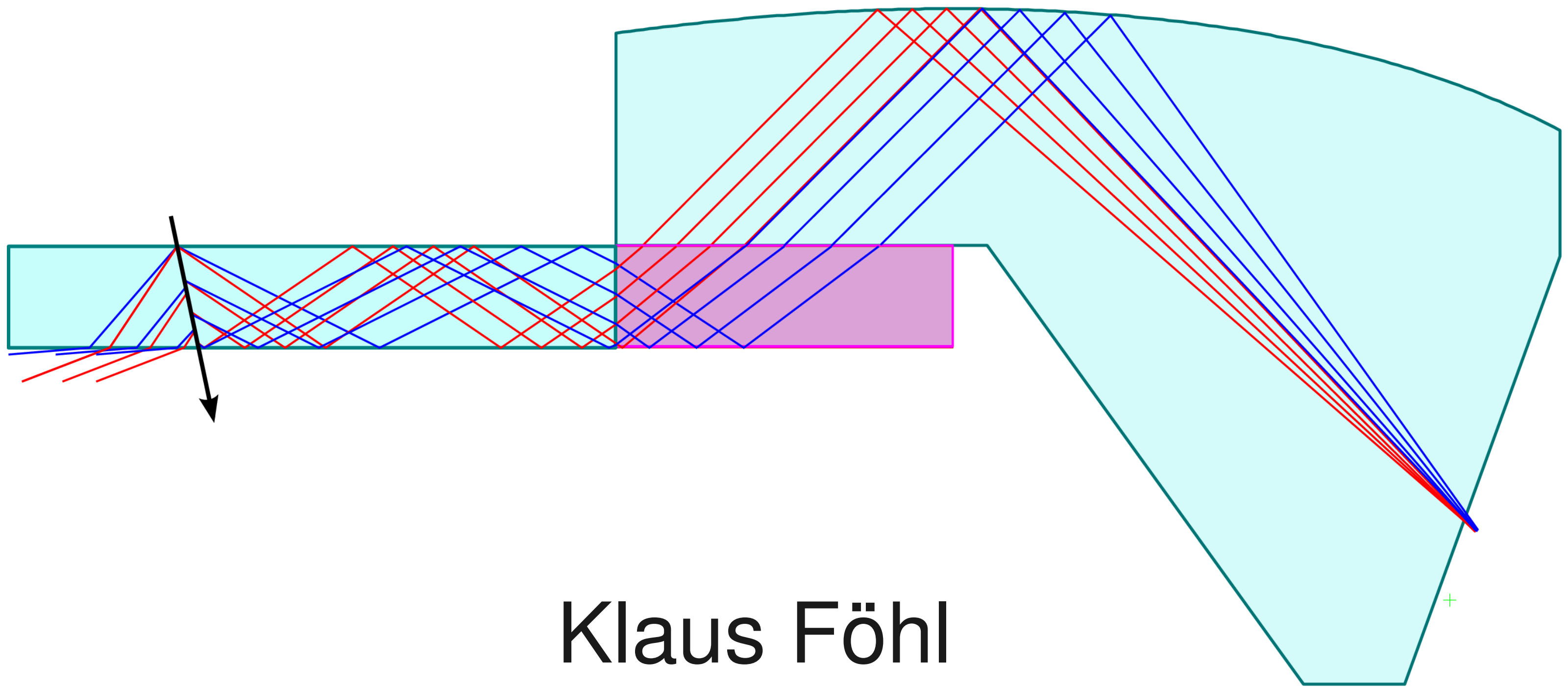
The Focussing Light Guide
Disc DIRC design



Klaus Föhl

Workshop on Fast Cherenkov Detectors

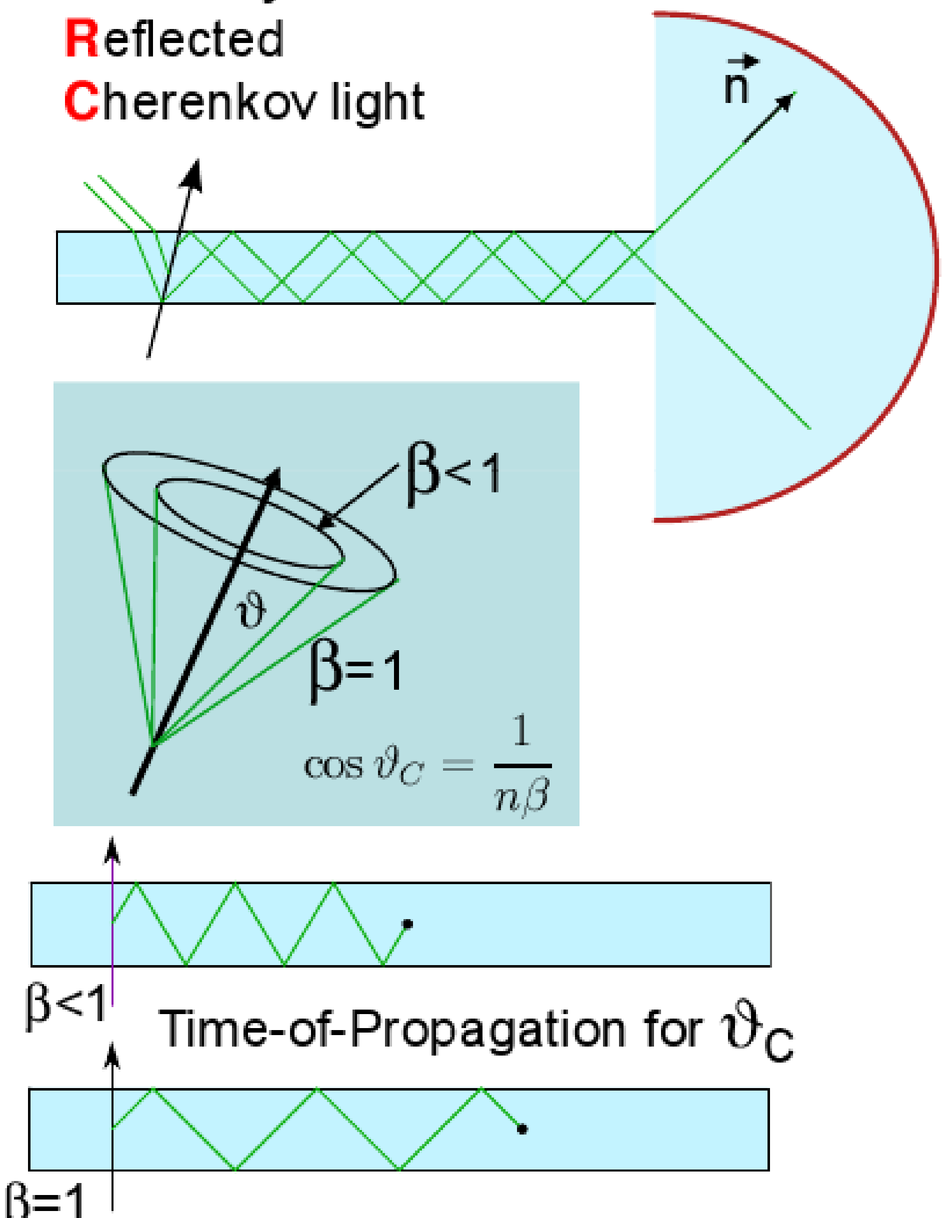
Gießen – Rauischholzhausen

12 May 2009

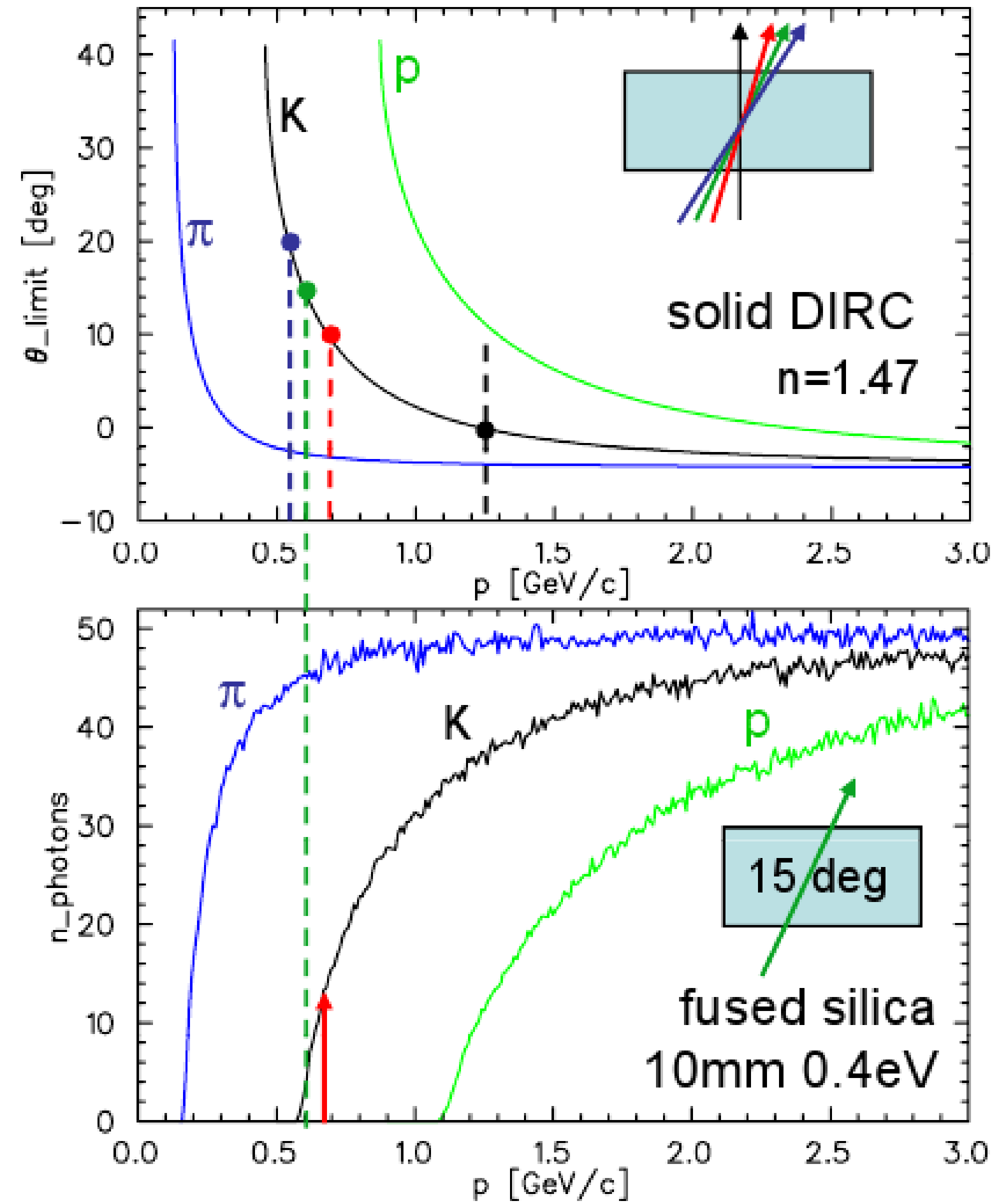
JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN

DIRC Principles

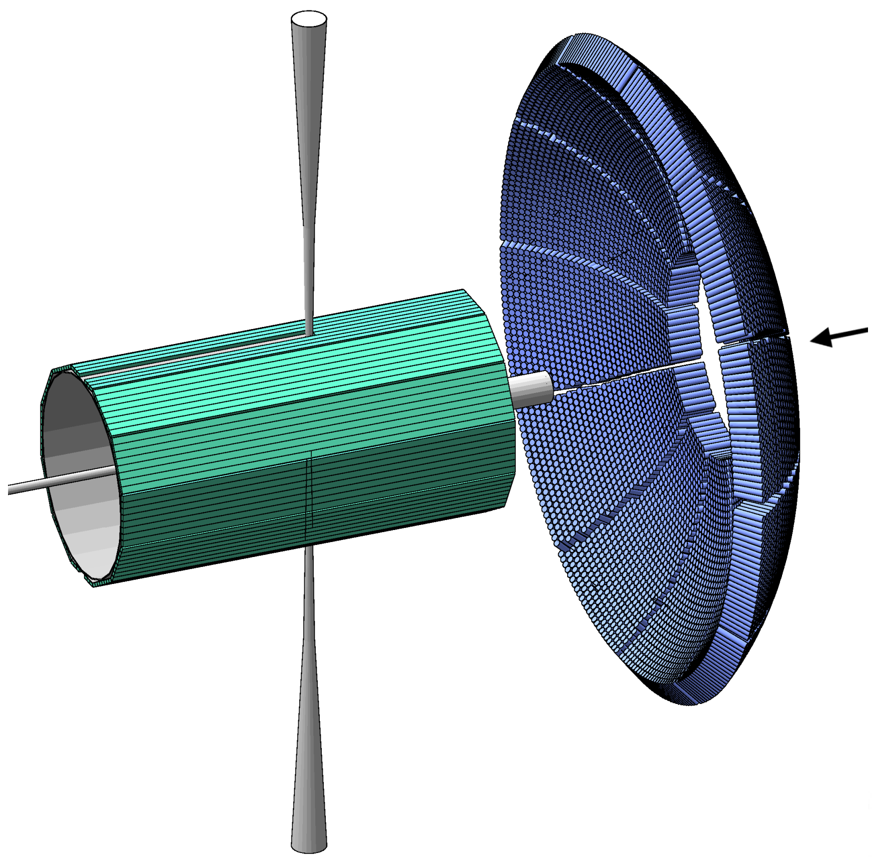
Detector of
Internally
Reflected
Cherenkov light



