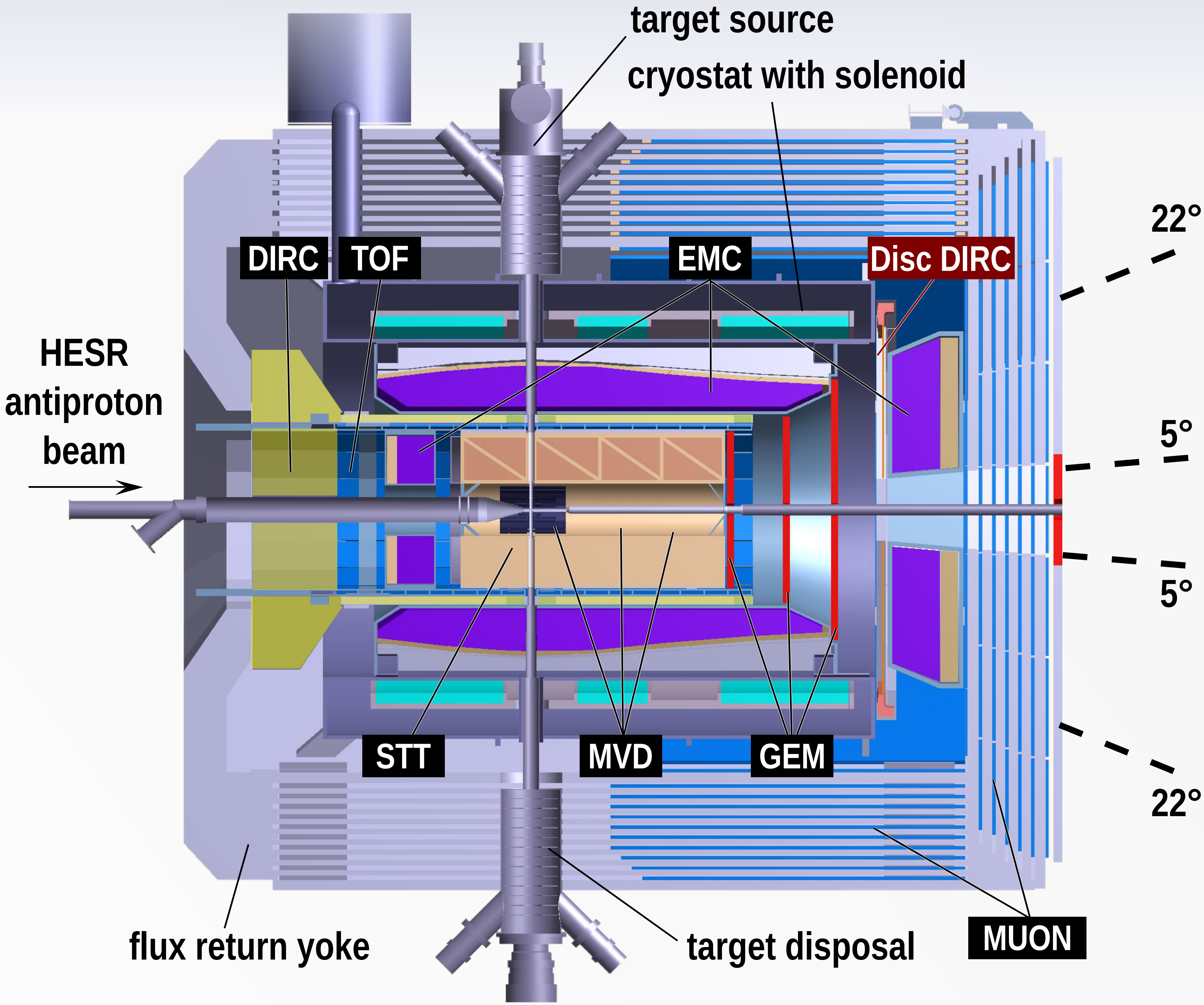
The

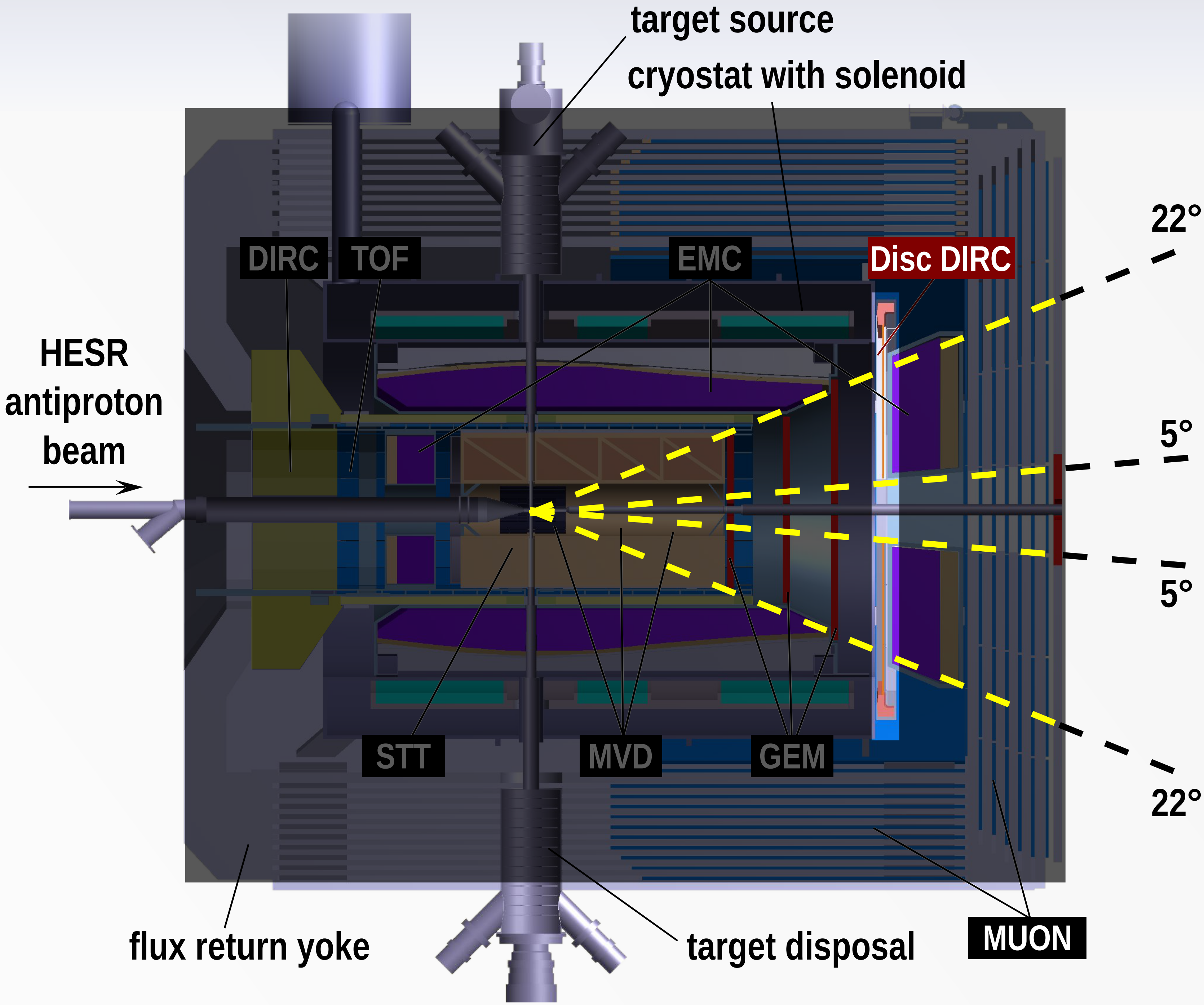
Disc DIRC Detector

for the PANDA experiment at FAIR

Oliver Merle, Justus Liebig Universität Gießen

DIRC 2013, Rauischholzhausen


target source
cryostat with solenoid
22°
DIRC
TOF
EMC
Disc DIRC
HESR
antiproton
beam
5°
5°
22°
STT
MVD
GEM
flux return yoke
target disposal
MUON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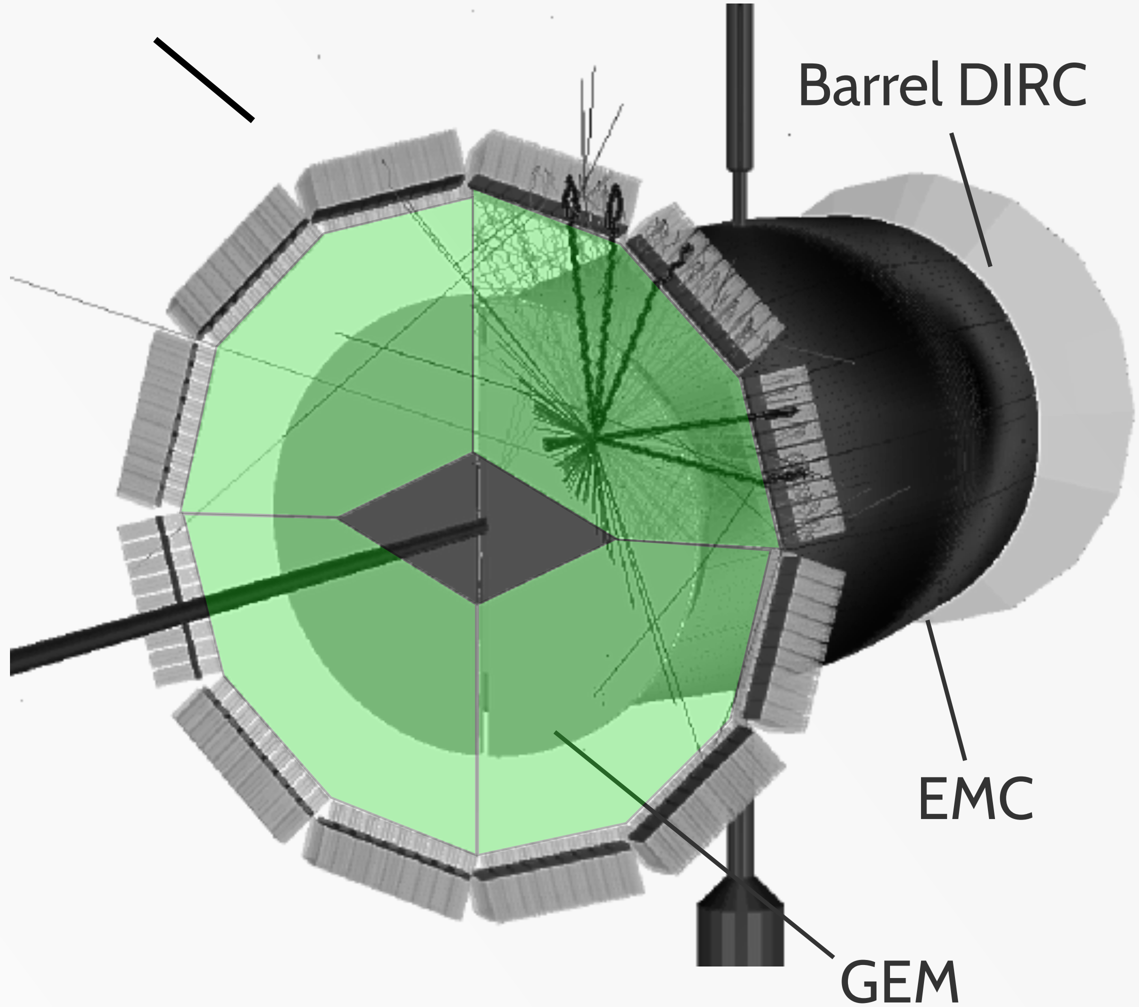
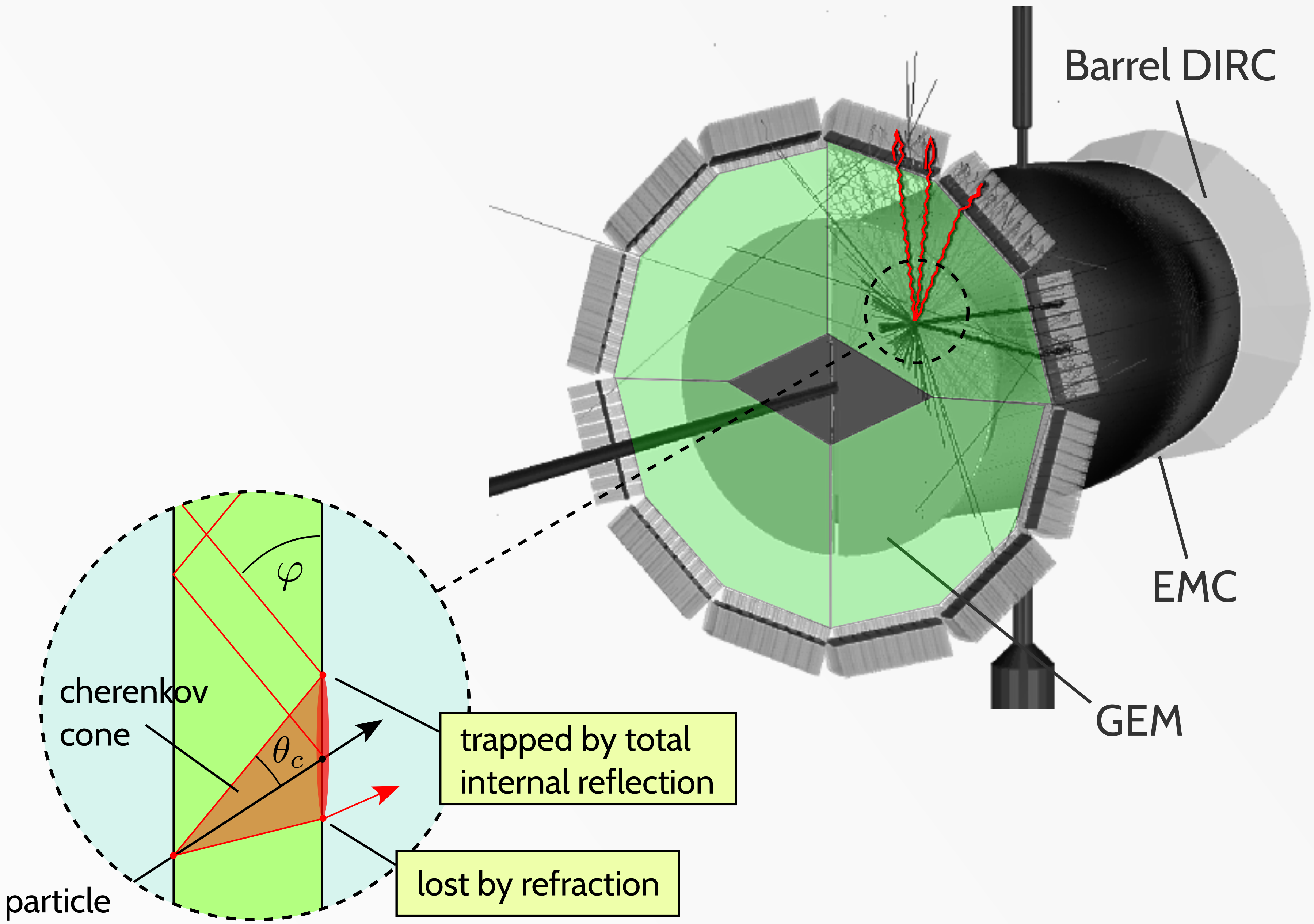
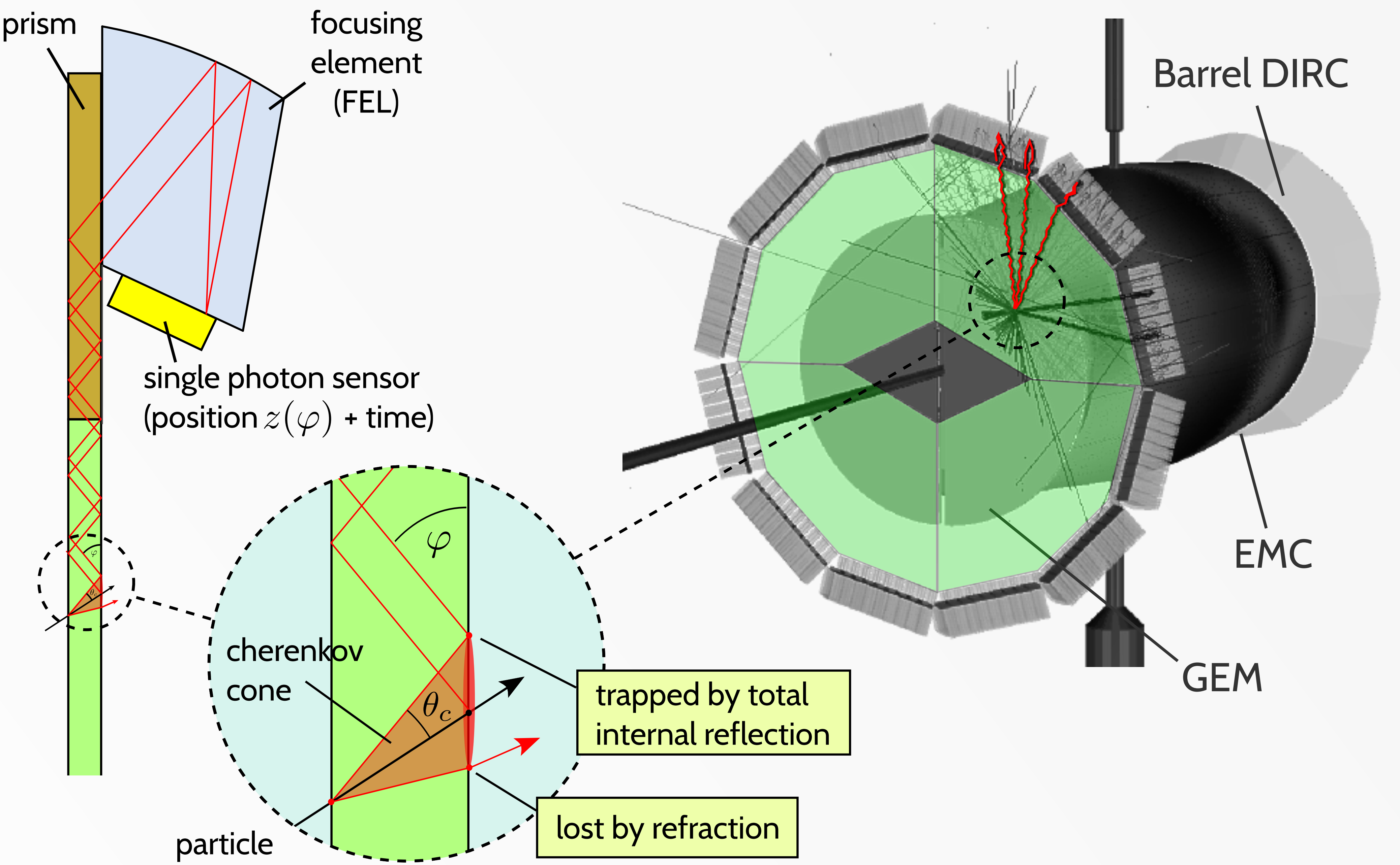
Disc DIRC



