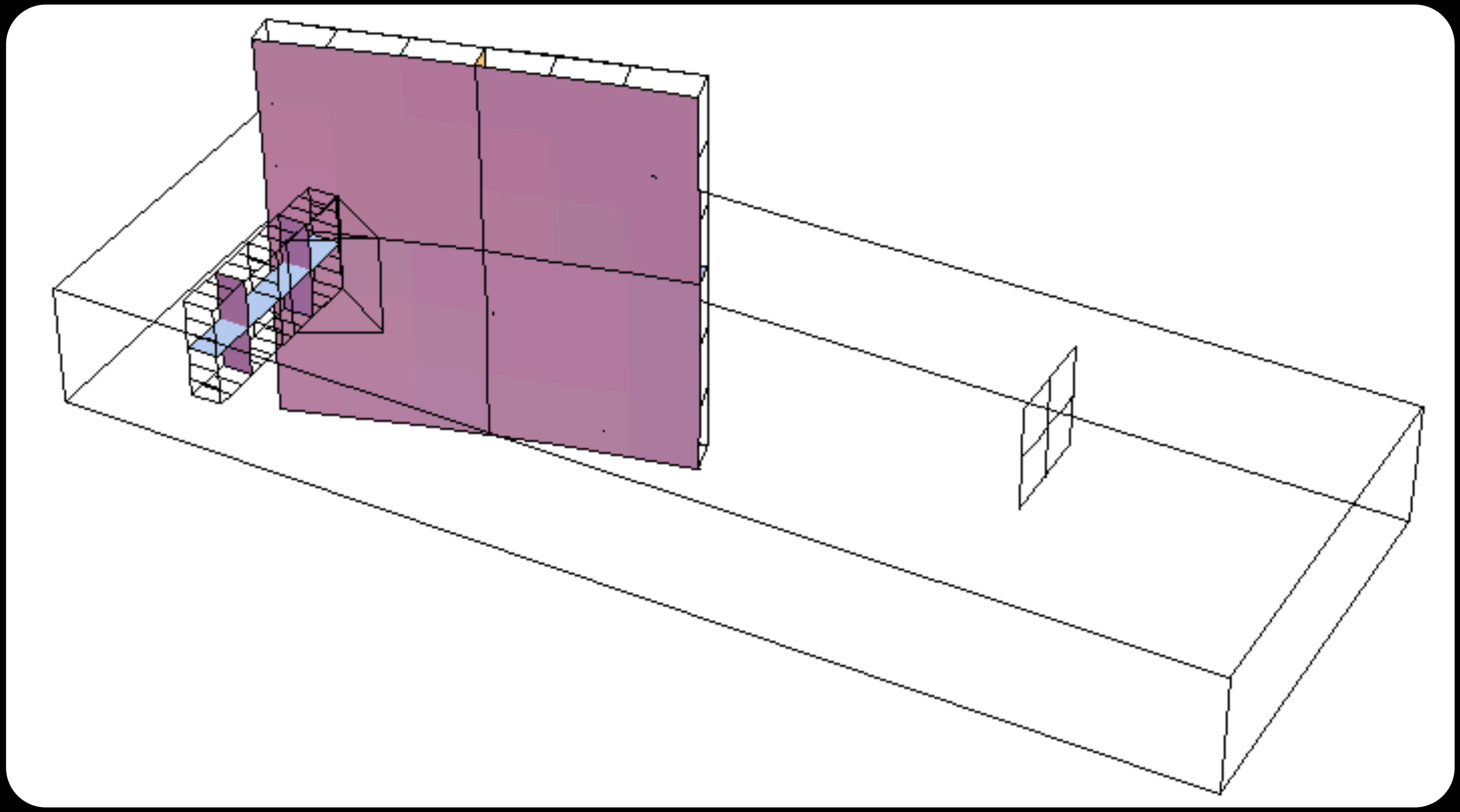


Planned Test Set-Ups

- Sequential testing of components (radiator, LiF, focussing, PMTs)
- Started with radiator and PMTs using cosmics
- Components available, working on multichannel readout
- 2 500x70x20mm^3 radiators ordered



Raditor-LiF-MCP setup
for e^-/p-beam in Q3/4 2008

Design Summary

- Compact design matching PANDA geometrical constraints
- Disc of 1100 mm radius and 20 mm thickness
- 128 light guides with 32 channels each (4096 chn. in total)
- Strip pitch 1.5 mm in accordance with image quality
- total detector mass ~750kg mass, mounted on F-ECAL
- Fused silica tested to be radiation hard
- Surface roughness < 0.6nm achieved and tested
- Time resolution of MCP PMT ~ 50 ps, expect ~120ps including TDC
- MCP-PMTs shown to work up to 1.5 T
- MCP-PMTs need lifetime improvement

Alternative Solutions

Performance comparison

	Focussing Disc DIRC	Liquid Radiator Proximity Imaging	Solid Radiator Proximity Imaging	Aerogel Proximity Imaging
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
Read out	TDC	TDC/ADC	TDC/ADC	TDC
N_{ch}	4096	> 35000	> 35000	35000
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