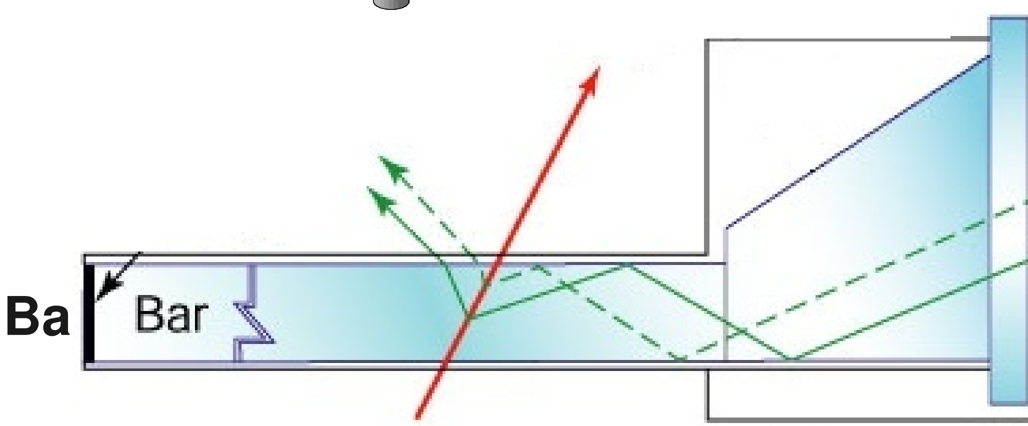
lower p threshold

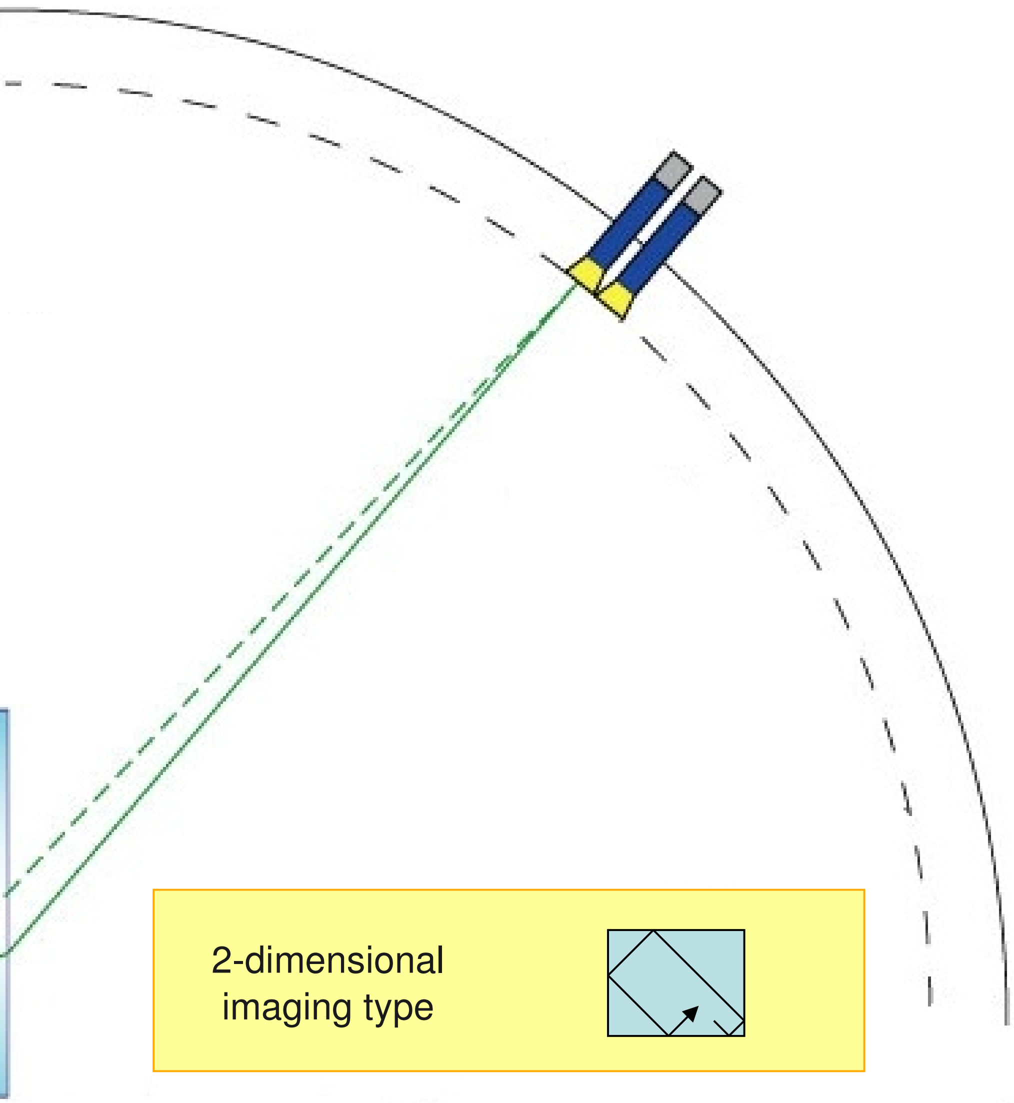


Existing DIRC

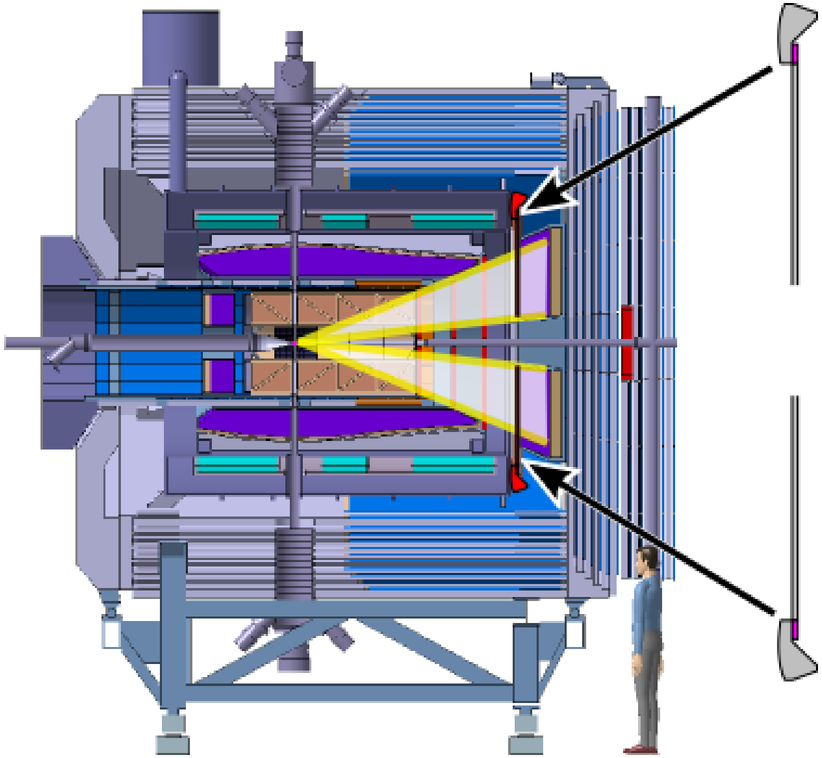


DIRC is already something known, see BaBar

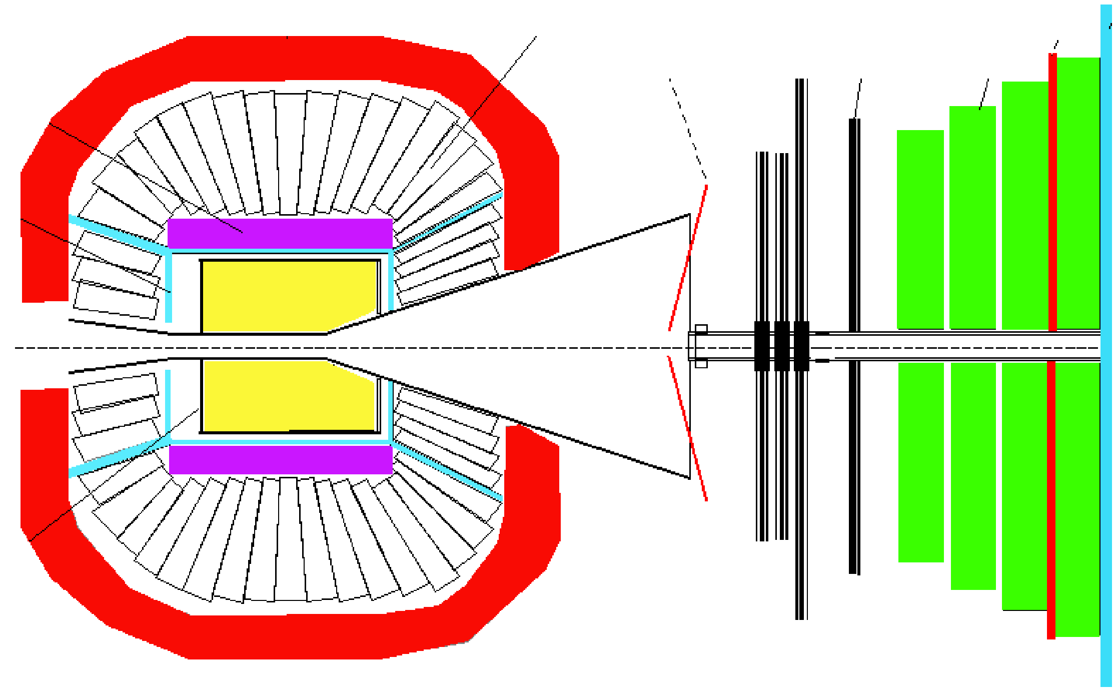




Experiments longing for “new” DIRC



PANDA Target Spectrometer



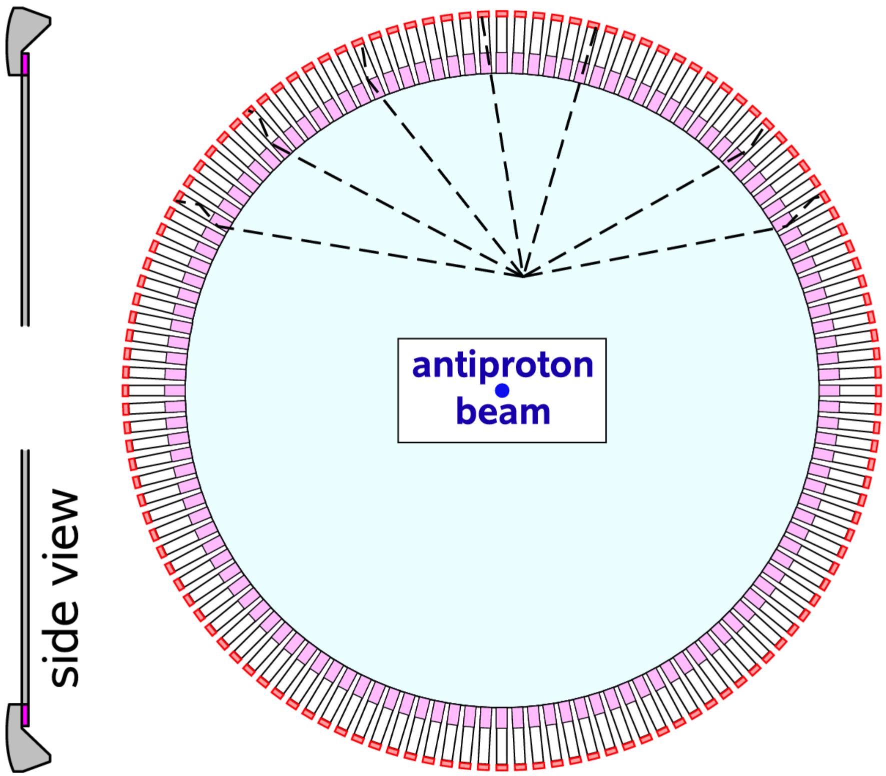
WASA experiment at COSY

measure beta for PID

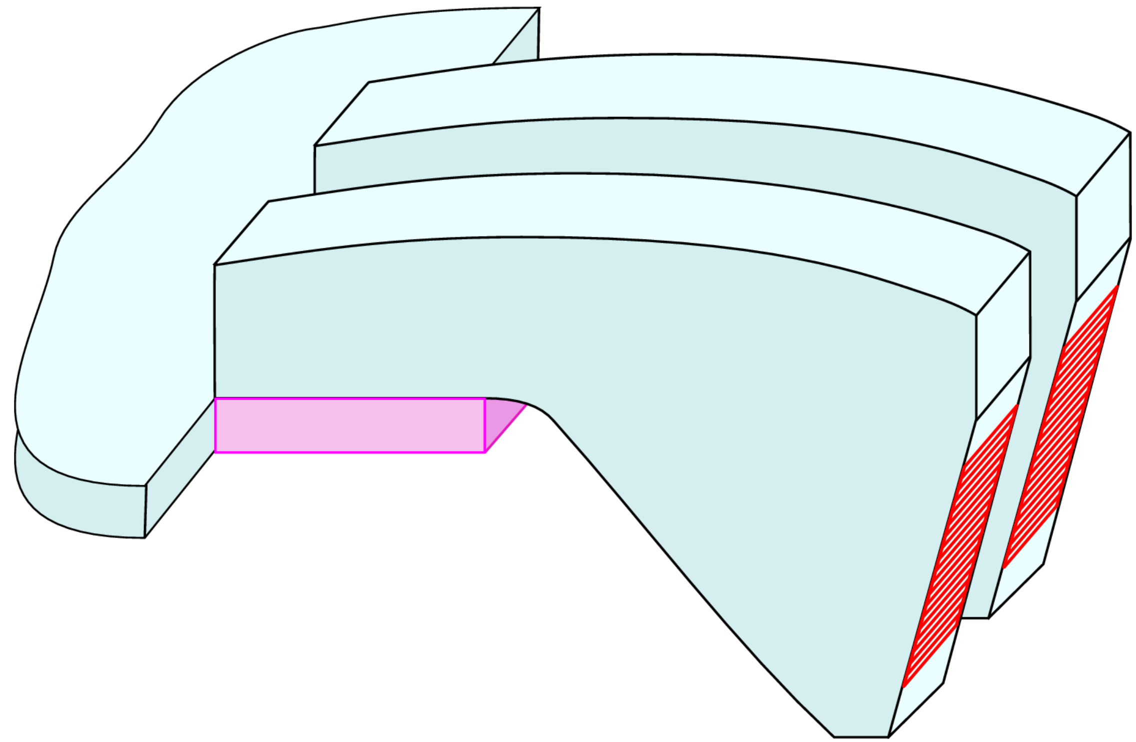
measure beta for energy determination

forward phase space to cover: theta=5-23deg for PANDA, theta=3-17deg for WASA

Focussing Light Guide Disc DIRC

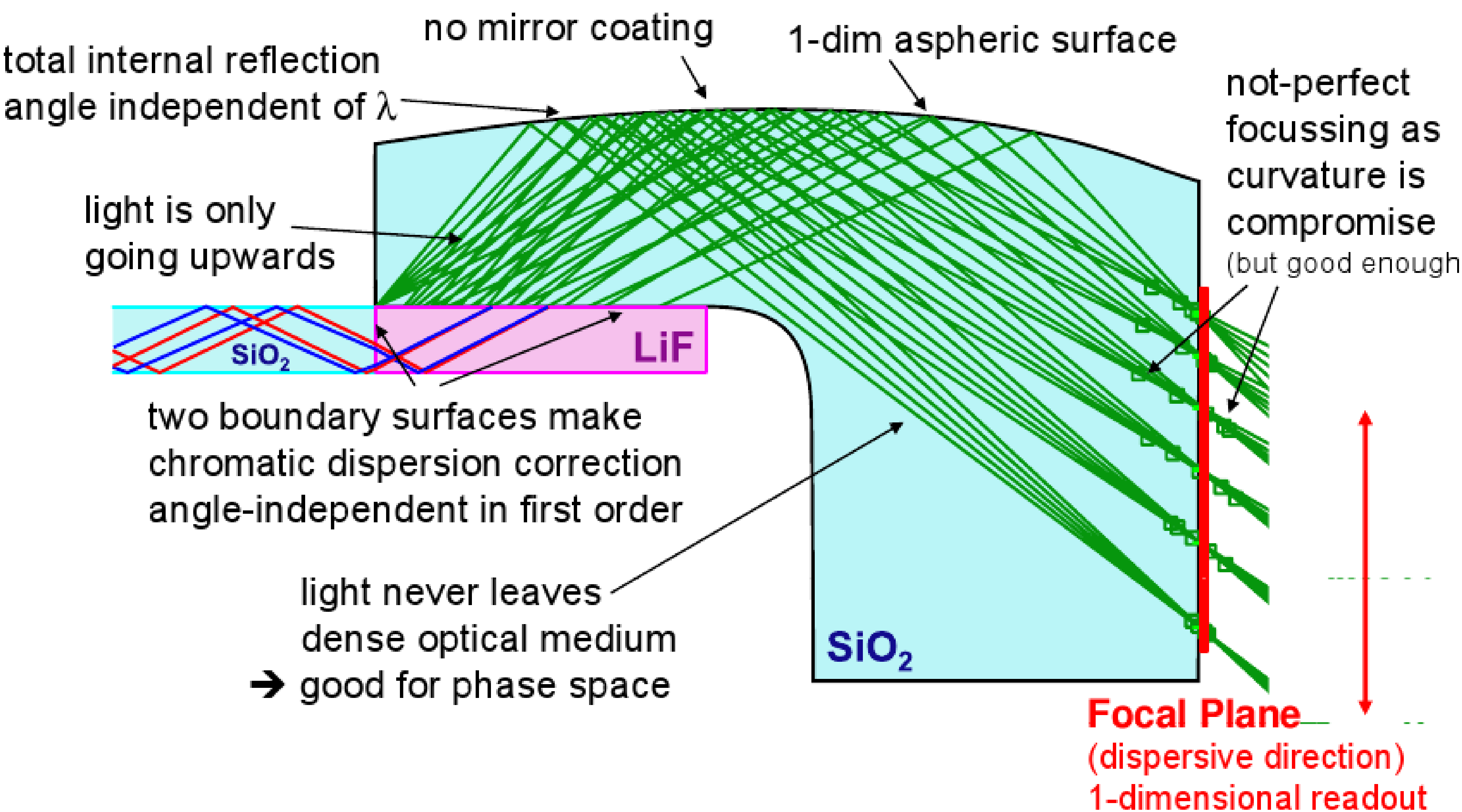


Disc DIRC seen from target

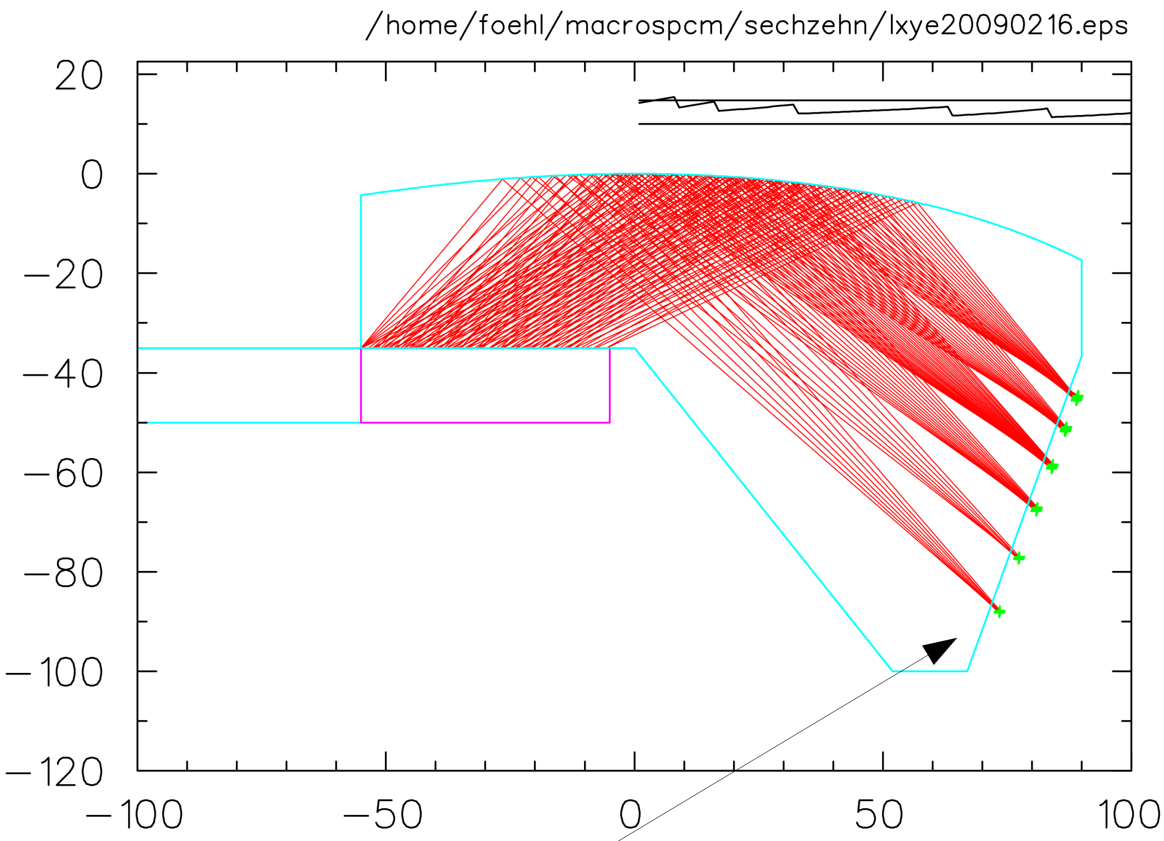