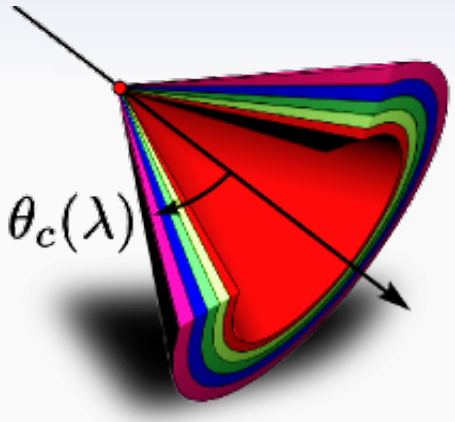
Working principle

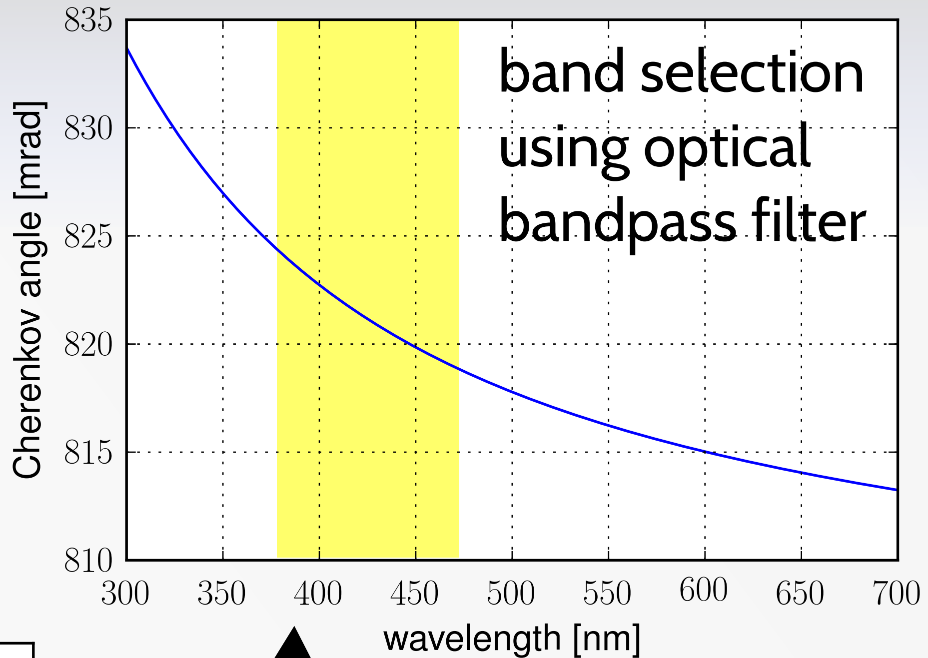


Working principle

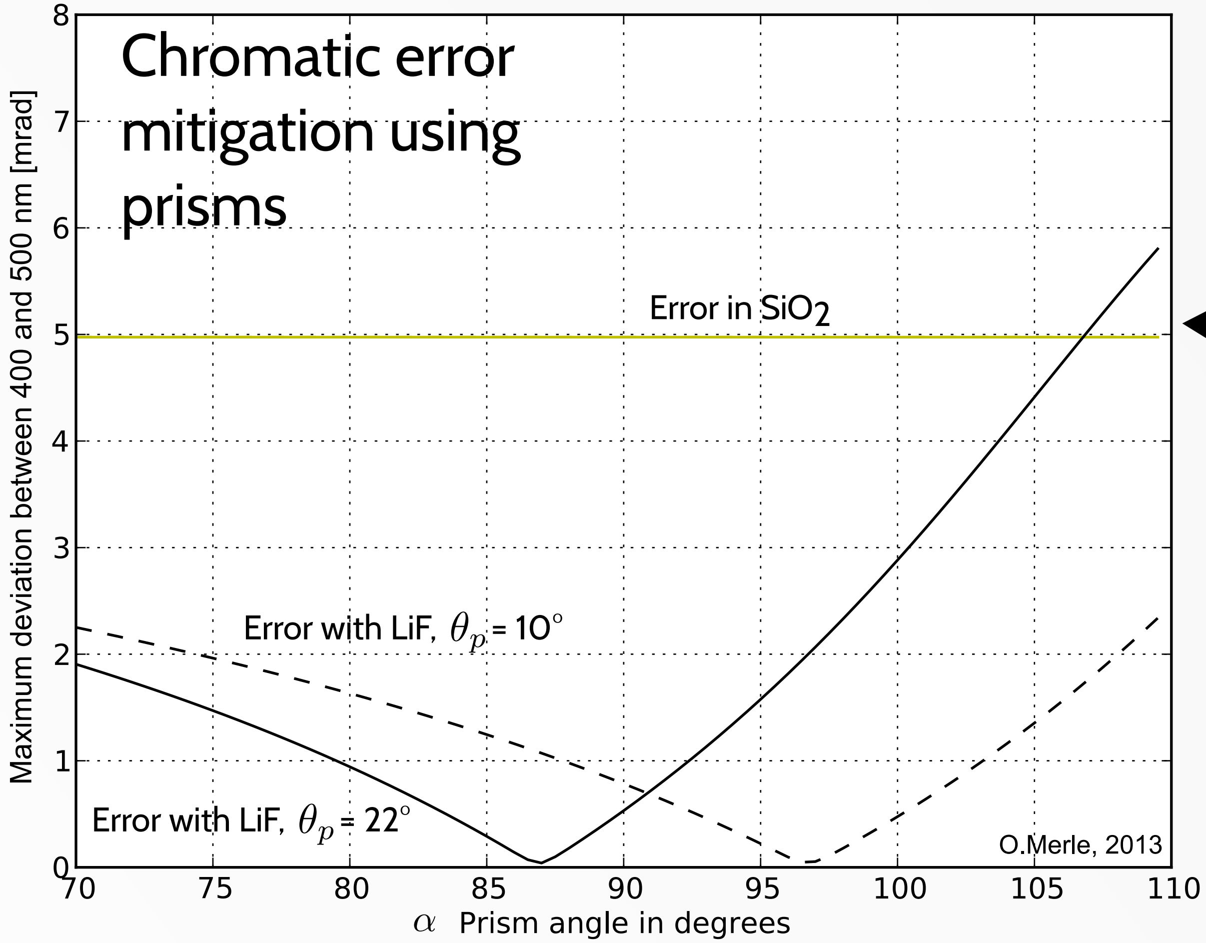


Dispersion correction

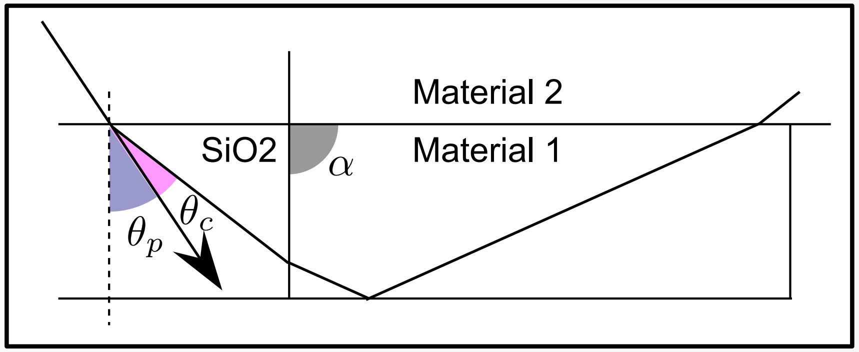




Filter: - corrects time and angle
- reduces photon count



Prism: - corrects only the angle
- just fresnel losses



Challenges

magnetic field: 1-2 T

avg. interaction rate ~ 10 MHz

peak rate > 20 MHz

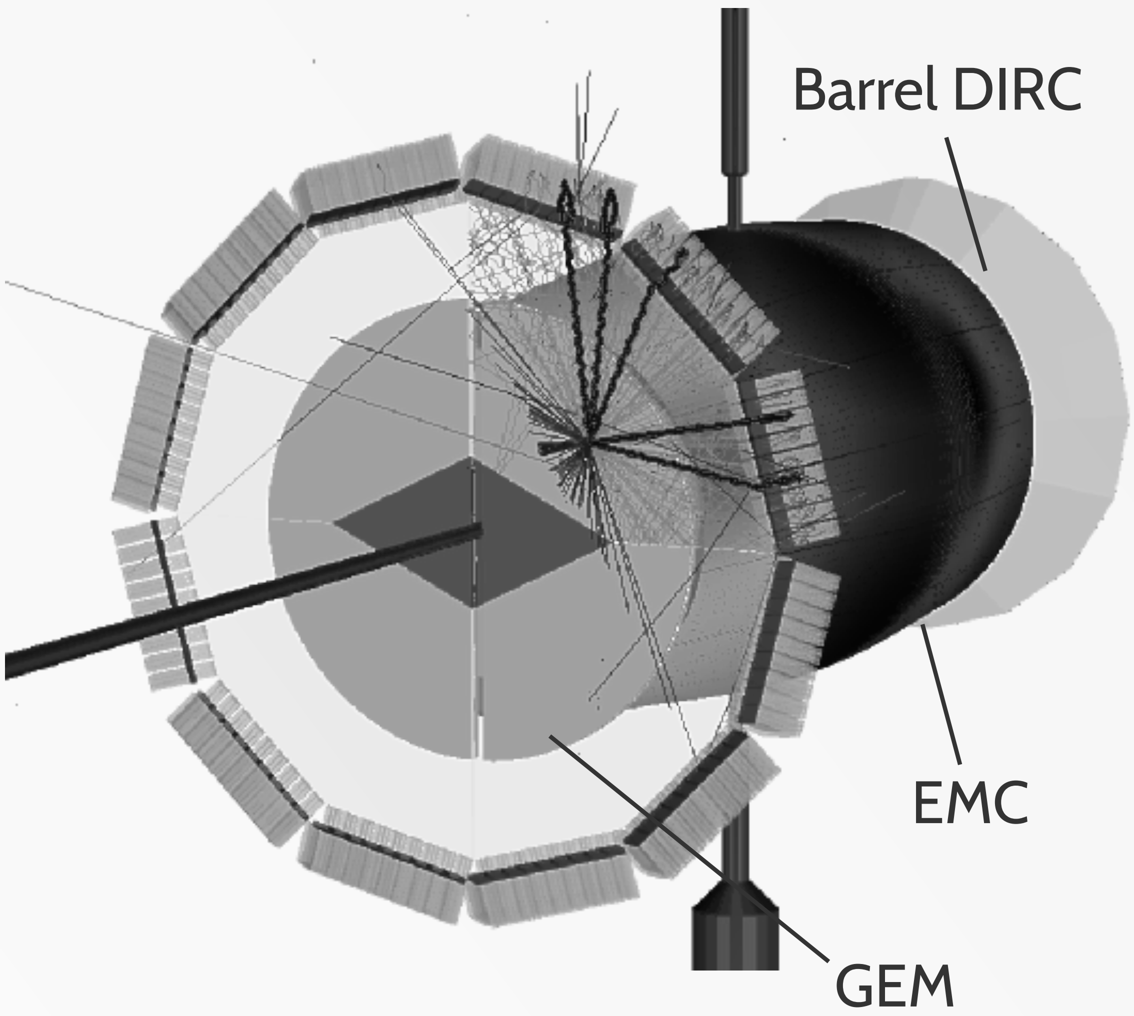
about 3 "Cherenkov emitting" tracks per interaction

triggerless operation

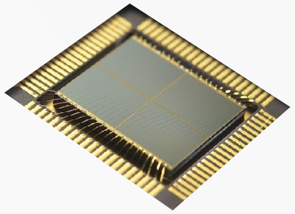
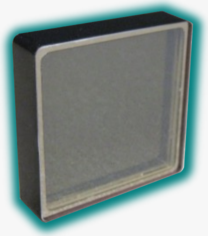
online particle identification

1 MeV neutron equivalent fluence: >$2 \cdot 10^{11}$ n_{eq}/cm^2

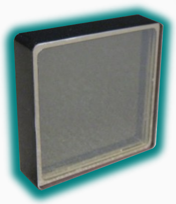
limited space



Sensor options

	Silicon Photomultiplier	Microchannelplate PMTs
	 e.g. Philips dSiPM	 e.g. Photonis Planacon
peak PDE	~ 30 %	~ 22 %
B-field	independent	has to be aligned
time resolution	50 ps	35 ps + σ(FEE)
position res.	sub-mm (modification)	sub-mm possible
radiation hard	no	yes
dark count rate	high	low
readout	integrated, fully digital	has to be developed
cooling	required, -20 to 0 °C	not required
lifetime limit	neutron fluence	total anode charge

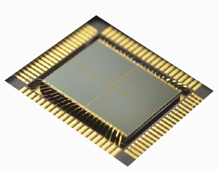
Sensor lifetime



Integrated anode charge Q for N_{ph} detected photons per track

$$Q/N_{ph} = \underbrace{3 \cdot 10\ \text{MHz}}_{\text{track rate}} \,/\, \underbrace{(108 \cdot 25\ \text{cm}^2)}_{\text{total area}} \cdot e \cdot \underbrace{10^6}_{\text{gain}} \cdot \underbrace{158 \cdot 10^6\ \text{s}}_{\text{time}} \approx 0.3\ \text{C/cm}^2$$

(2010)	$Q_{max} = 0.3\ \text{C/cm}^2$	$\Rightarrow$ $N_{ph} = 1$	impossible	👎
(2013)	$Q_{max} > 5\ \text{C/cm}^2$	$\Rightarrow$ $N_{ph} > 16$	feasible	👍



1 MeV neutron equivalent fluence estimate: $\Phi_{eq} > 2 \cdot 10^{11}\ n_{eq}/\text{cm}^2$

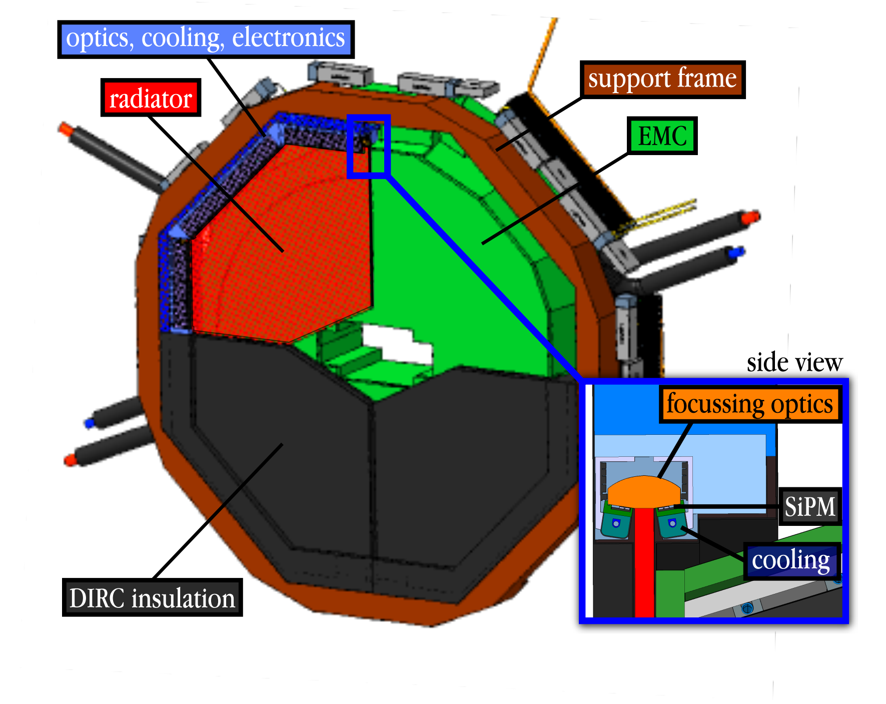
(2013) $\Phi_{eq} < 4 \cdot 10^{9}\ n_{eq}/\text{cm}^2$ (DCR too high) impossible 👎

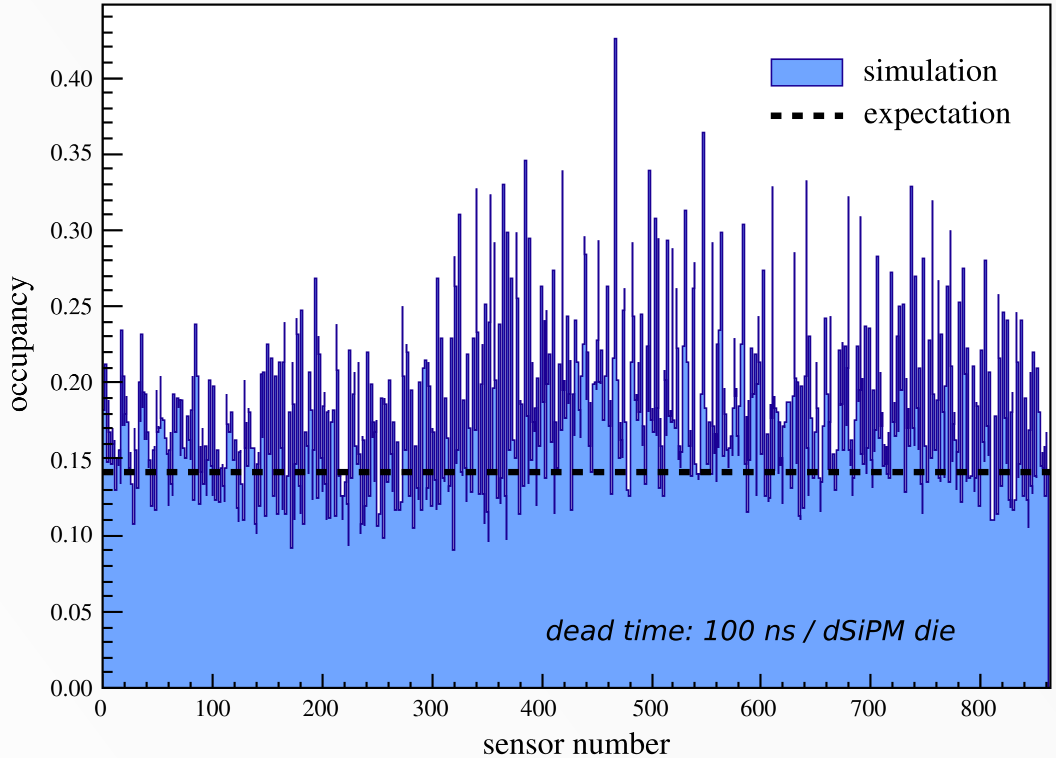
(future) radiation hardened designs ??