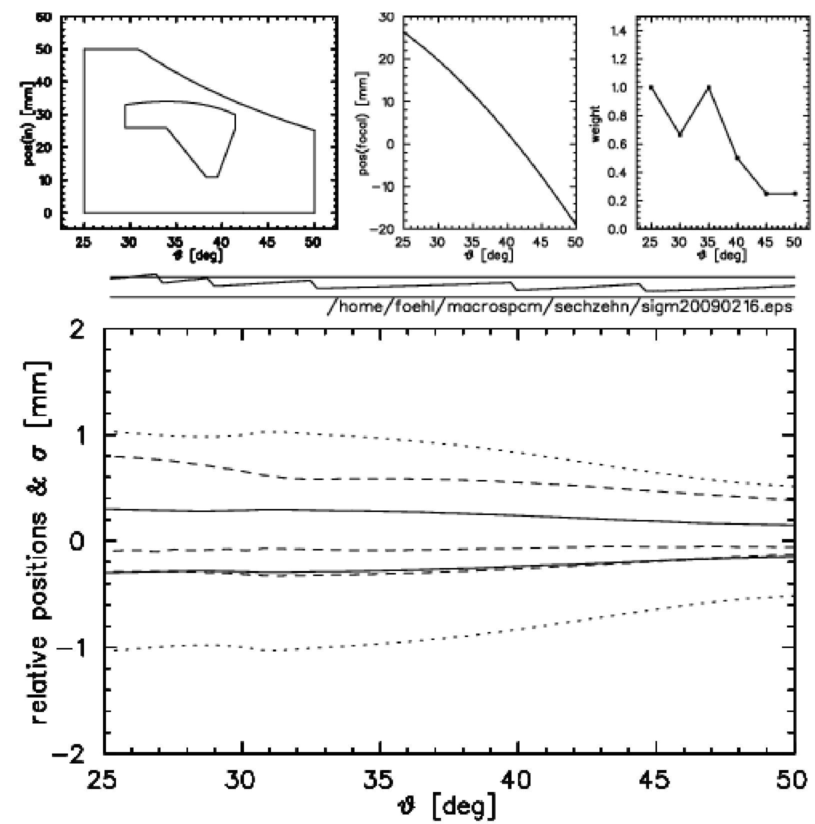
Lightguides with LiF - 3D visualisation

Focussing & Chromatic Correction



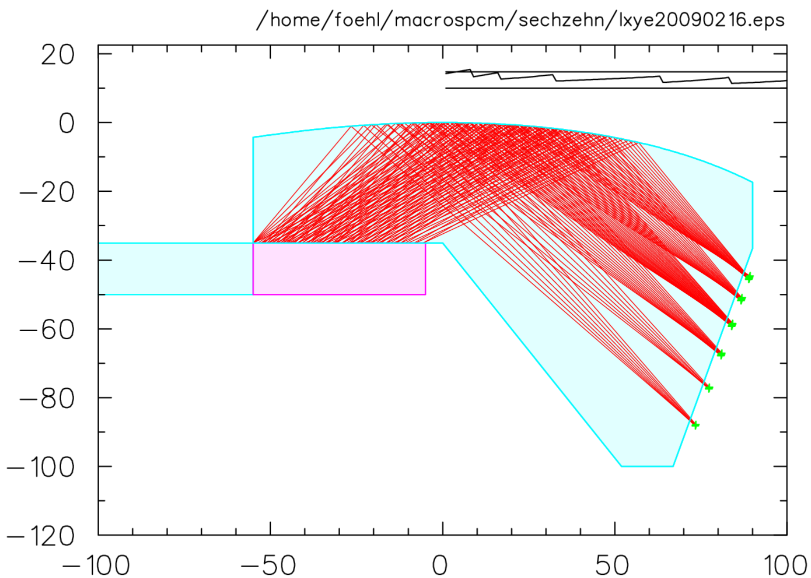
Light Guide – Shape Optimisation

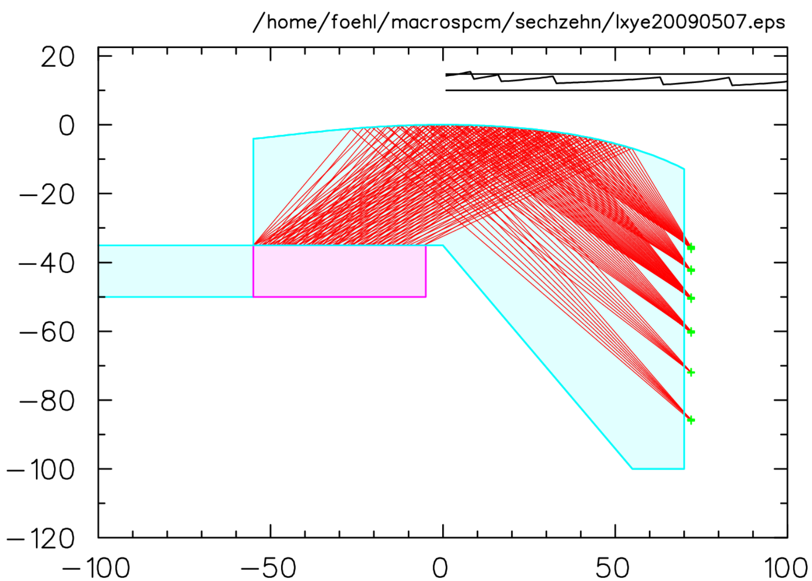


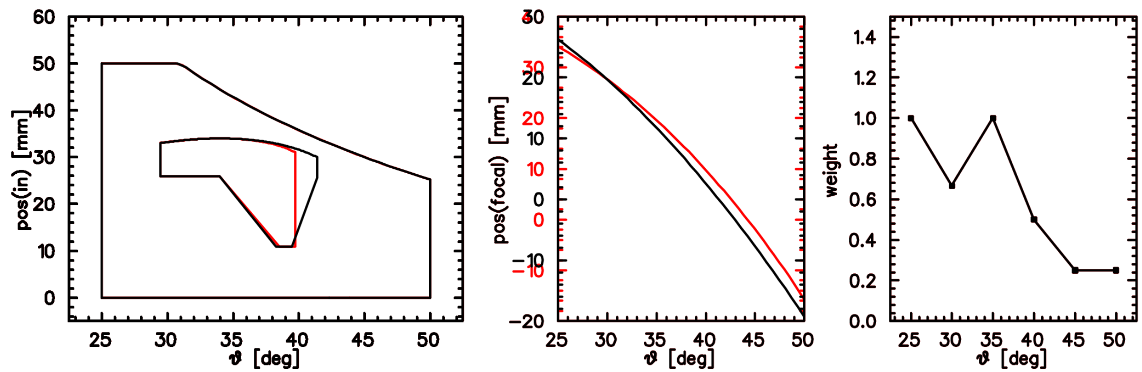


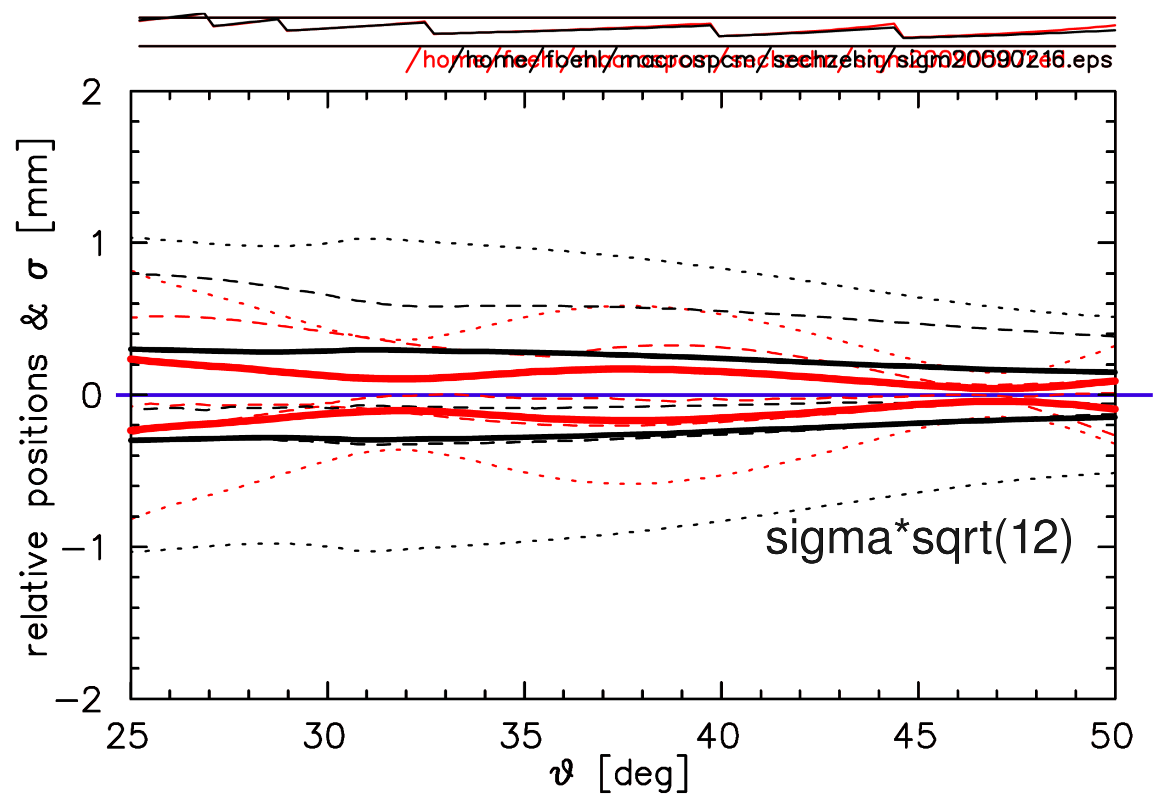
focal plane oriented normal to magnetic field direction

Focussing Light Guides - Comparison





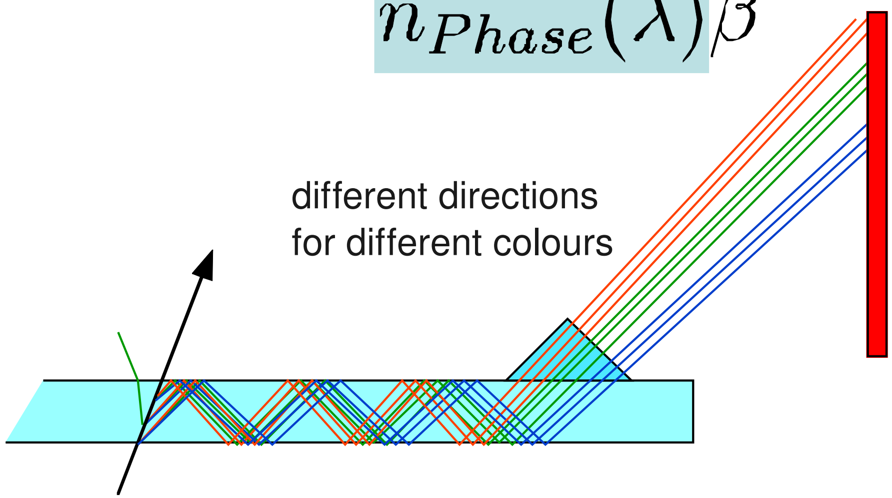


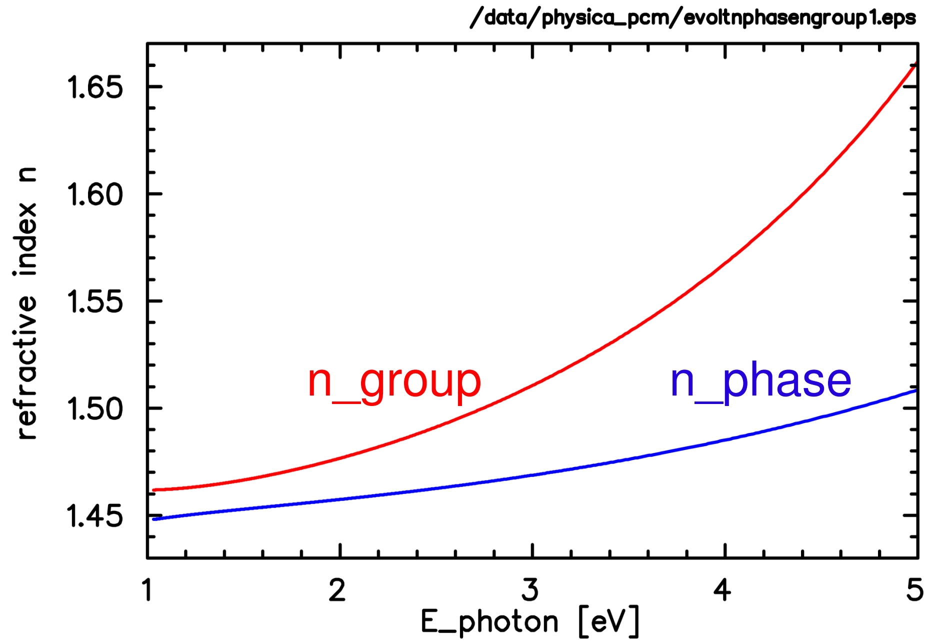


similar improvement for thinner quartz+LiF plate

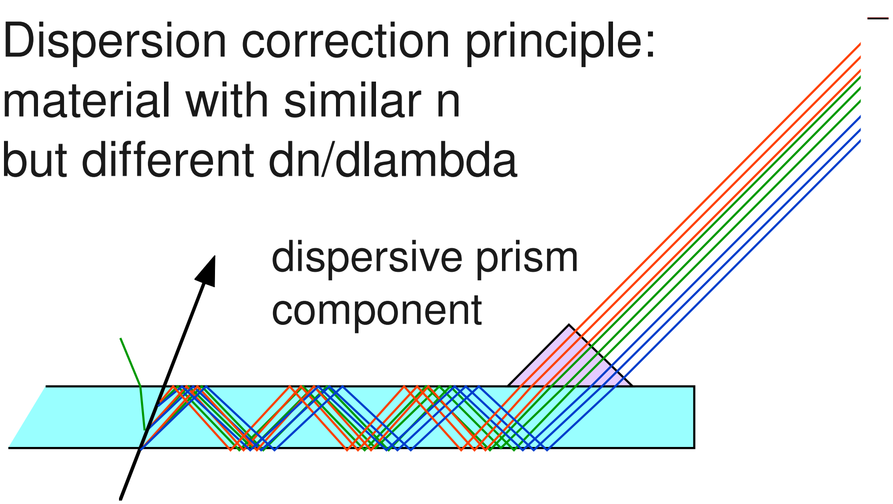
Cherenkov Radiation Dispersion

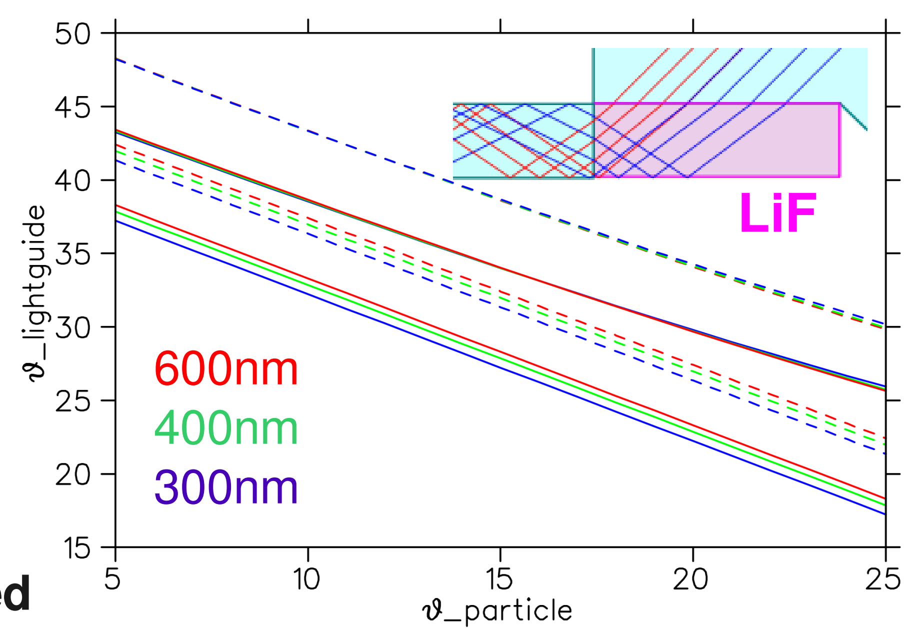
$$\cos\vartheta_C = \frac{1}{n_{Phase}(\lambda)\beta}$$





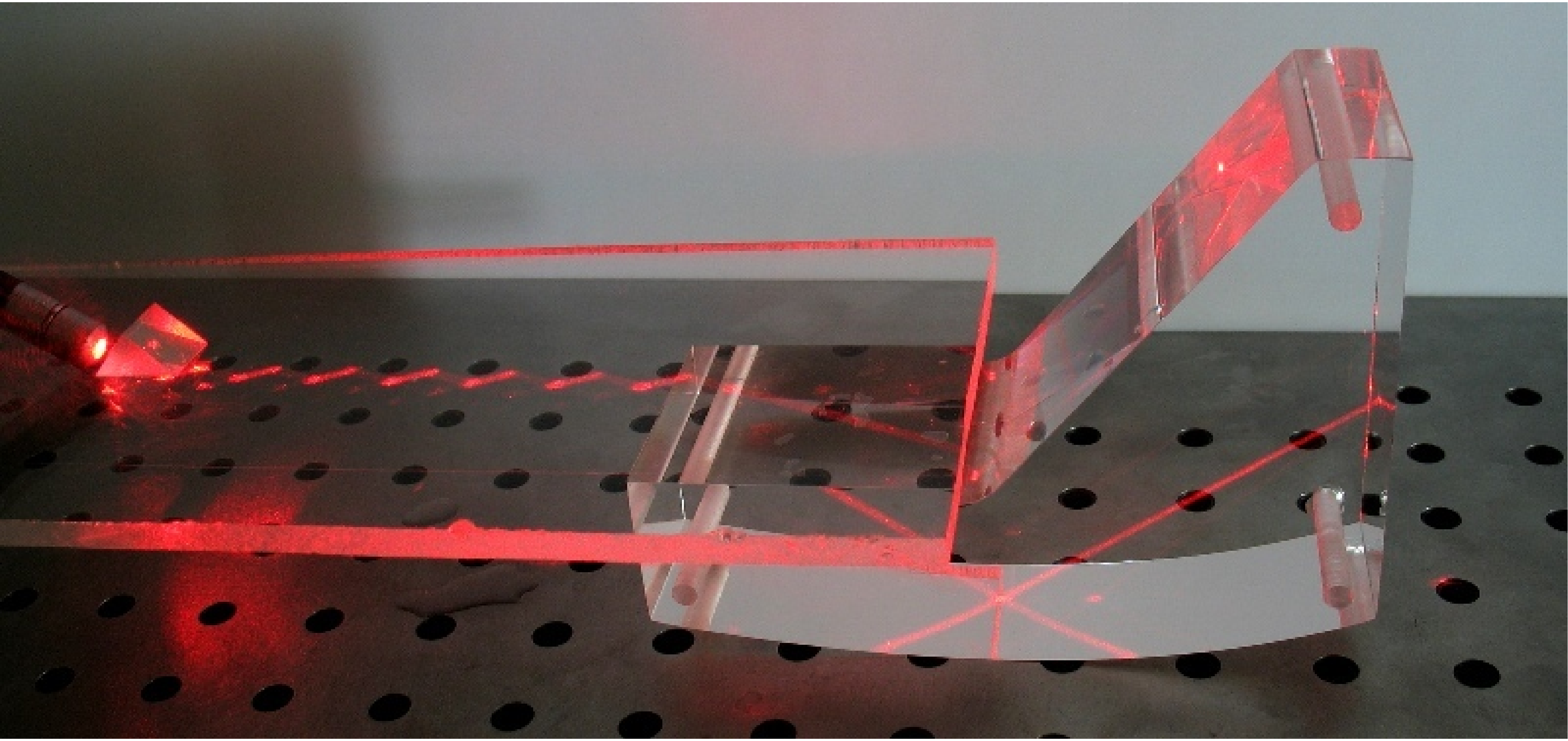
Dispersion correction principle:
material with similar n
but different dn/dlambda





N.B. choice of corrector materials rather limited

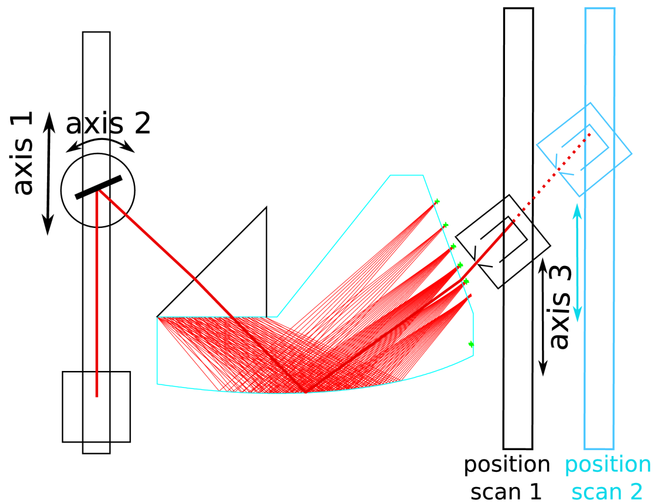
Qualitative LG Assessment

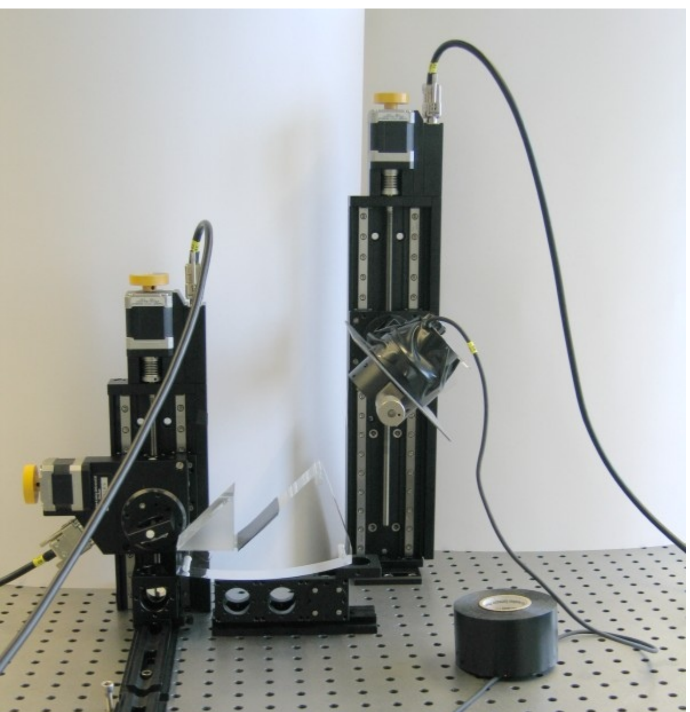


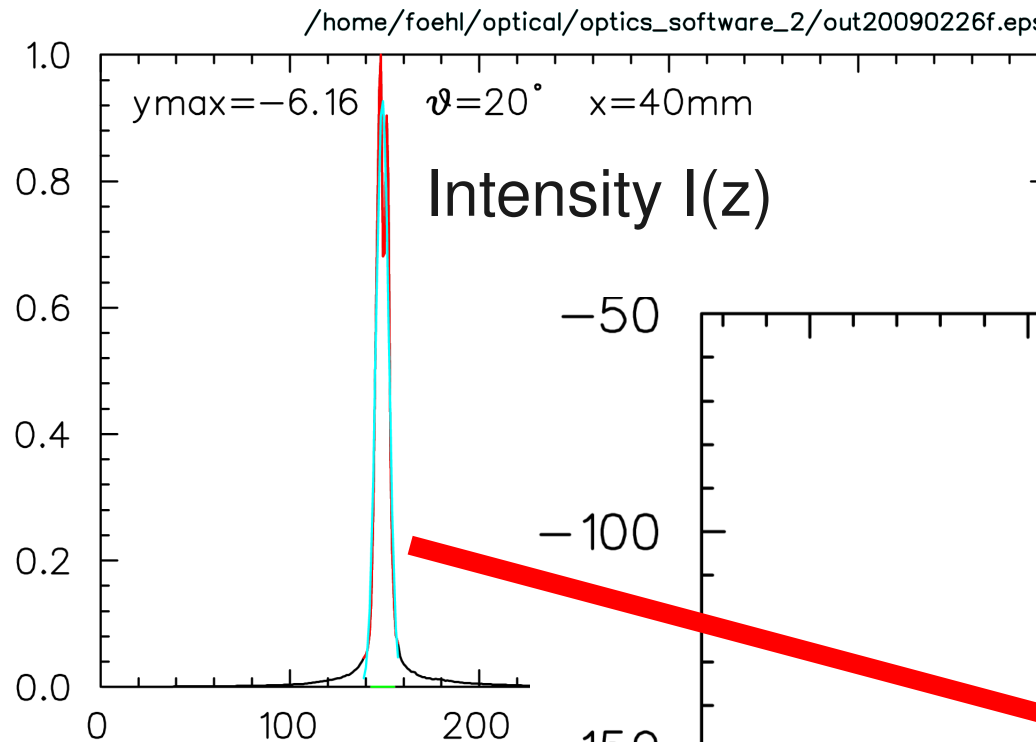
thanks to Marko Zühlsdorf and Oliver Merle