dSiPM design option

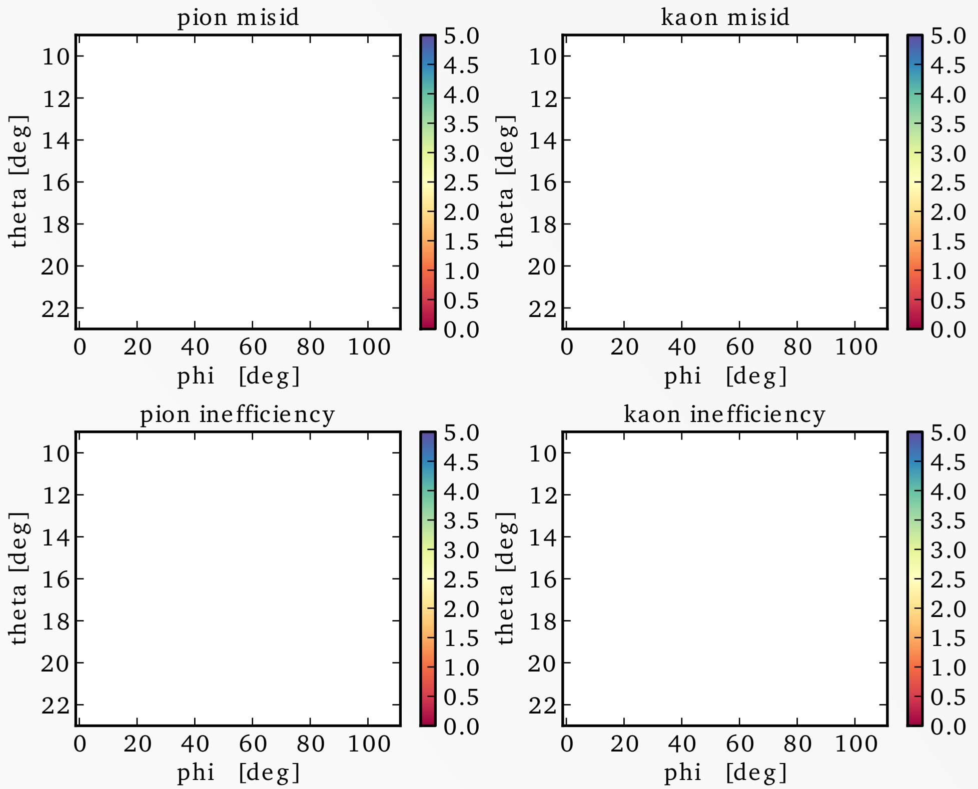
can reach 4σ at 4 GeV/c at high rates and experimental background