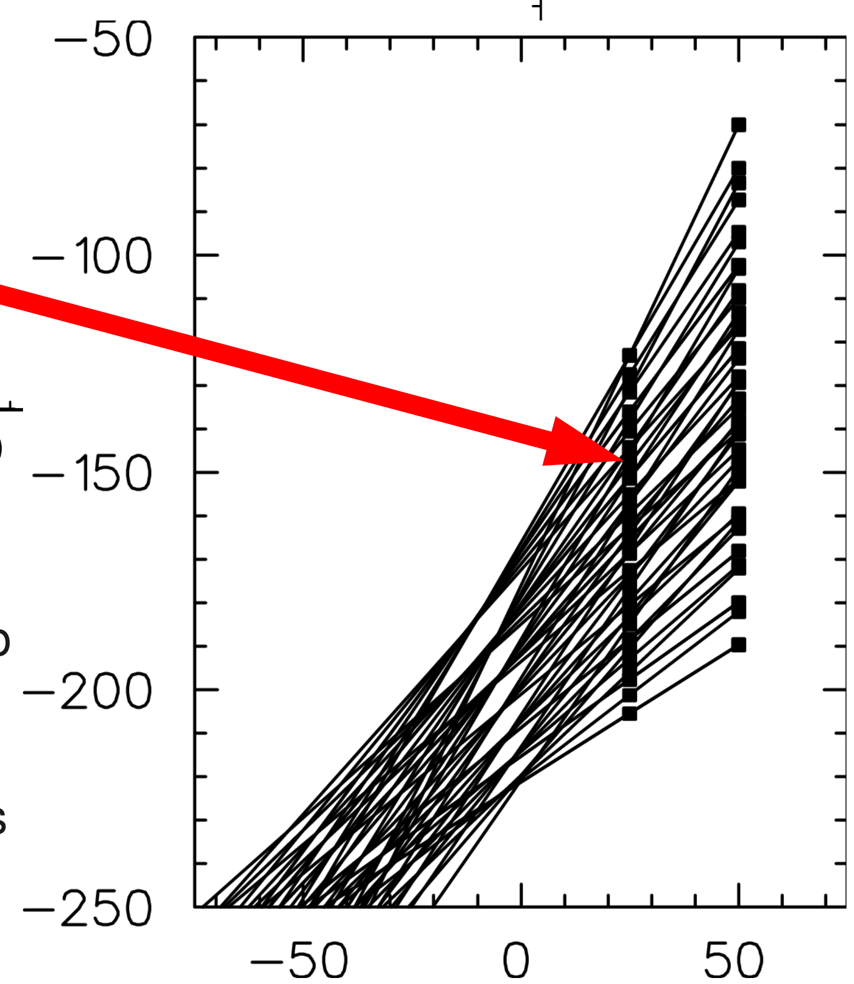
Quantitative LG Assessment

schematic setup 2009-02-25

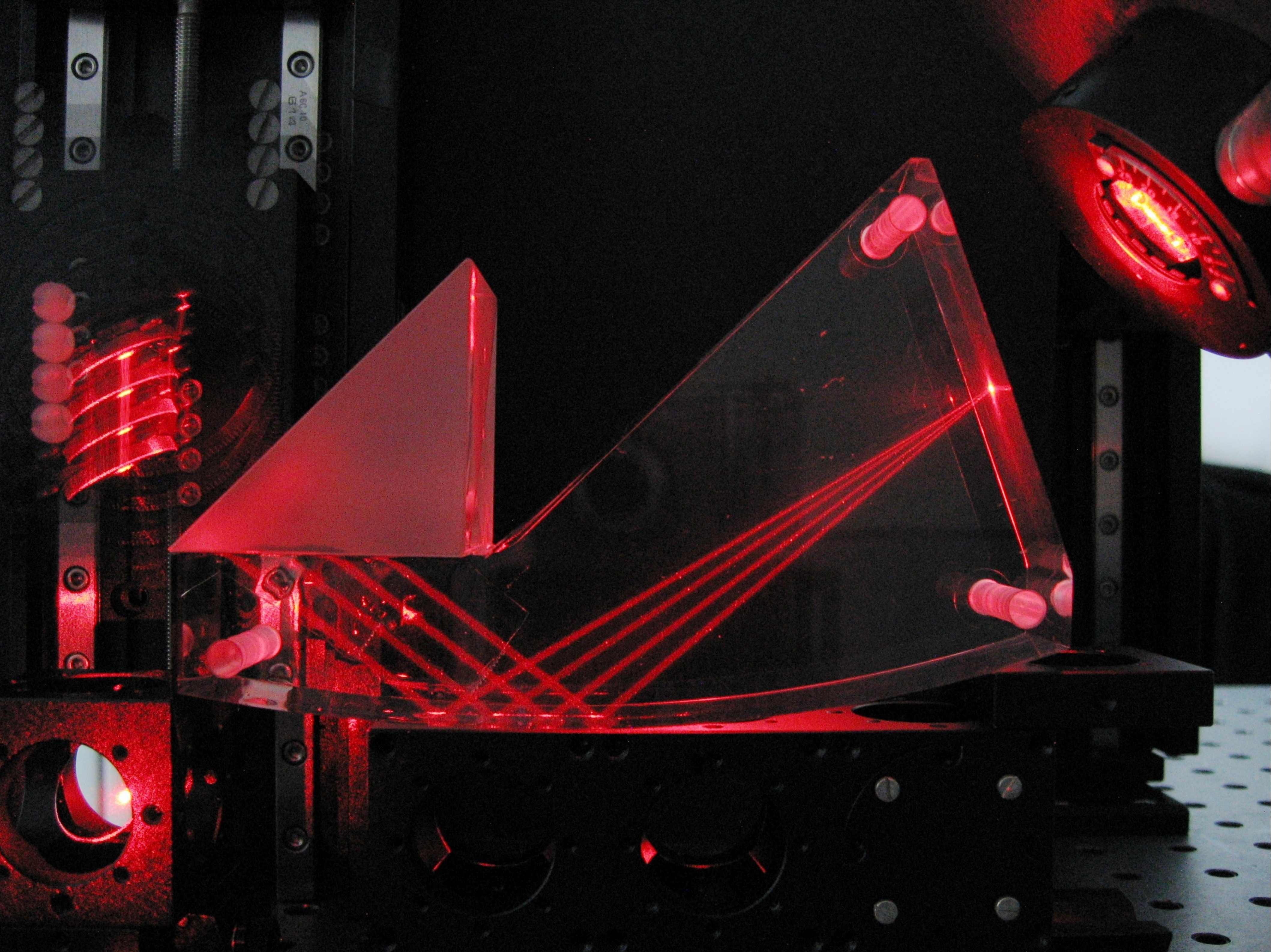




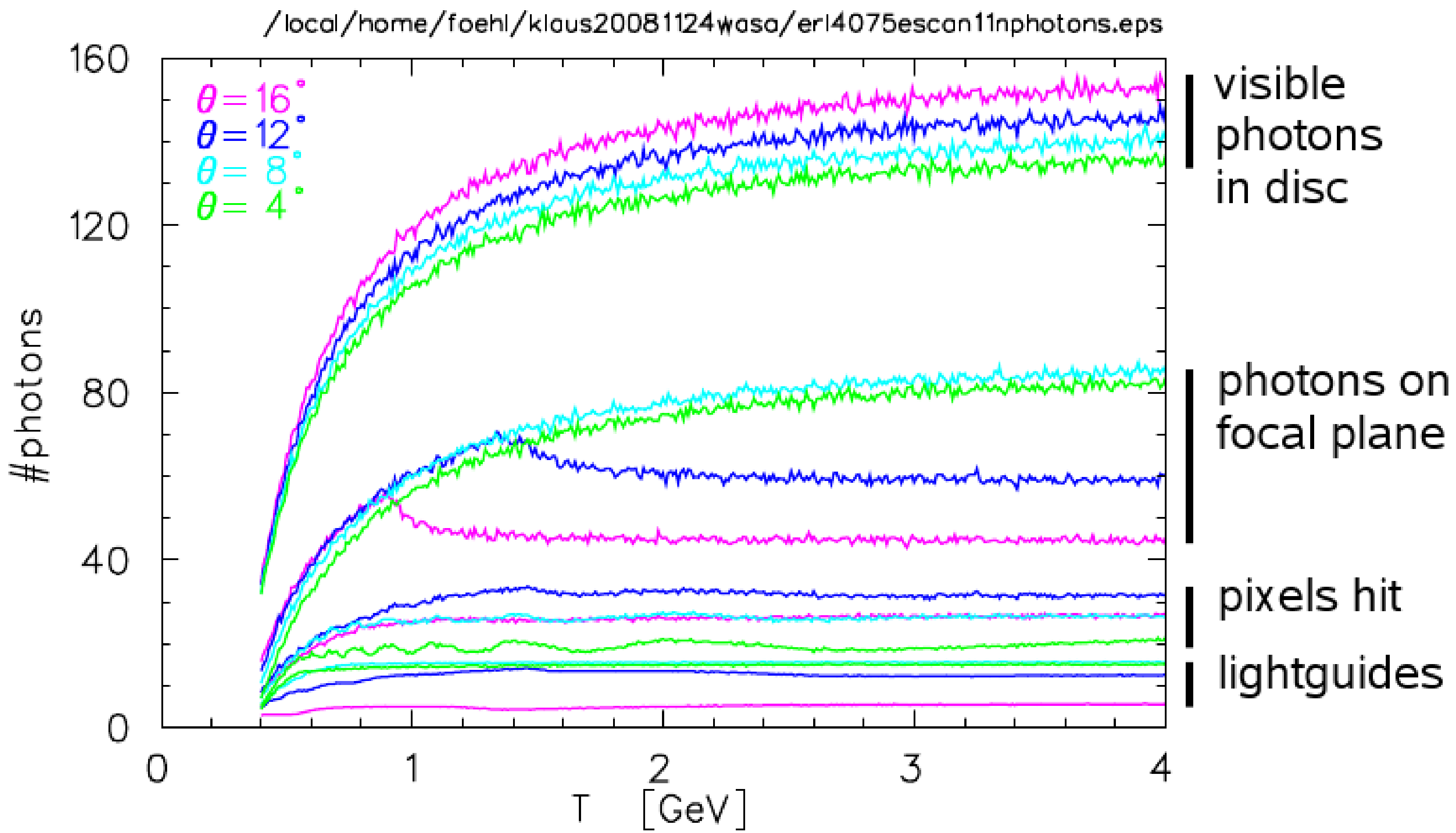




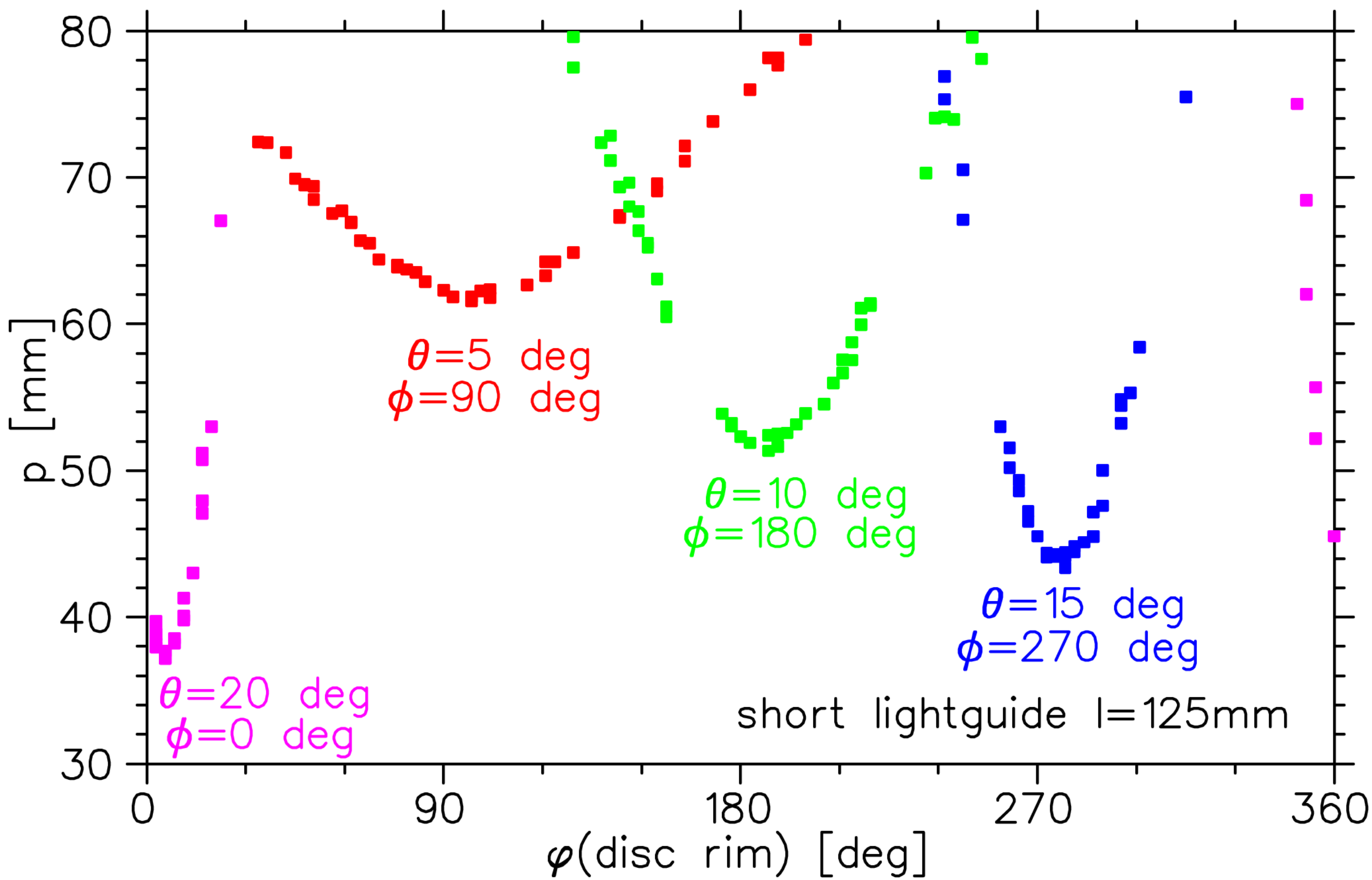
first demonstrator setup
to verify proper optics
of workshop machined
Focussing Light Guides



Photon Statistics (WASA example)

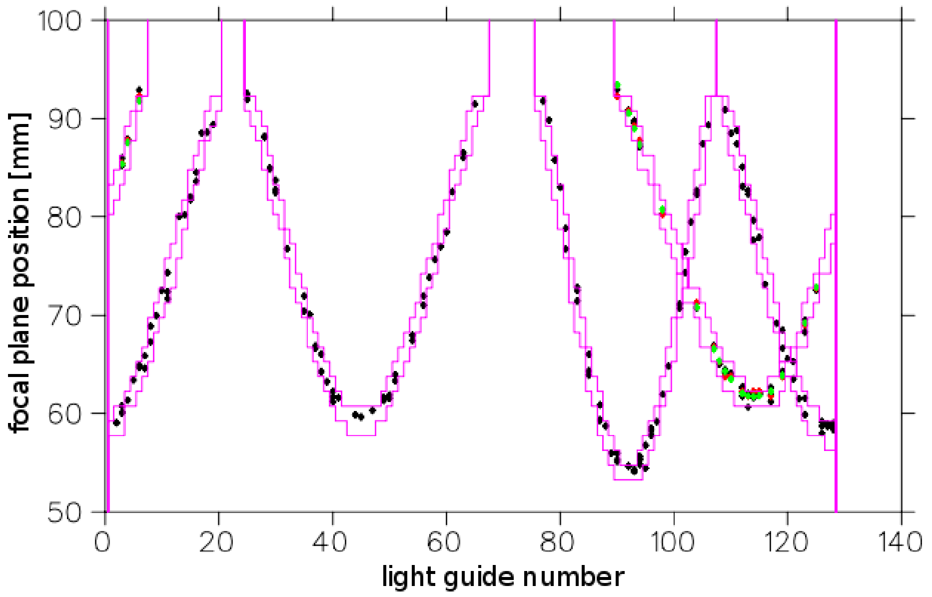


Photon Hit Pattern (PANDA example)

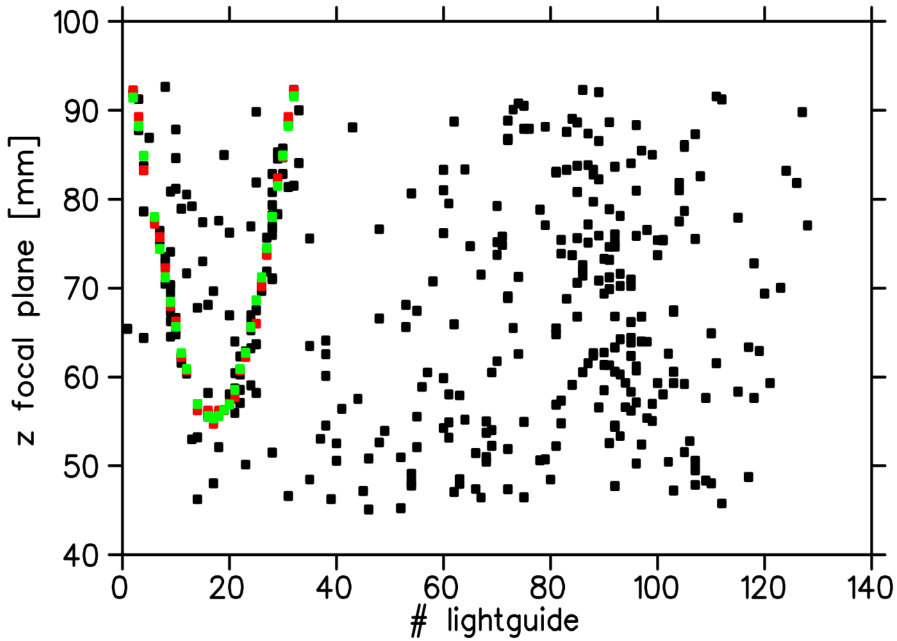


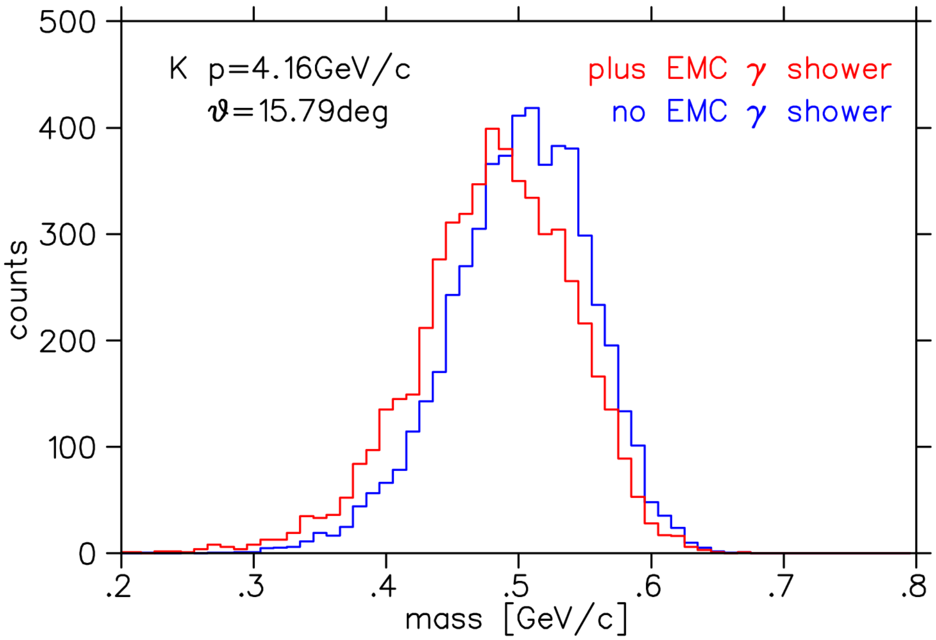
Particles & Background

Photon pattern analysis performed for several particles in the disc and for background photons present.

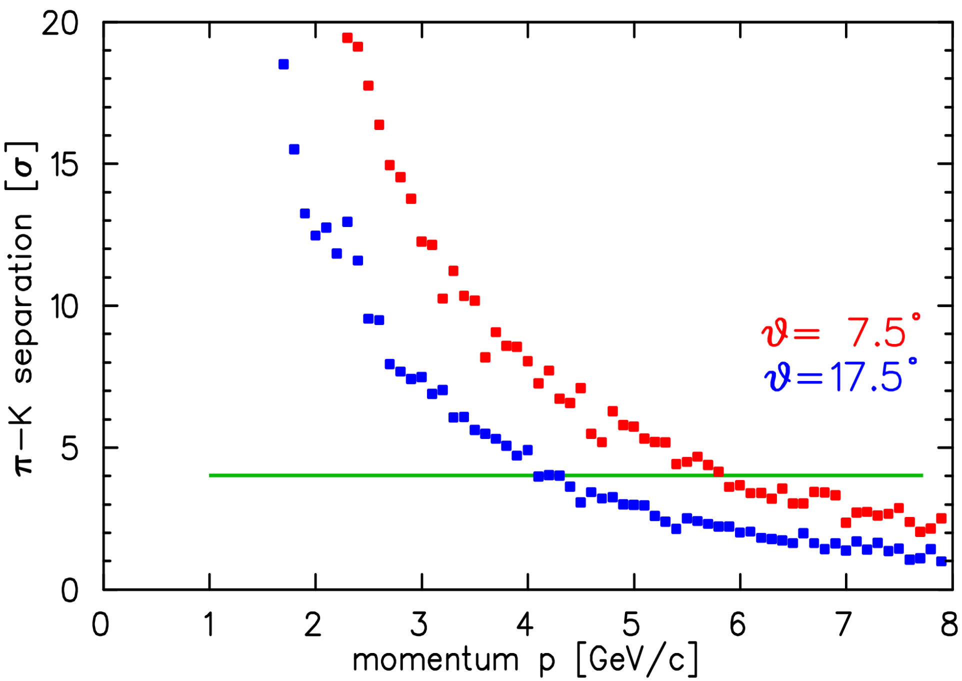


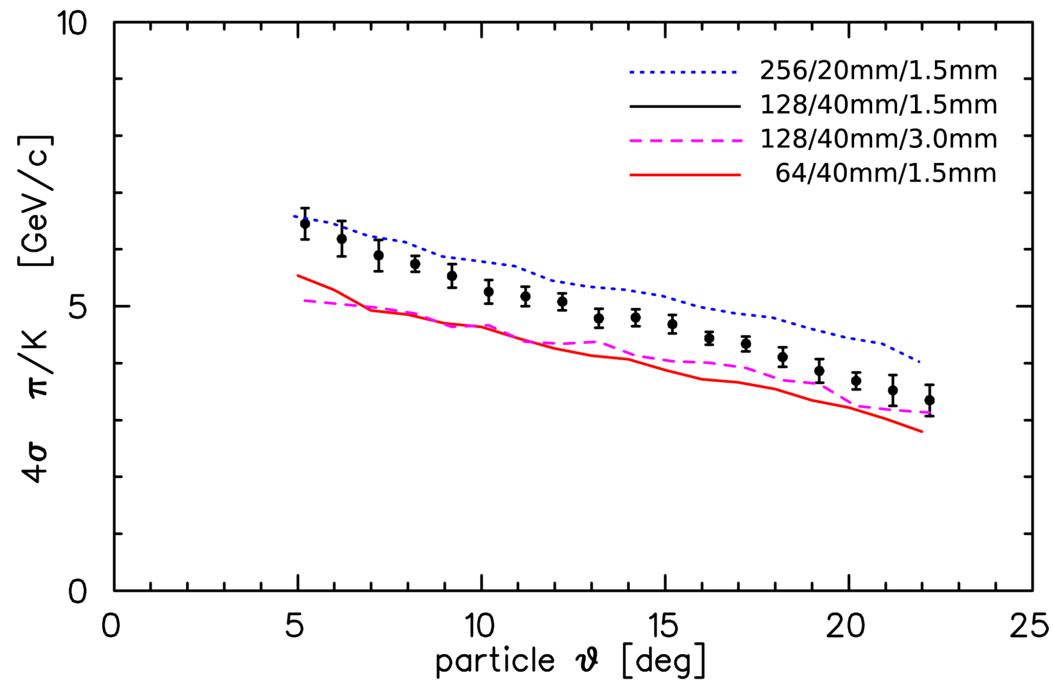
Signal+background pattern below analysed without using photon timing information (yet...).





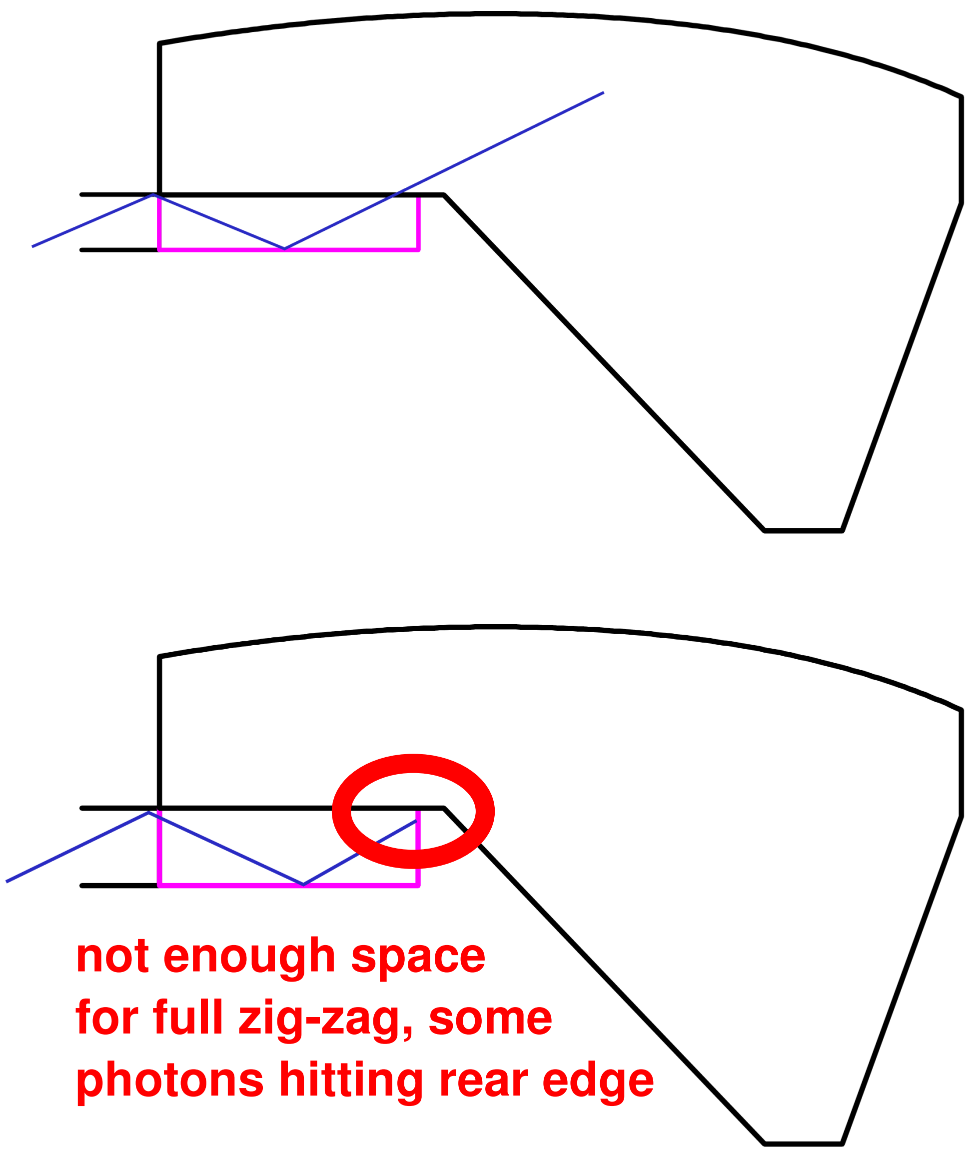
PANDA Endcap FLG-disc-DIRC





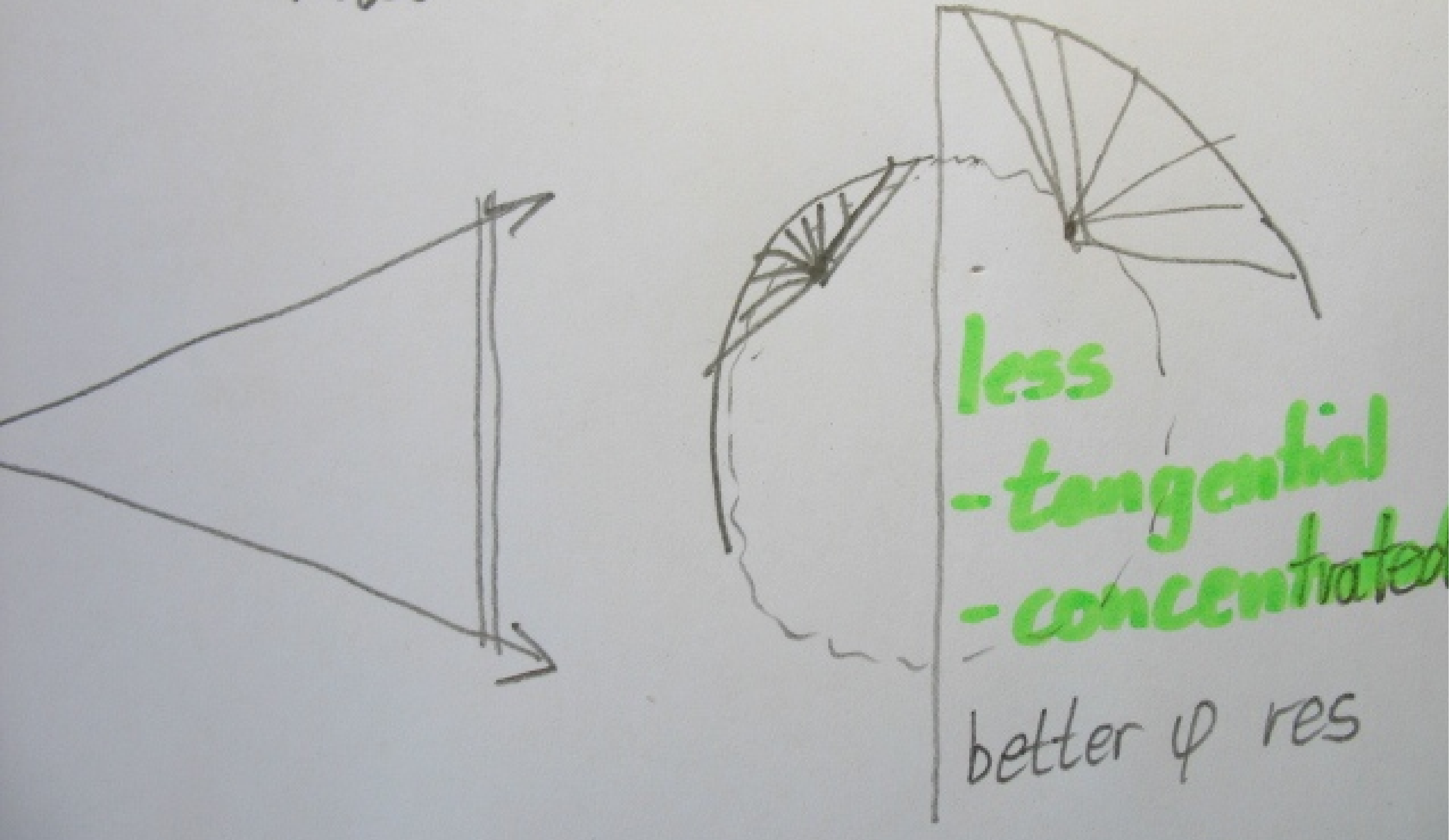
- optical disc r=1100m
- 128 optical elements
- 4096 pixels

Compromises

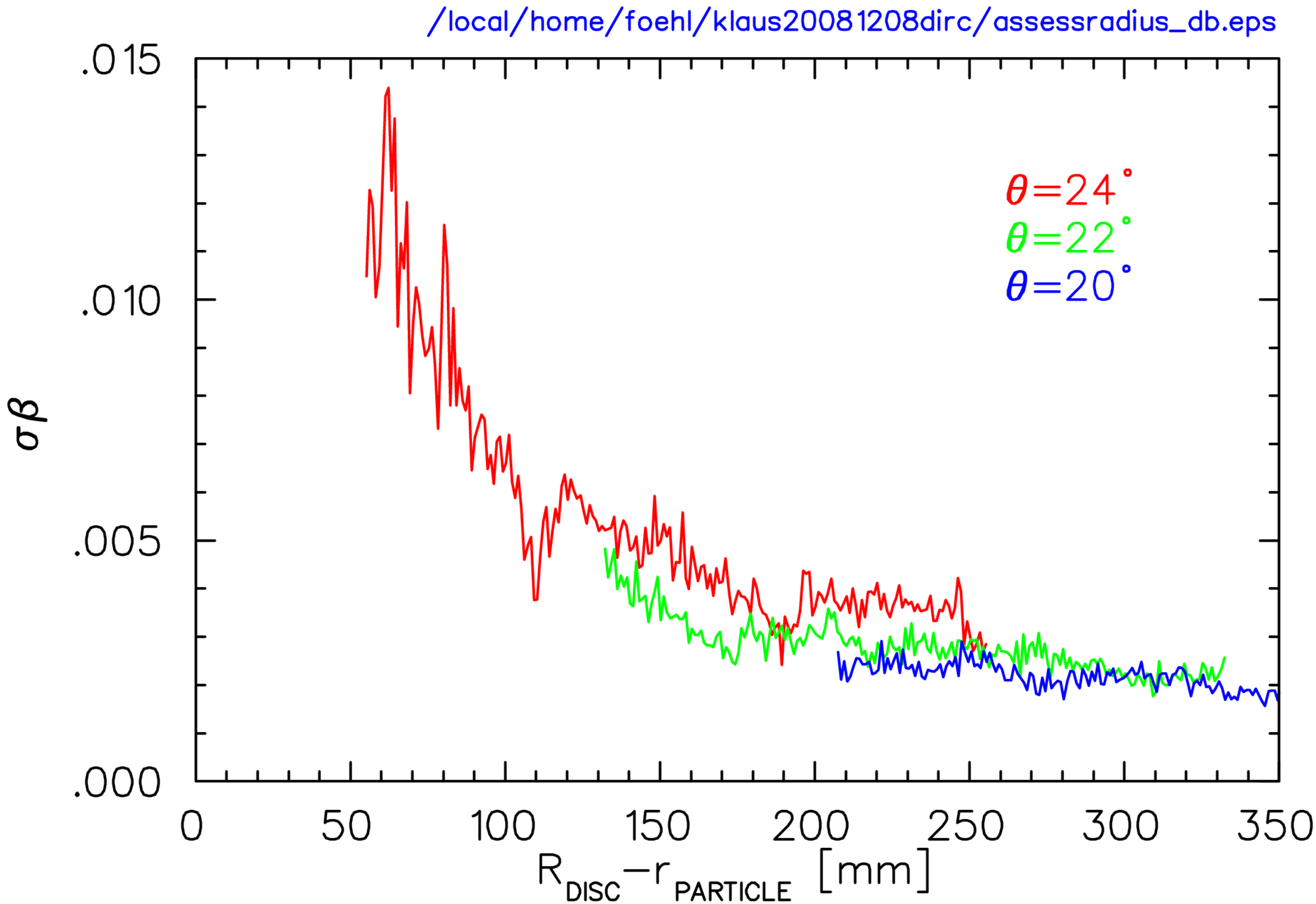


- radiator thickness choice is influenced by external conditions
- light guide size is limited as well
- thicker or shorter LiF (less elongated aspect ratio) makes one loose some photons