assuming: cooling to 0° C
"Cherenkov readout"
100 ns dead time/die





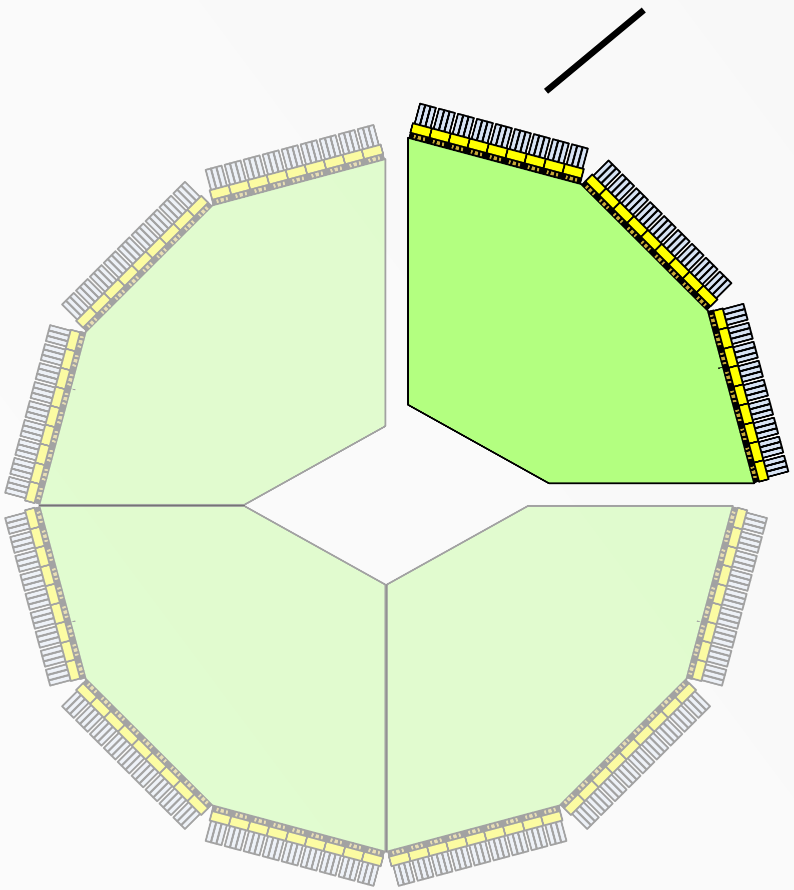
sensor occupancy from simulation

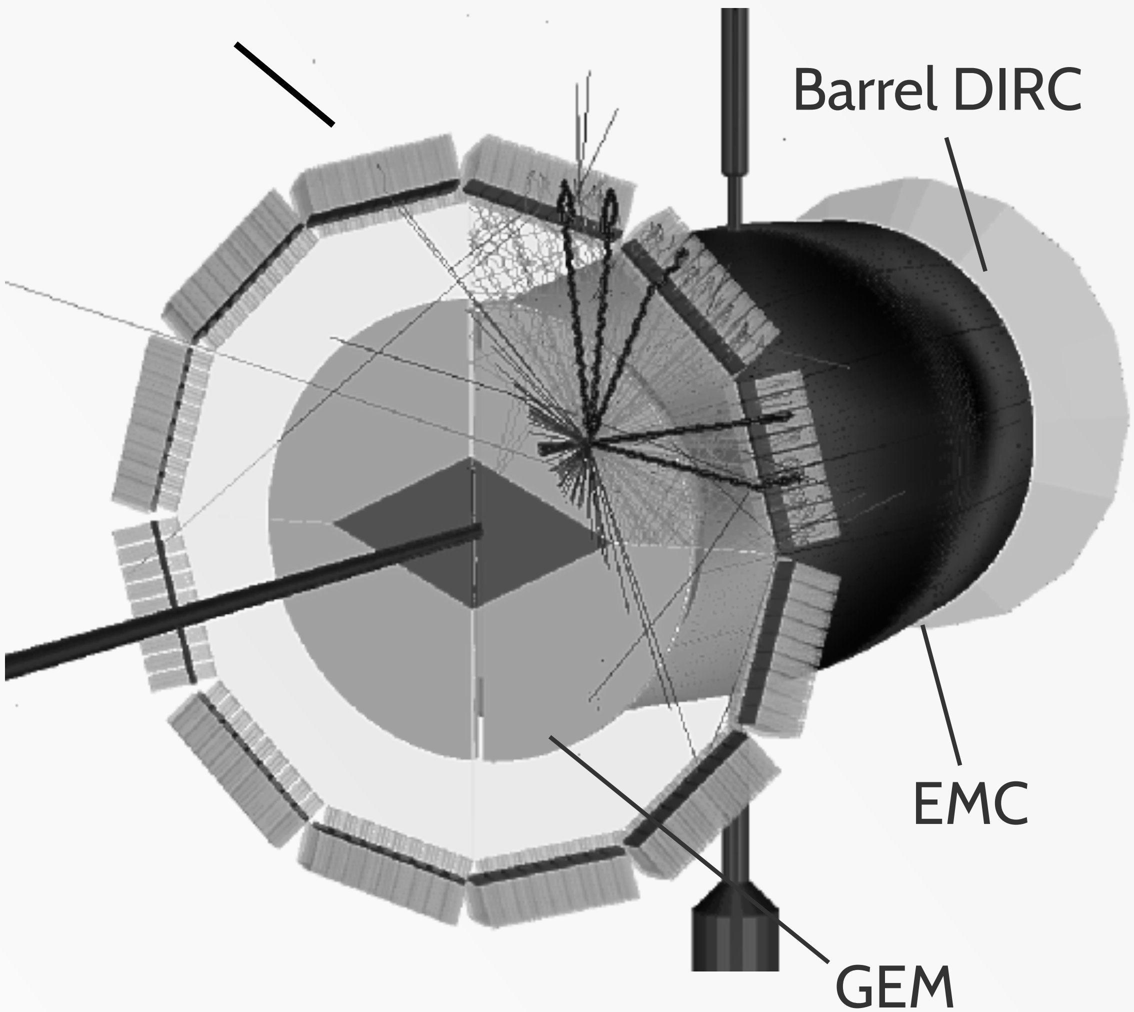


performance θ vs φ

$\sigma_{x,y}$ = 2.5 mm $\sigma_{\theta,\varphi}$ = 1 mrad

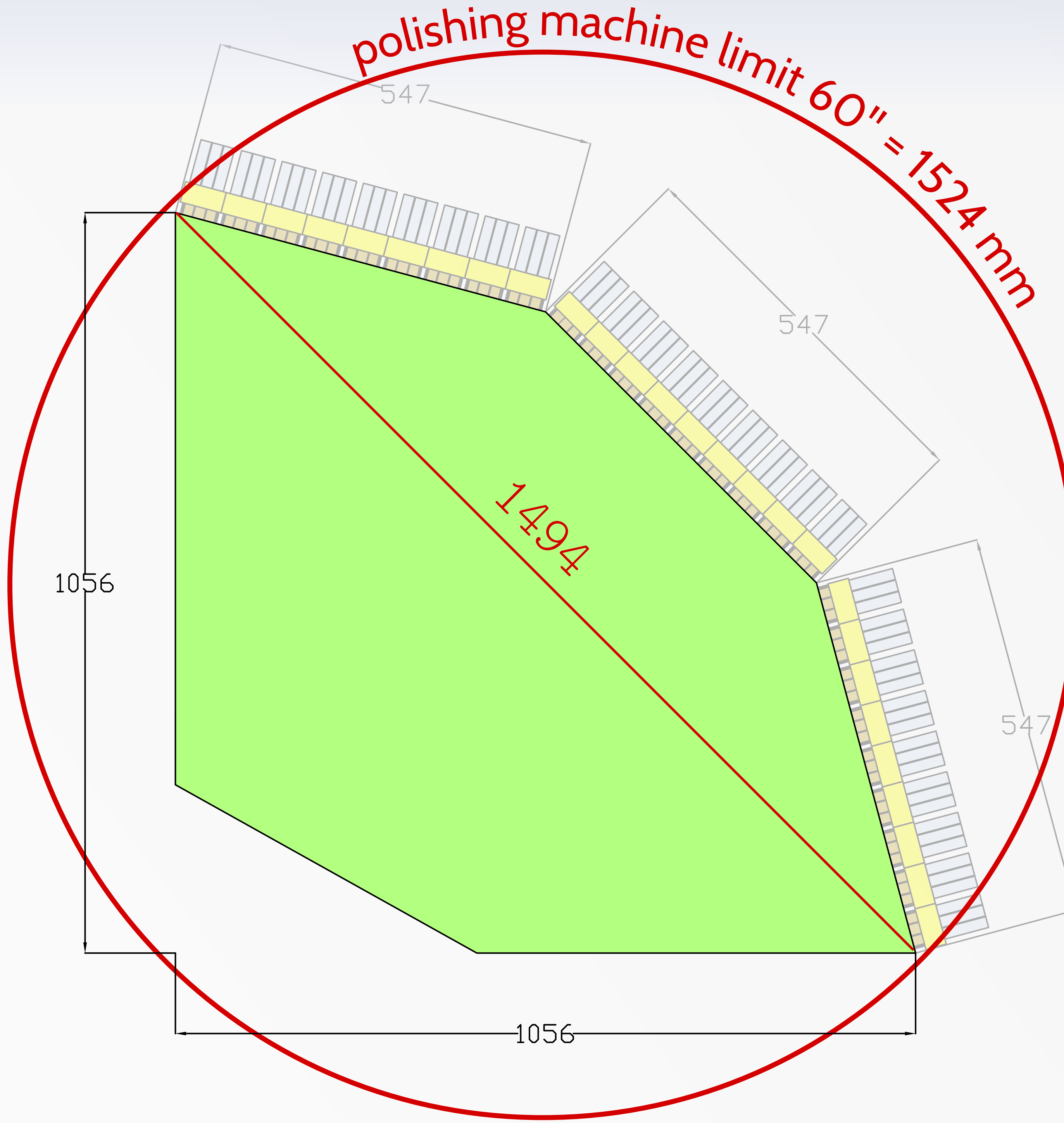
4 sub-detectors

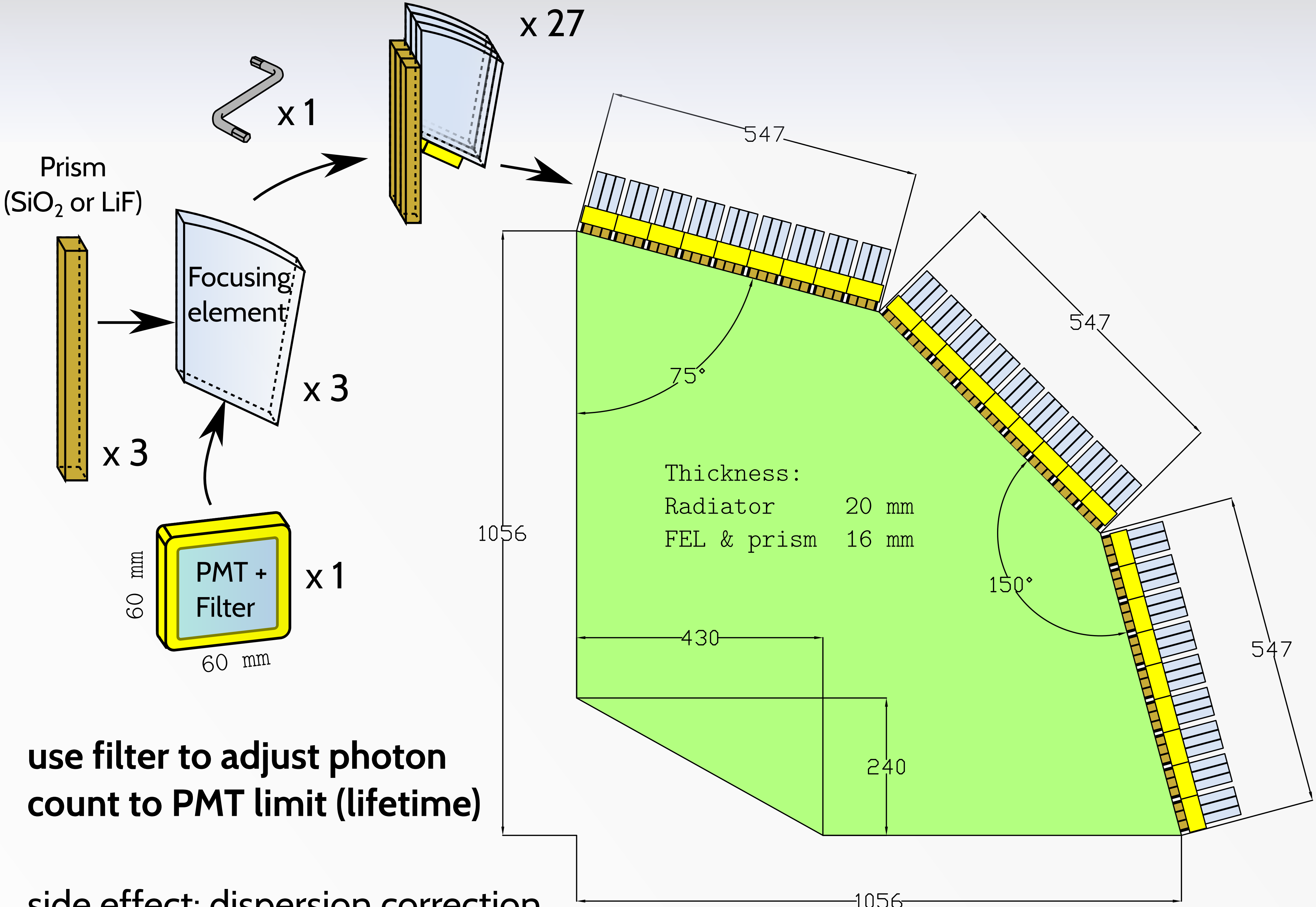