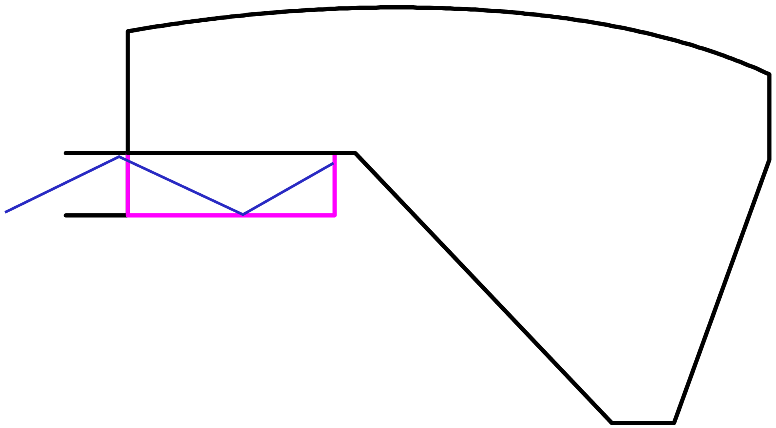
Radiator Radius

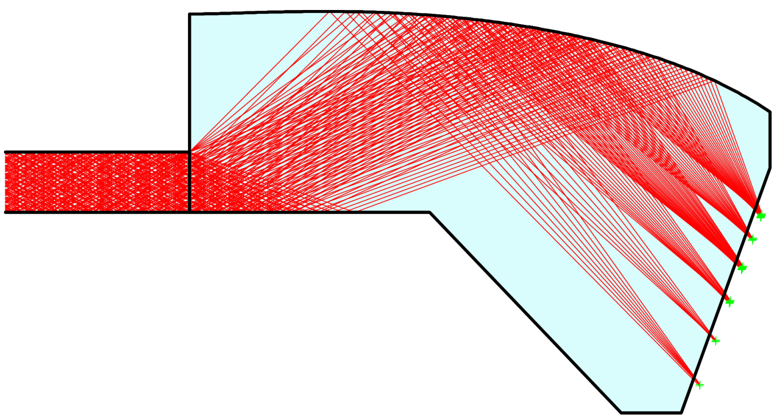


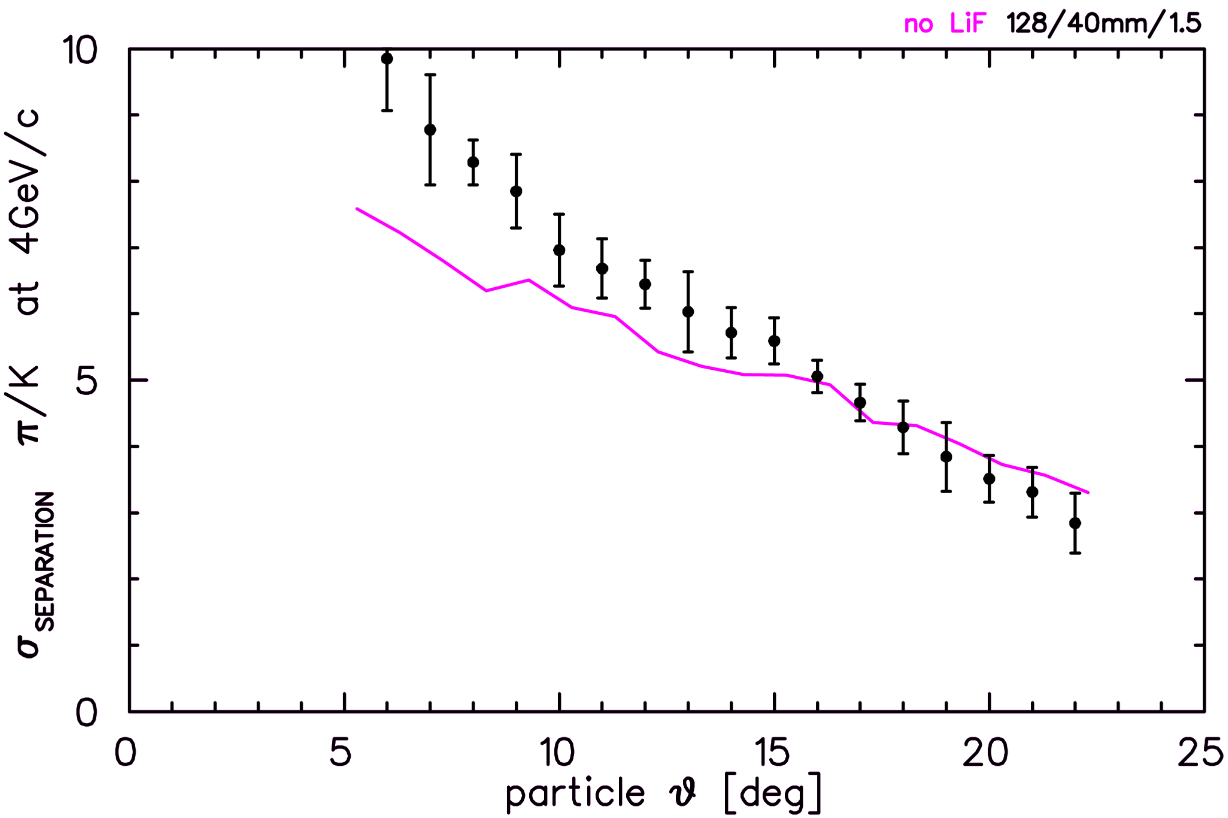
Expansion Volume - Effect



What if? no Lithium Fluoride







only one material, same mechanical properties

same expansion coefficient

no glueing of quartz and LiF

full ledge length usable for reflection

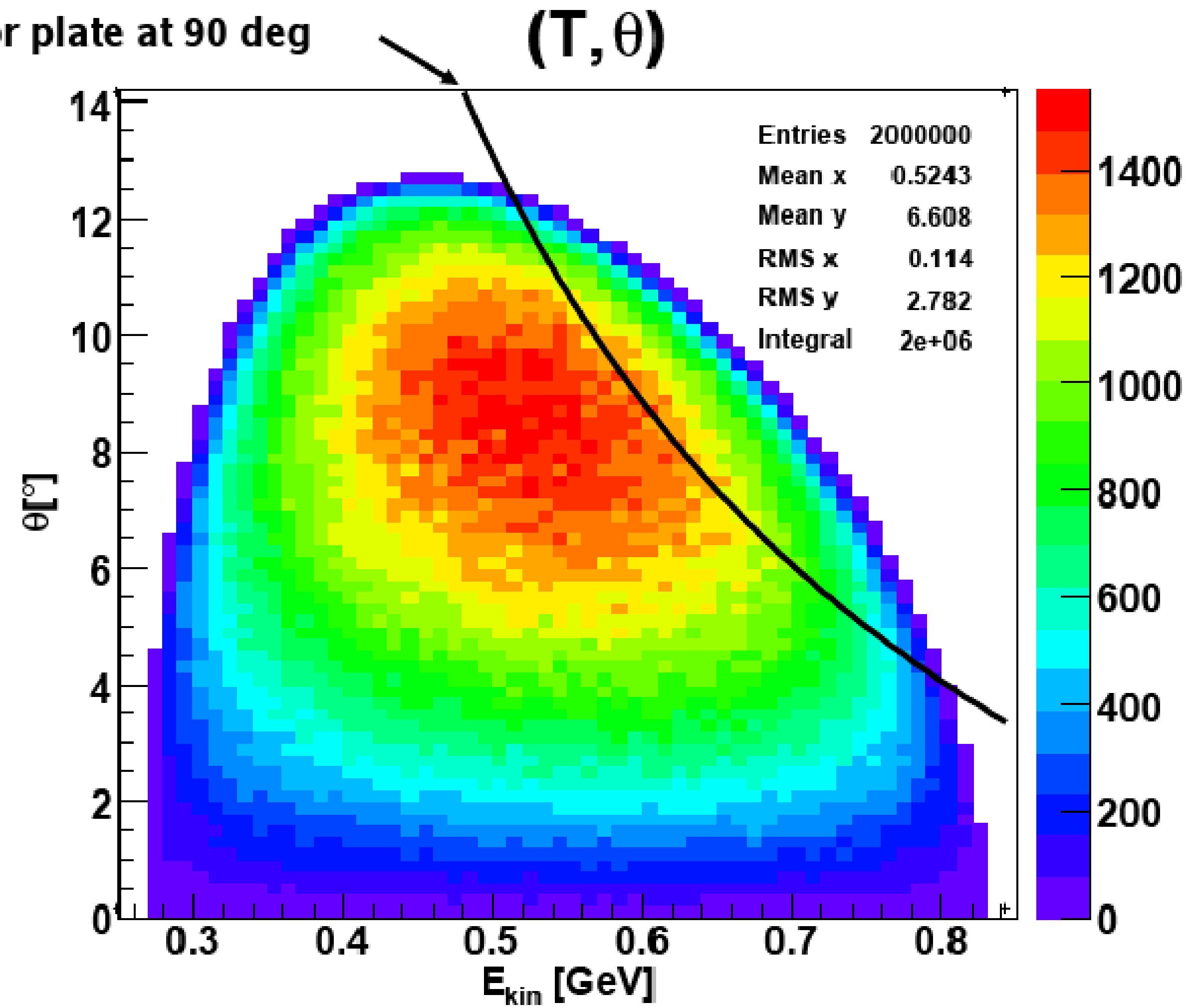
DIRC detector / prototype for WASA

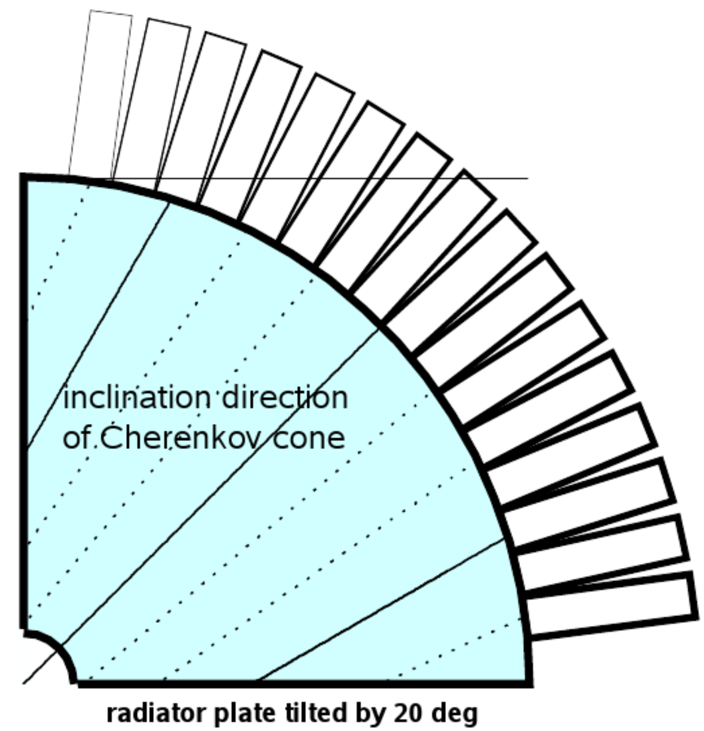
- acrylic glass radiator
- no UV wavelengths
- less detector pixels

Sigma Errors

	PANDADIRC	WASADIRC
pixel	• 3-6mrad	• 20mrad
imaging	• 1-4.5mrad	• 3-10mrad
straggling	• 1.4mrad (2GeV/c)	• 1.2mrad at 2GeV/c
tracking	• 0.4mrad	• 3.4mrad (or better)
chromatic	• 5mrad	• 2mrad

Eta': pp → ppη' (p=3.35GeV/c)

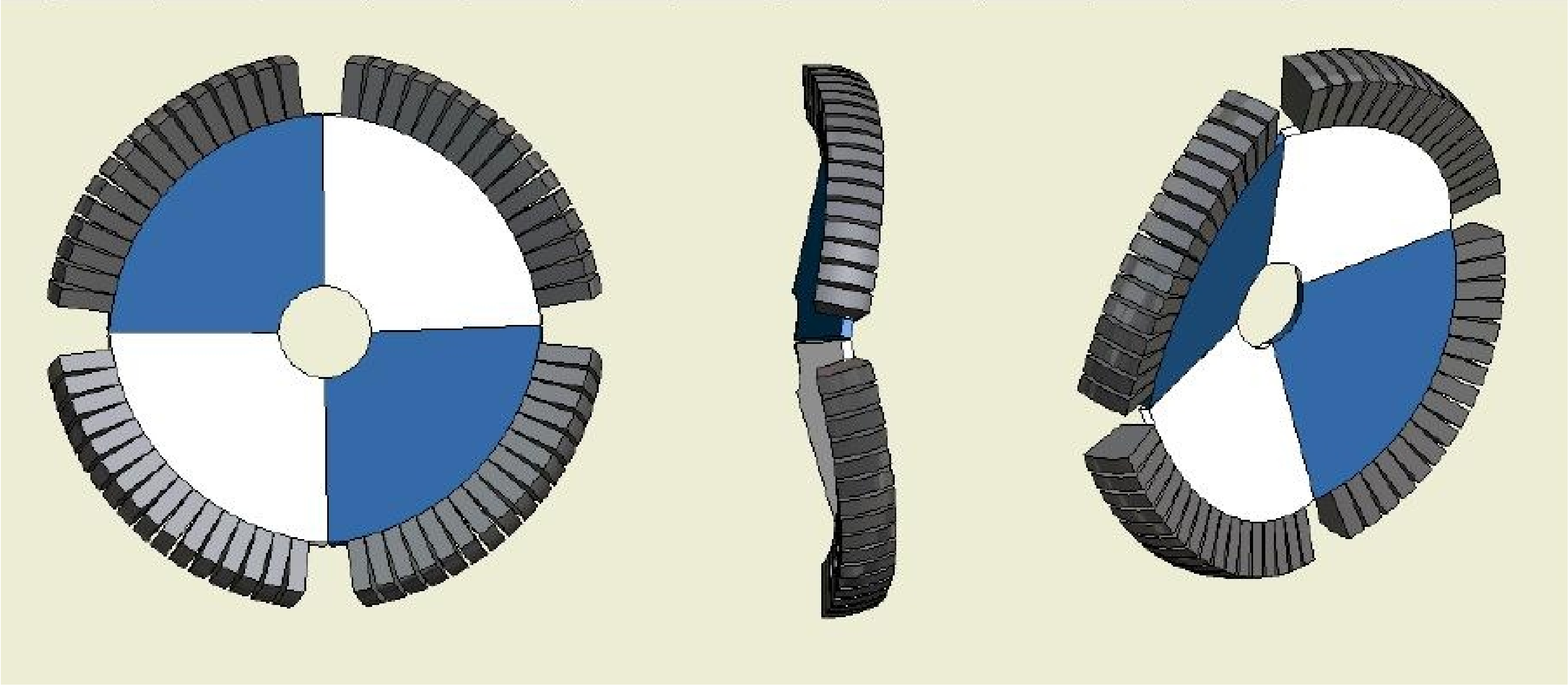




entire range is punch-through energies

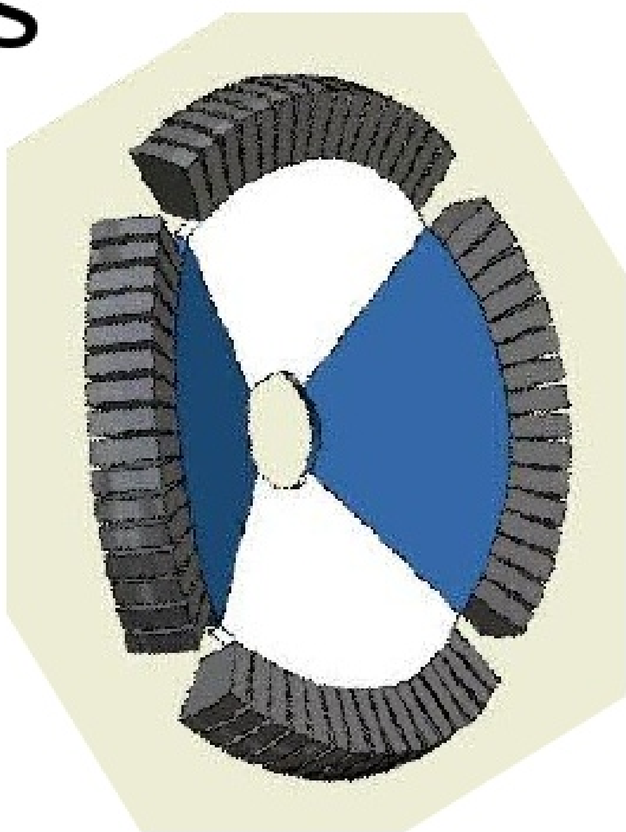
most energies below threshold for vertical radiator disc

CEARA-Detektor



Cherenkov-**E**missions-**A**nalysierender **R**ingscheiben-**A**pparat

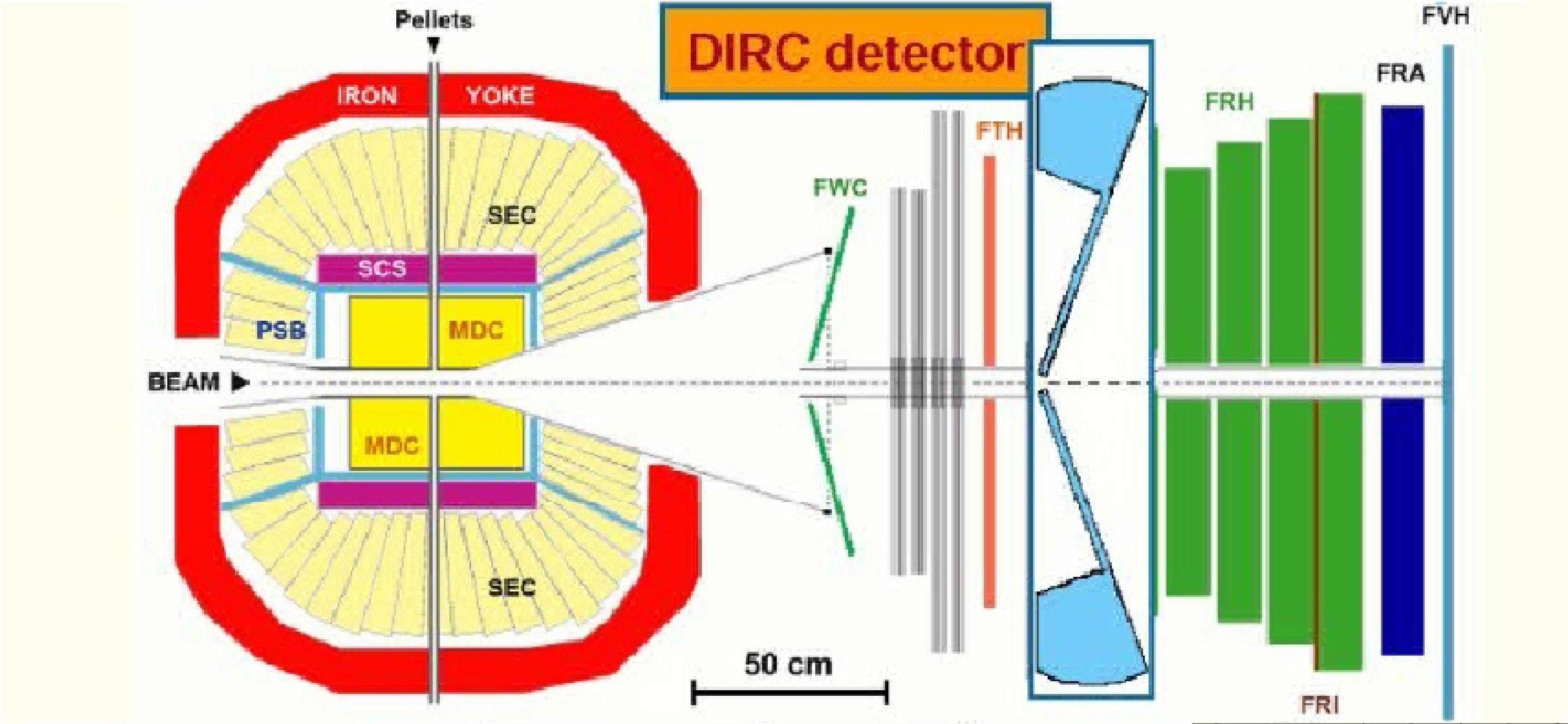
Design Choices



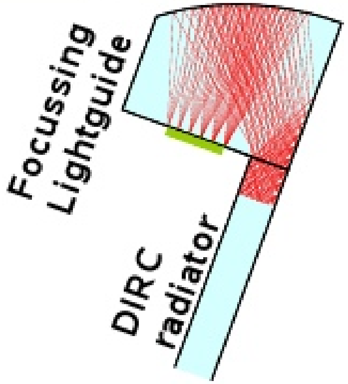
- 4-fold rotational symmetry
- DIRC radiator tilted by 20°
- plexiglas radiator material
- no dispersion correction
- MaPMTs 64x(6mm)² pixels