avoid gluing of several radiator pieces (transmission problems, production risk)

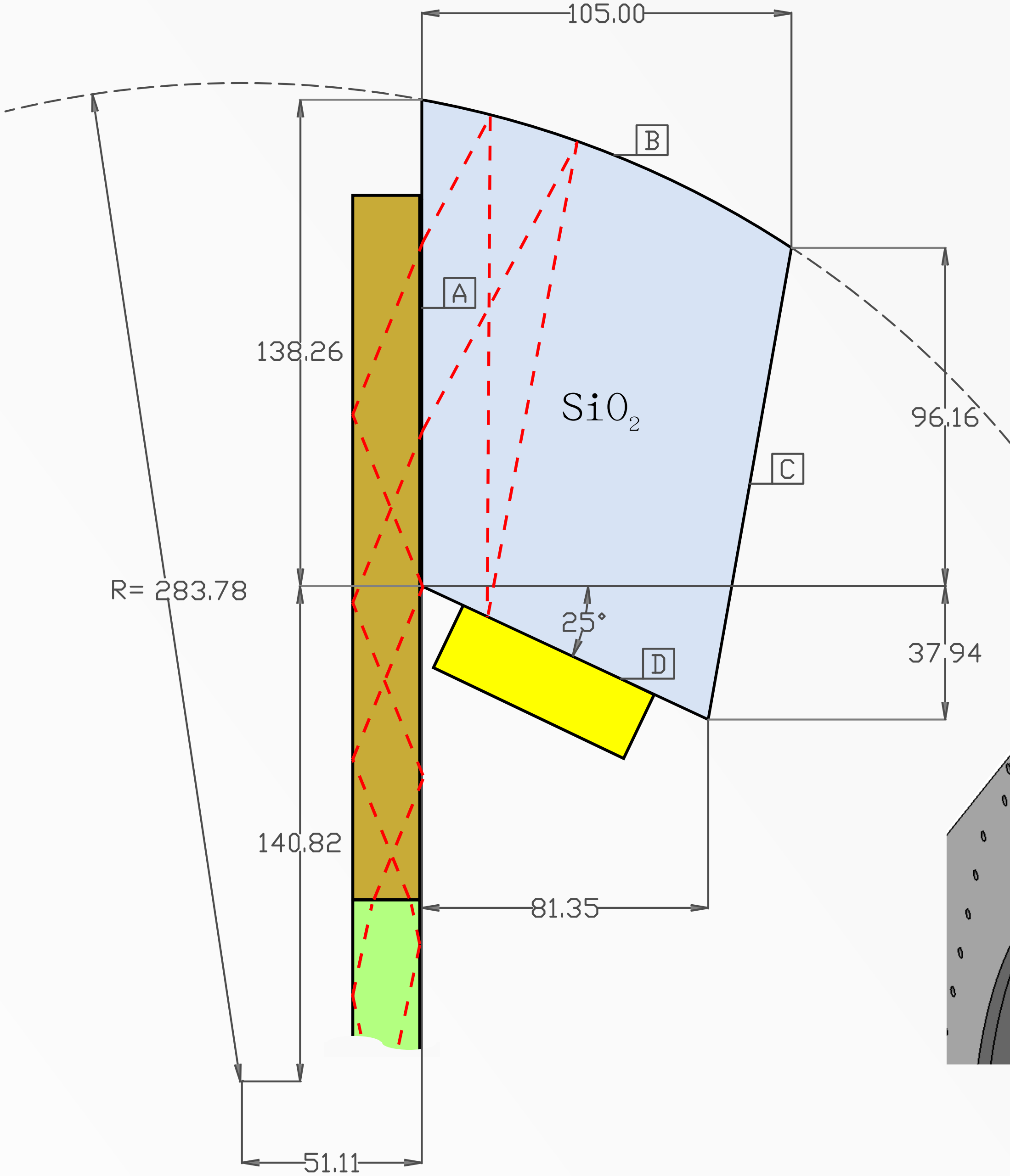
smaller plate is easier to handle (construction, transport)

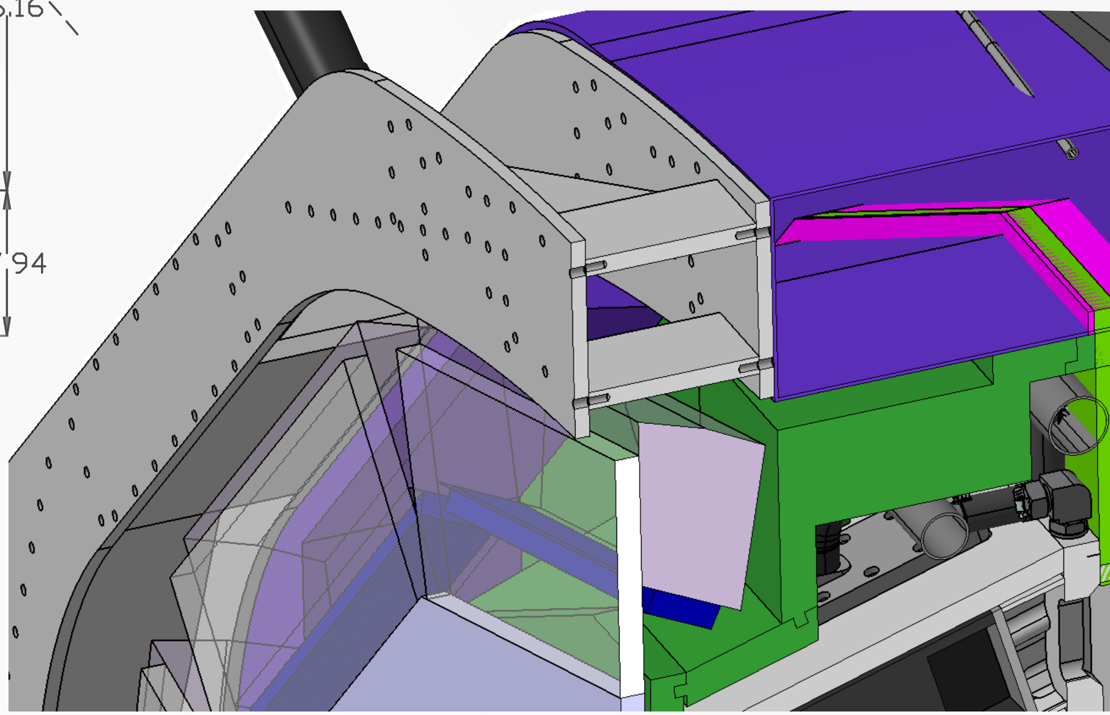




use filter to adjust photon count to PMT limit (lifetime)

side effect: dispersion correction
(can be enhanced by choosing LiF prism)

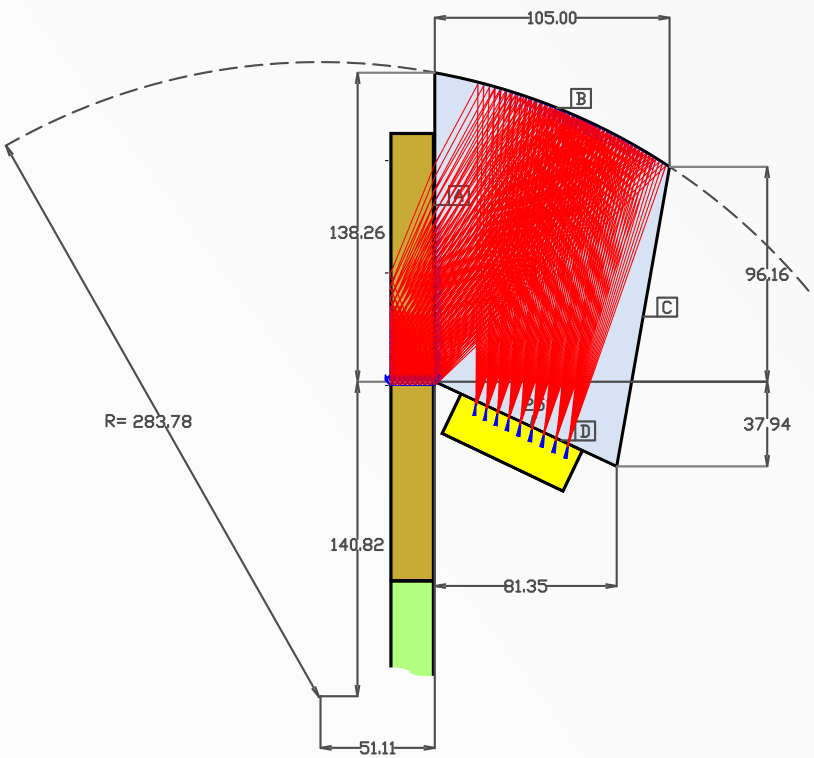

105.00
B
A
C
D
138.26
140.82
96.16
37.94
81.35
51.11
25°
R= 283.78
SiO_2

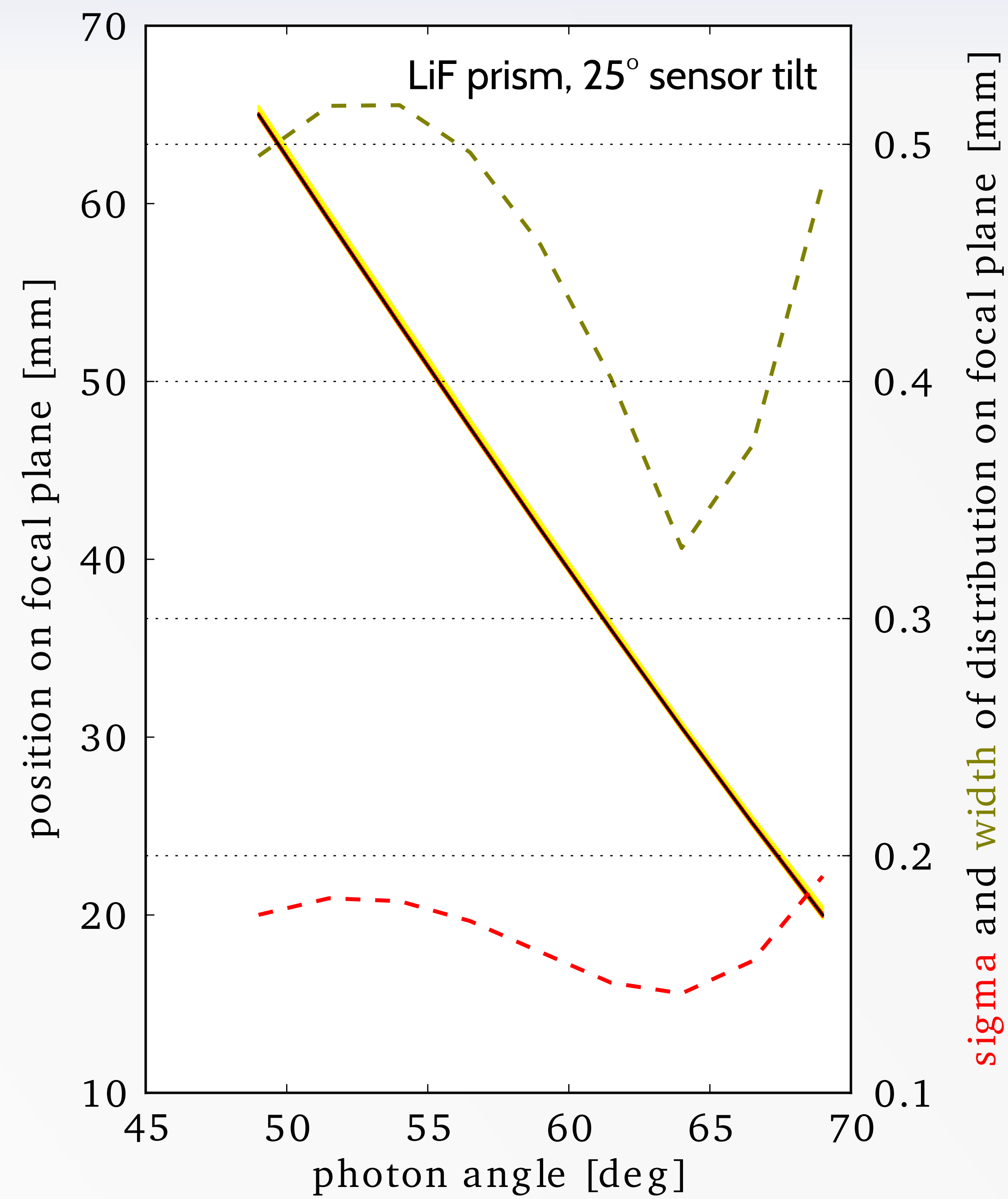


Optics with LiF

cylindrical surface

good alignment to B-field



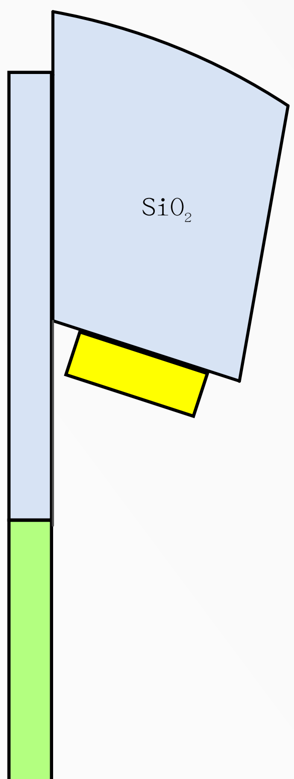


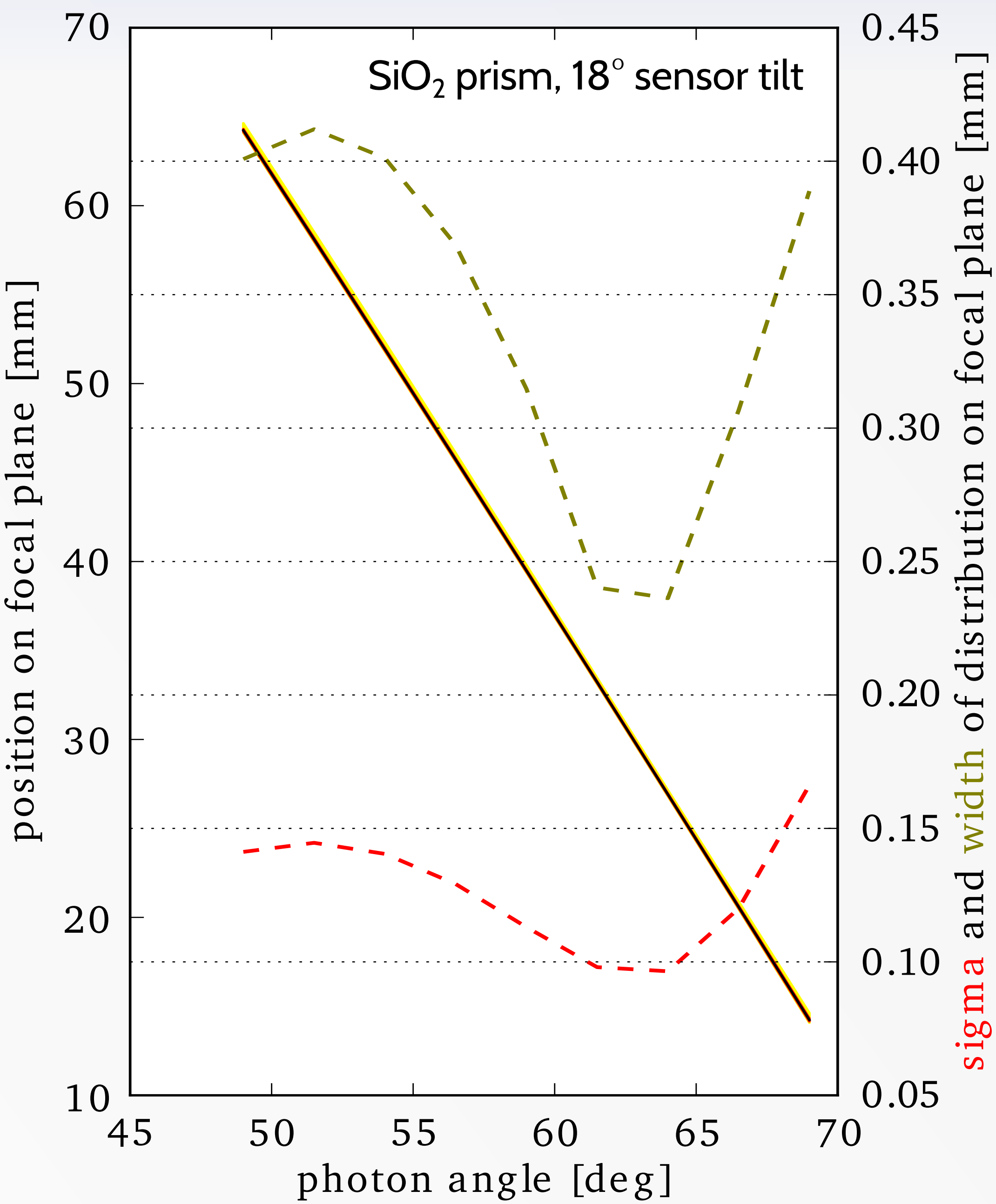
Optics with SiO_2

cylindrical surface

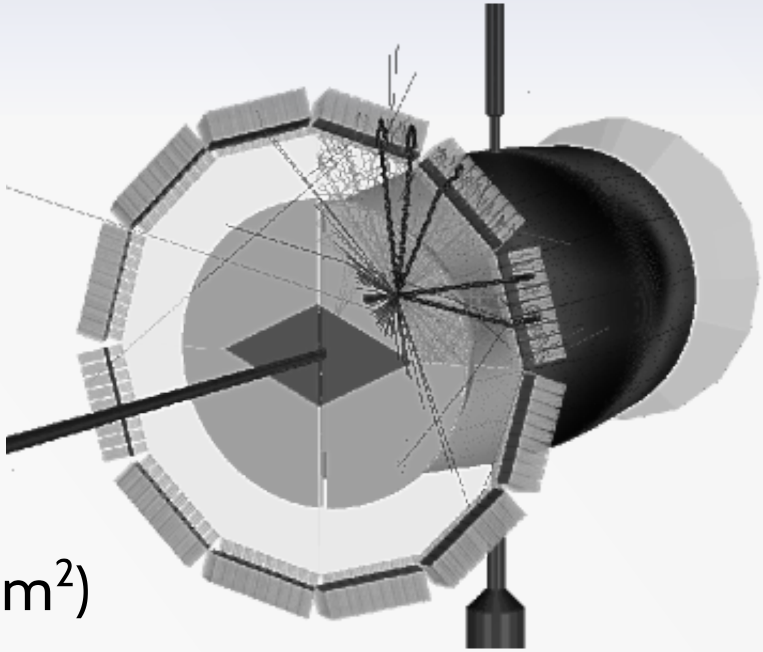
marginal alignment to B-field

prism becomes obsolete in case of a larger radiator (less glue joints)





Advantages



no aspheres -> simpler to produce, lower cost

improved imaging resolution

realistic MCP-PMT lifetime requirements (5.5 C/cm^2)

flexible, can ...

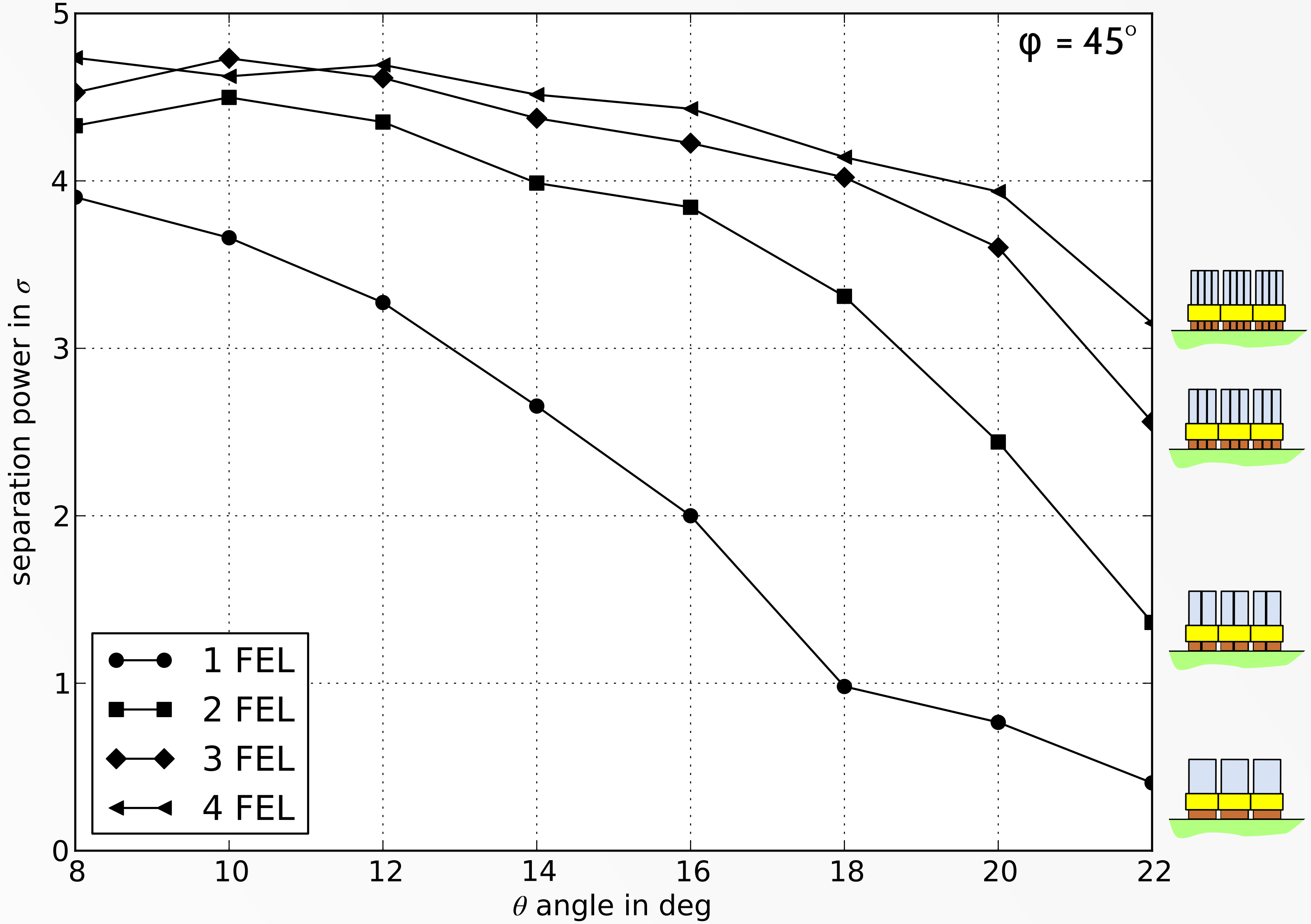
- be tuned to work with different photodetectors
- use LiF correction without major changes to the design

π/K separation at 4 GeV/c for different number of FELs (SiO_2 prism)

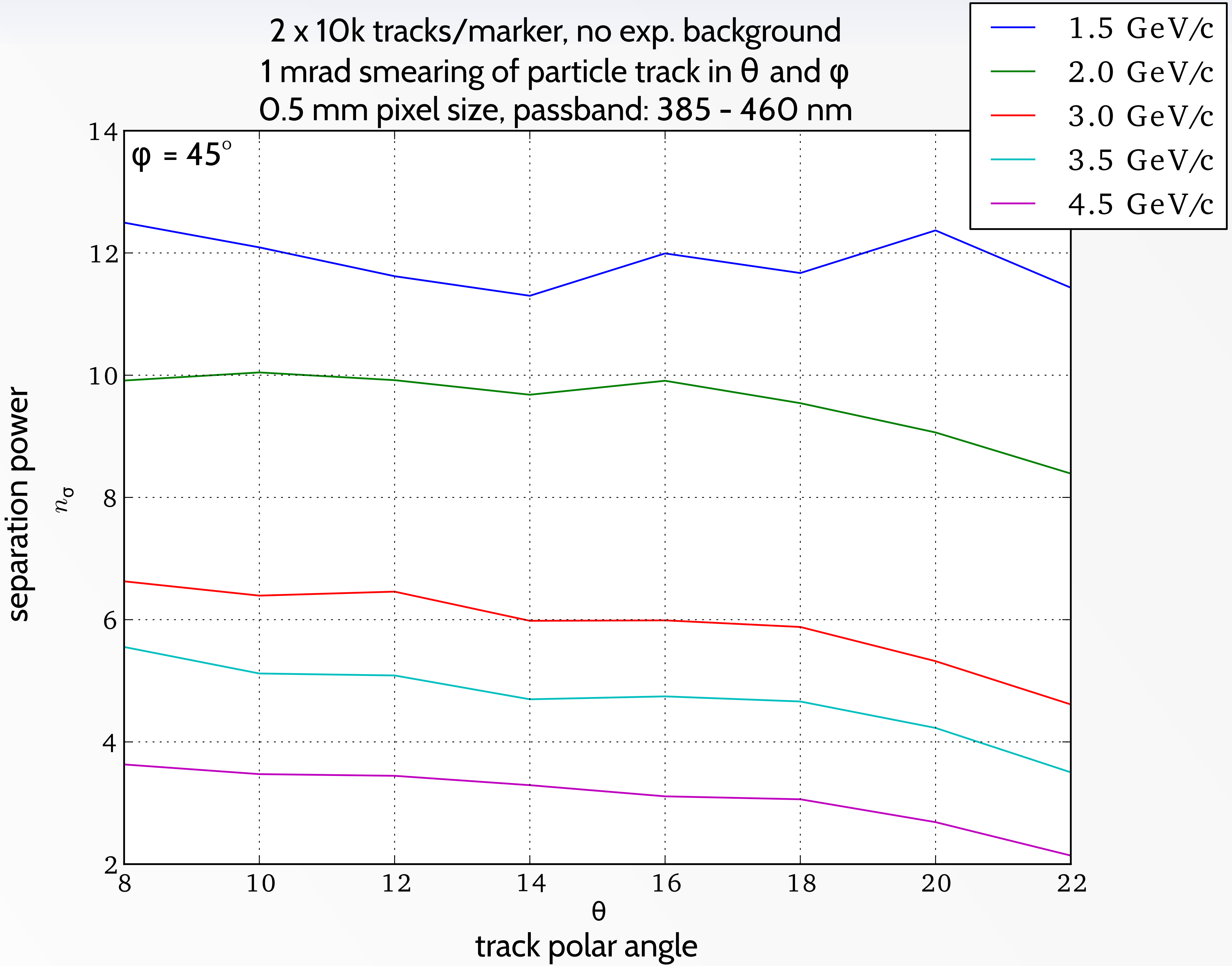
2 x 10k tracks/marker, no exp. background

1 mrad smearing of particle track in θ and φ

0.5 mm pixel size, passband: 385 - 460 nm

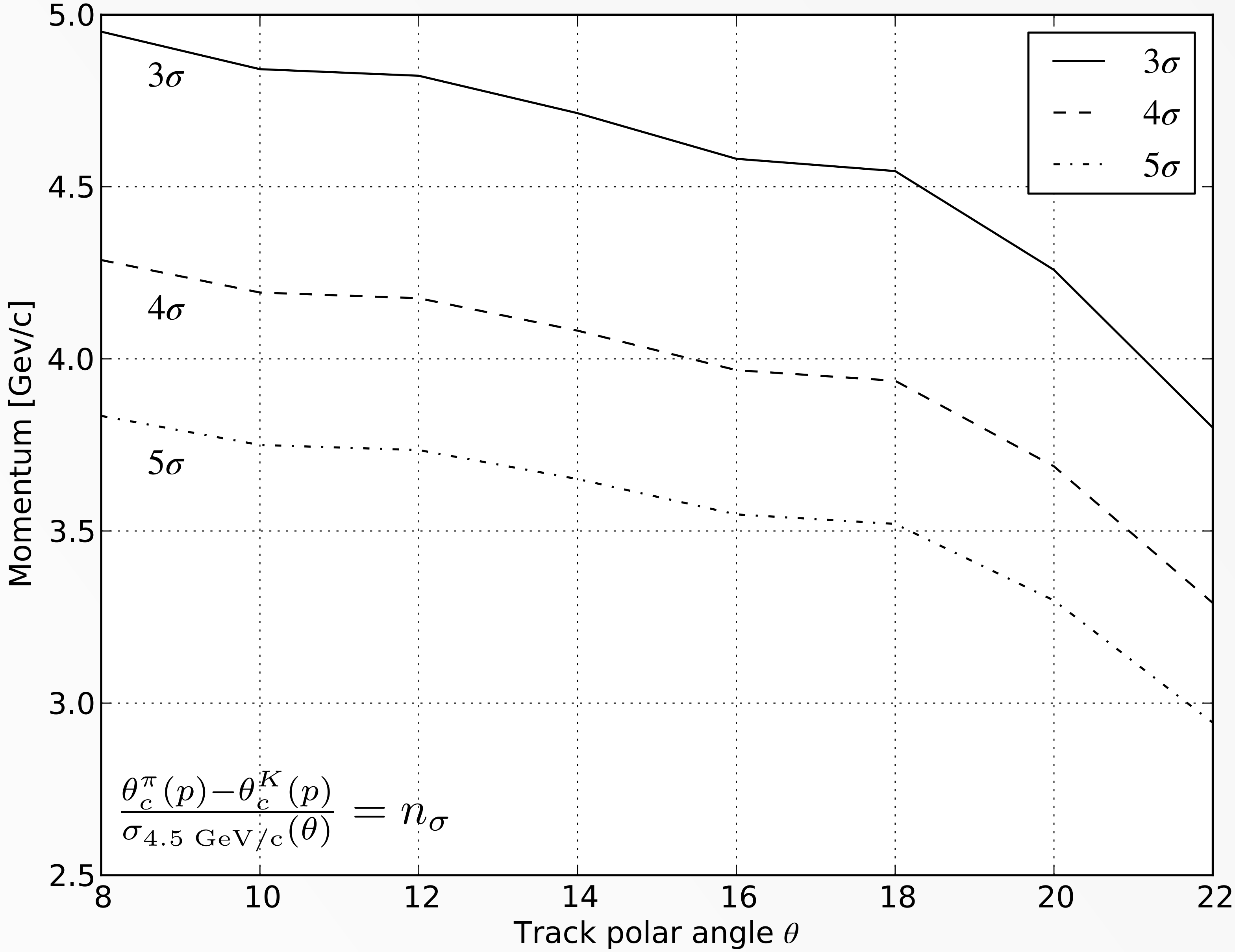


π/K separation at different momenta (3 FELs, SiO_2 prism)



π/K separation theta vs. momentum (3 FELs, SiO_2 prism)

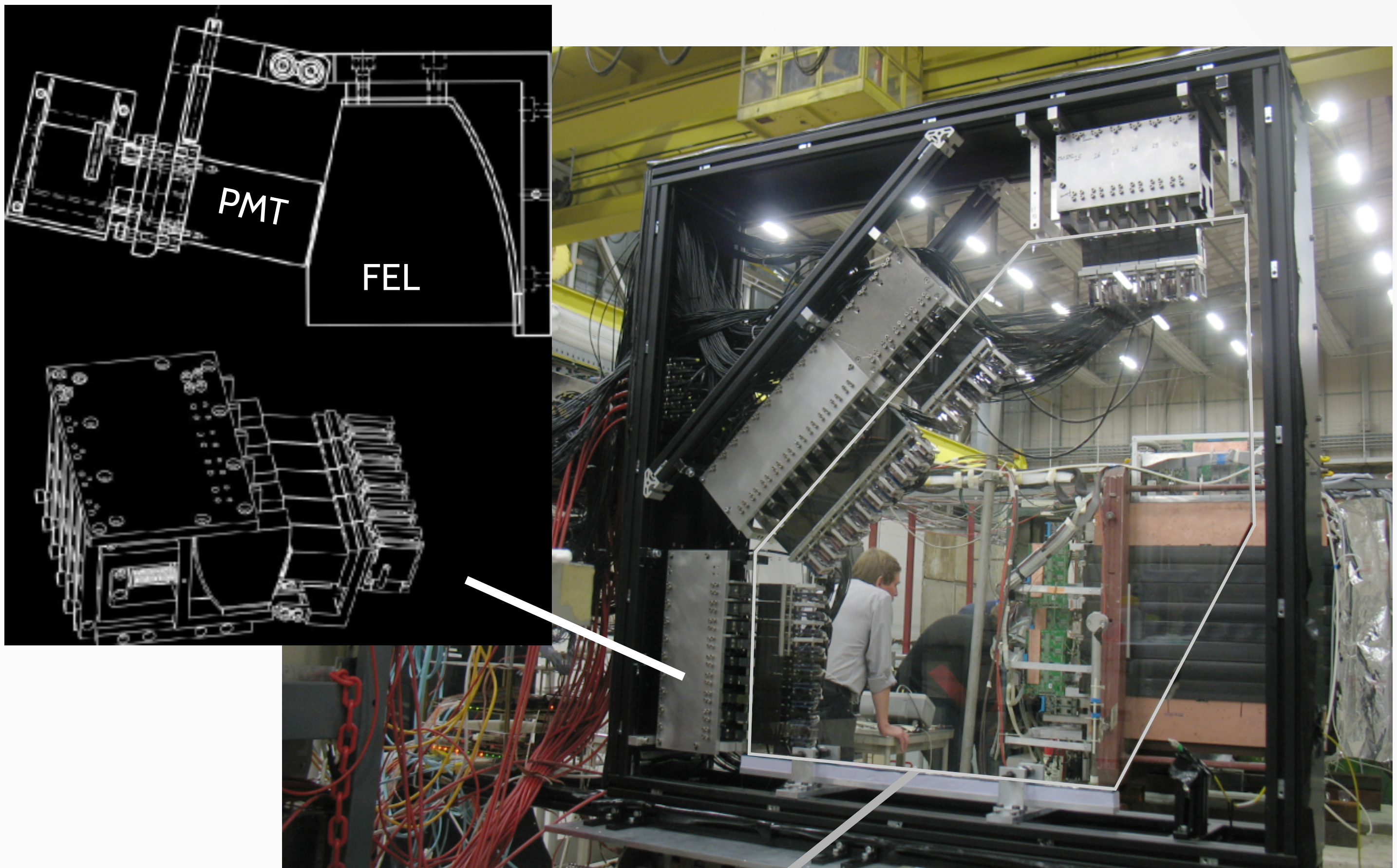
extrapolated from separation power at 4.5 GeV/c
shown in previous plot

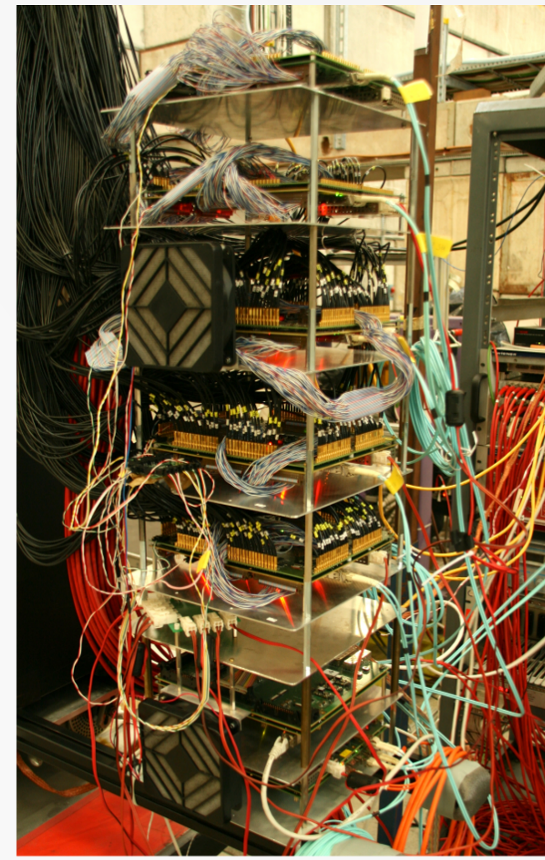


Prototyping

Small scale prototype equipped with PMTs

TRB2 readout



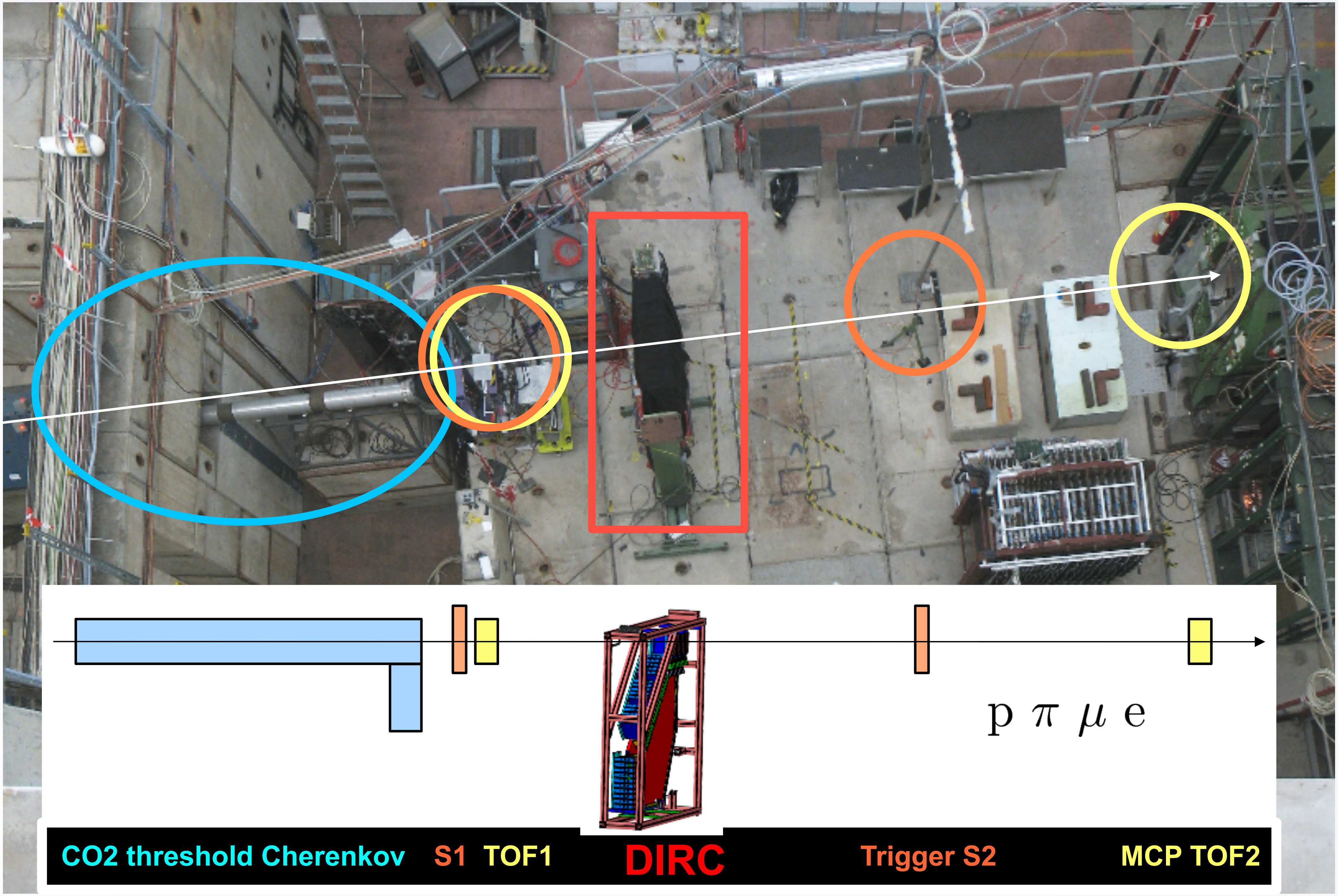


borofloat radiator

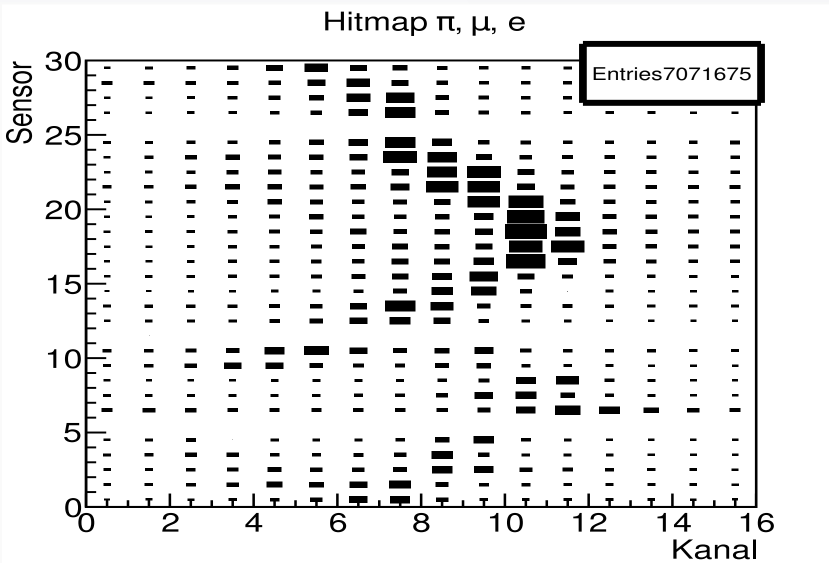
30 focusing elements (PMMA +Vikuiti ESR film)

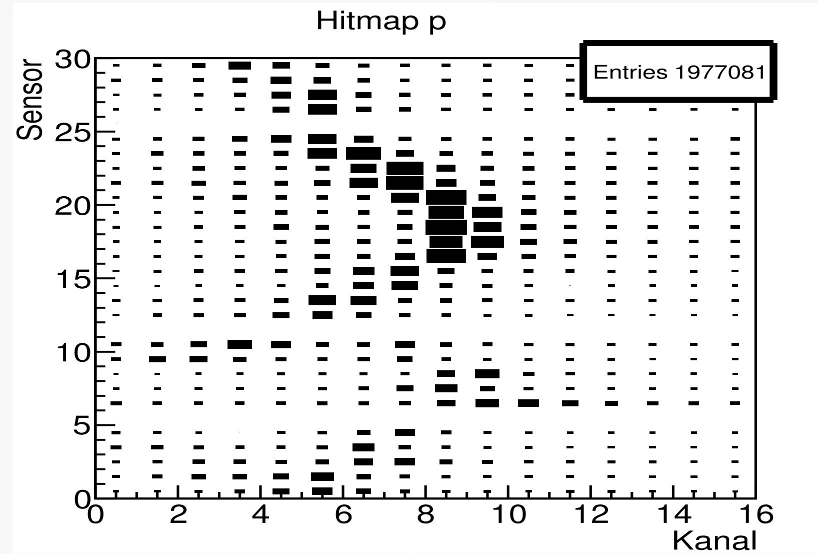
30 PMTs (H10515B-100) with 16 pixels each -> 480 channels

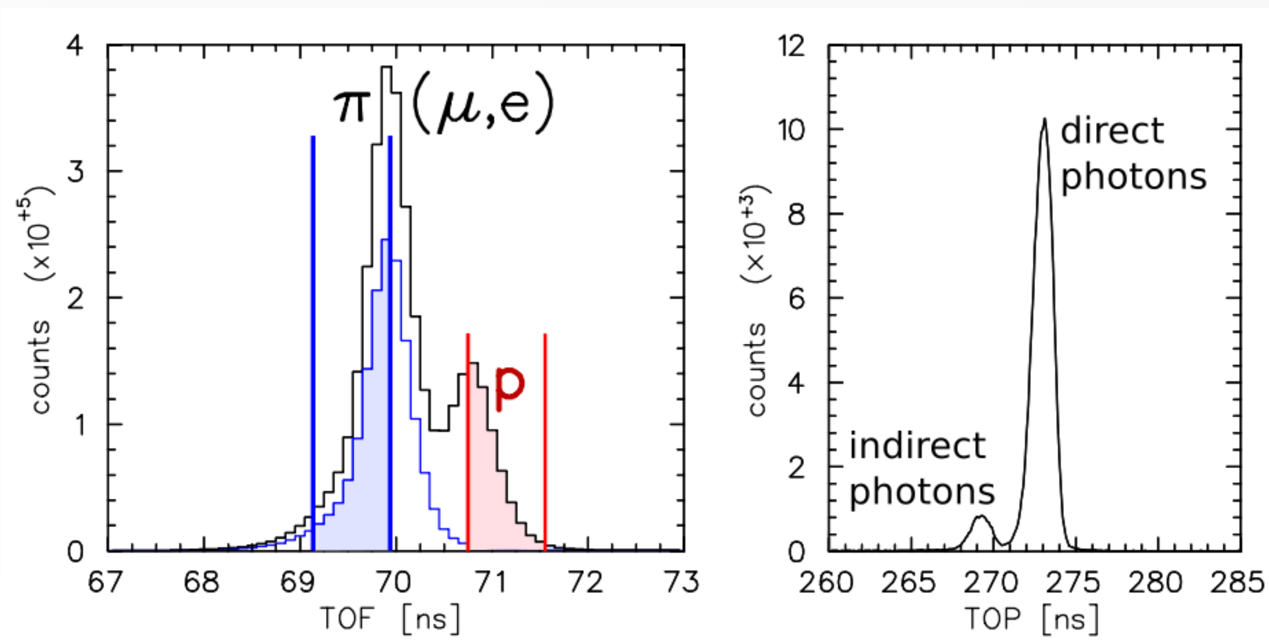
Setup at CERN T9 beamline Details in Benno Kröck's talk, Friday

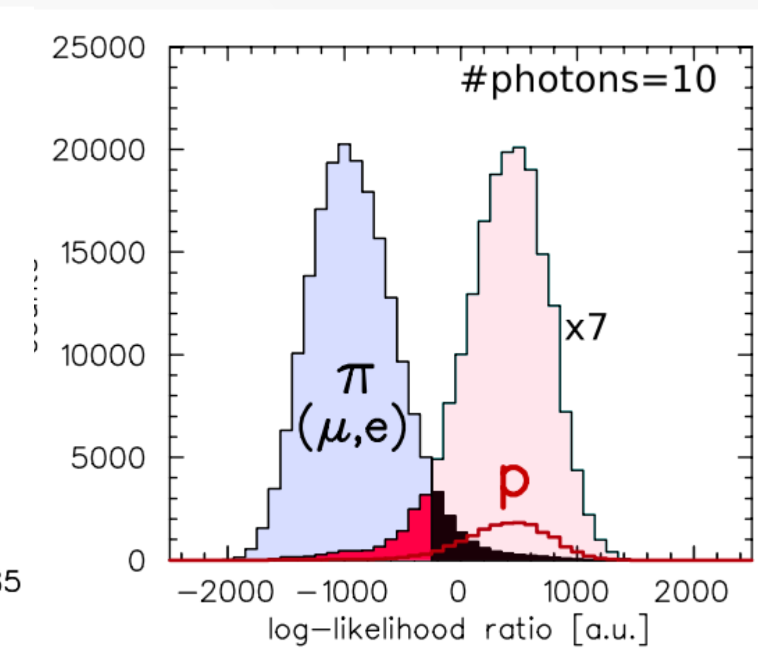


Results









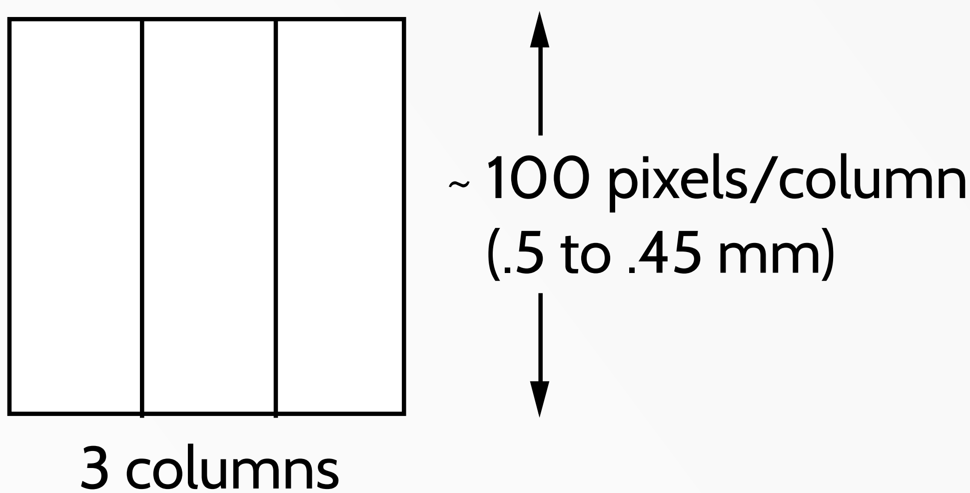
Particle identification on a single event basis

We still need sensor, anode and readout options for the final device

B-Field: ~ 1 T

Active area: 50 x 50 mm^2 to 45 x 45 mm^2

Spatial resolution:



Rate: up to 15 MHz per tube

Time resolution: < 100 ps
(have to evaluate if ns resolution is feasible)

Solutions?

TOF-PET ASIC

Timepix

CDIR