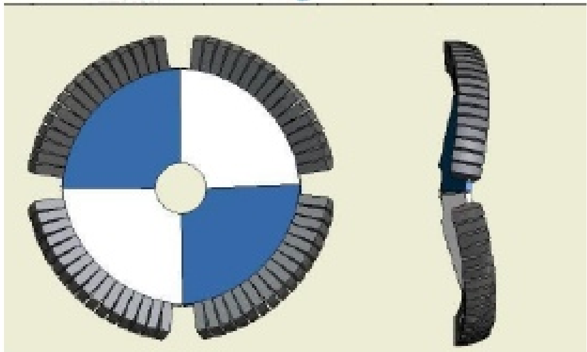
- Focussing Lightguide, range i.e. 20°-50°
- 2 PMTs per FL, worth 16 pixels 6mmx48mm

Concept status end of 2008



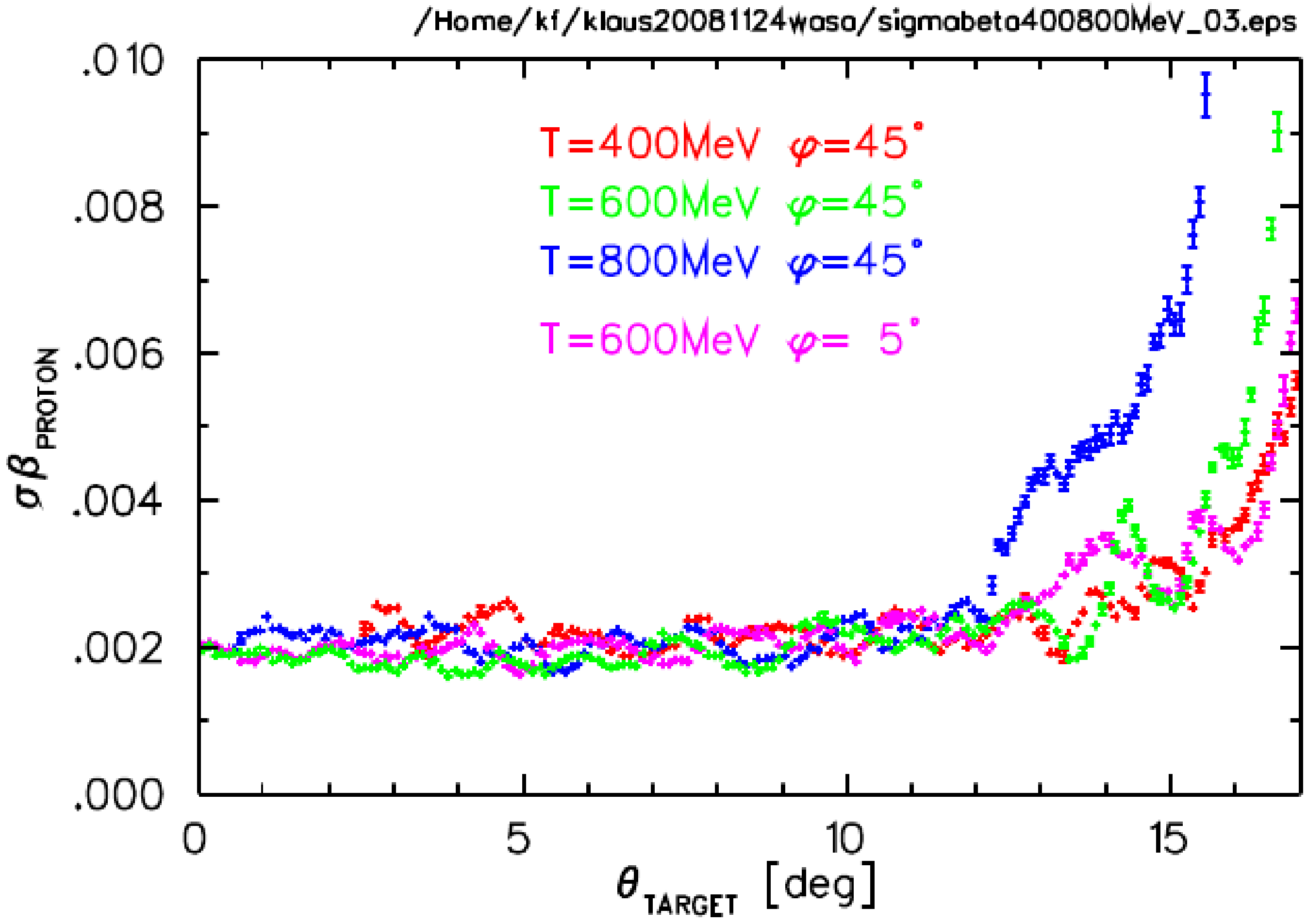
- 20 degrees tilt
- extra space for tilt

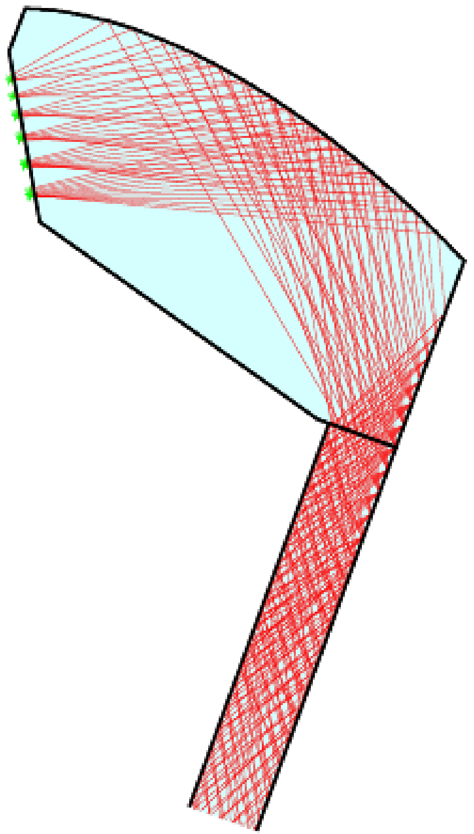


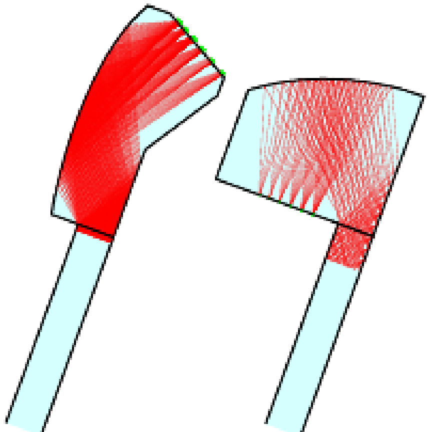


CEARA-detector

β resolutions



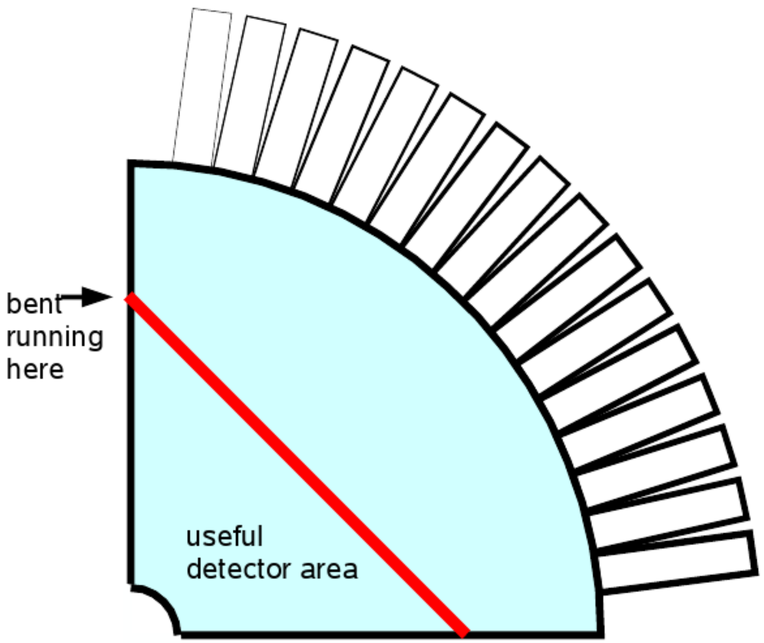


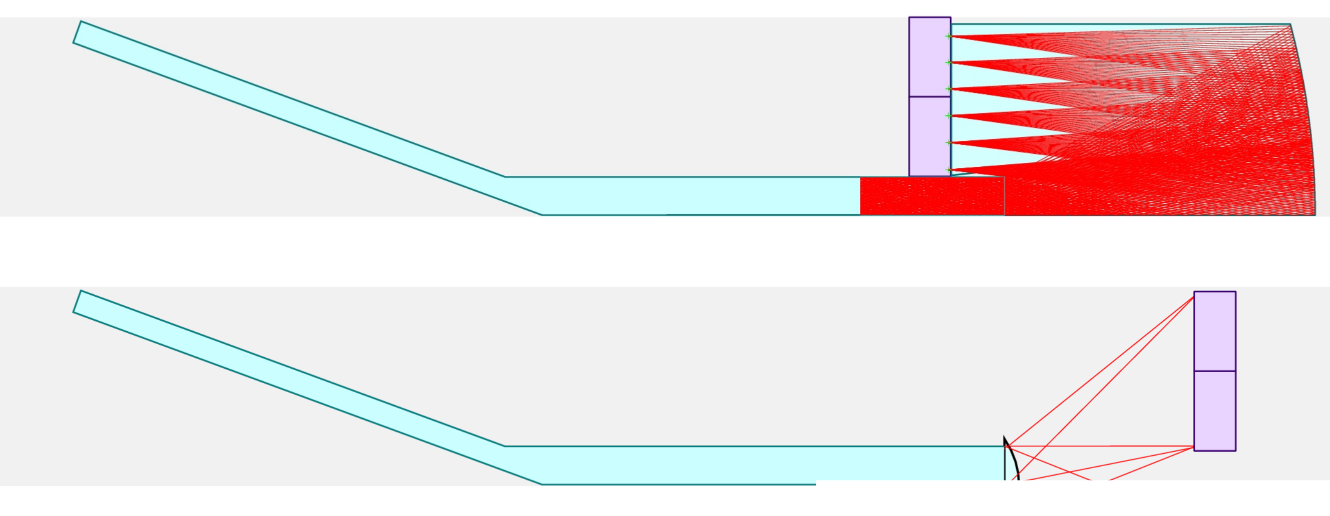


FL Tübingen (40/70) 20deg – 50 deg range

WASA DIRC into 130mm wide layer

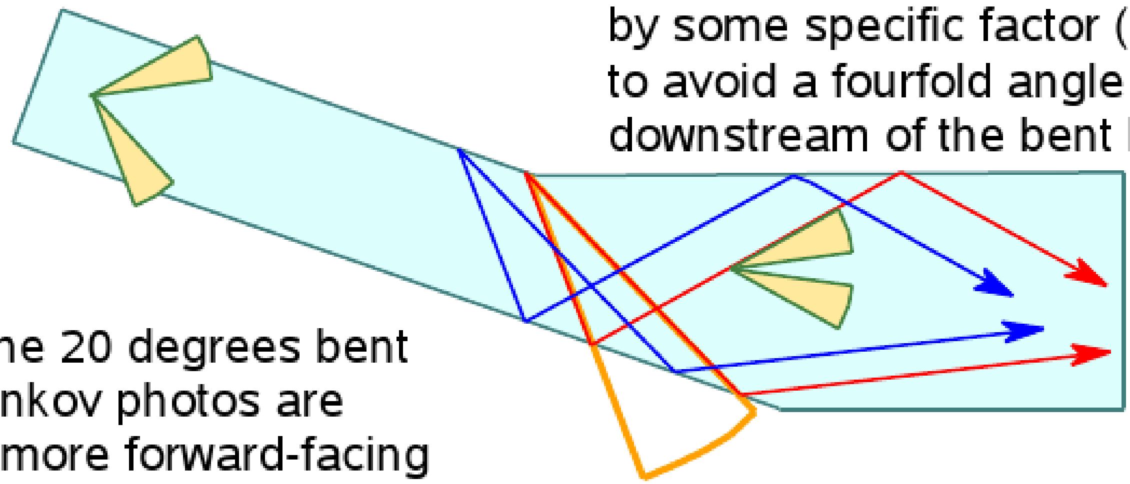
status of discussions December 2008:
fit a DIRC disc into a slice 130mm thick



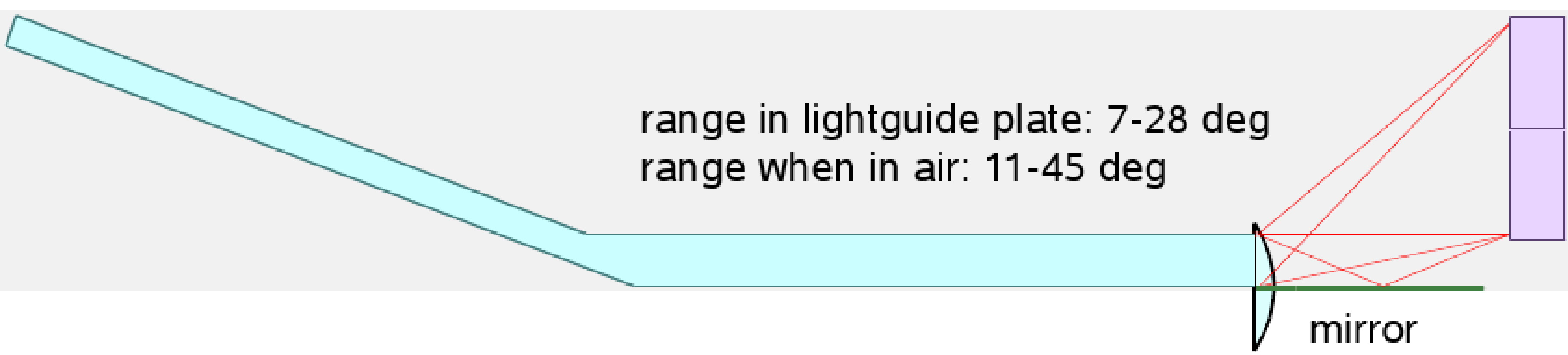


Possibility of lense imaging

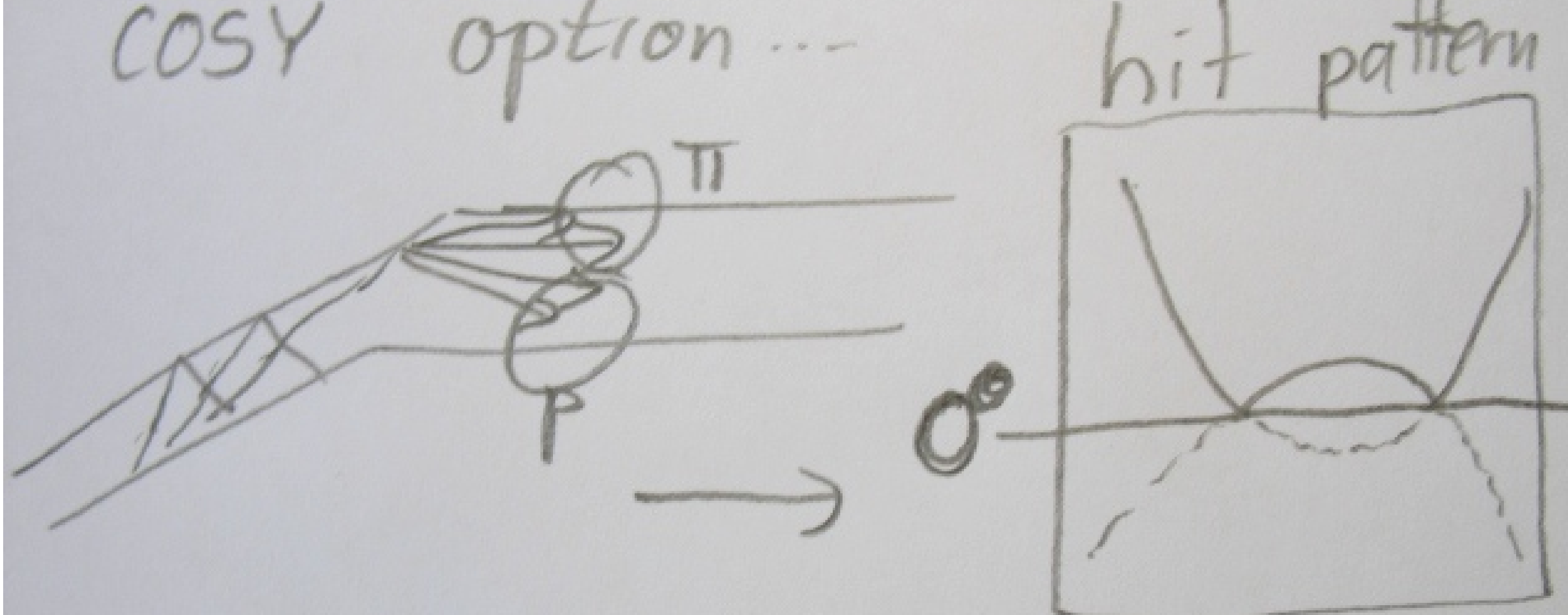
the plate angle change requires that the plate thickness increases by some specific factor (here 1.6) to avoid a fourfold angle ambiguity downstream of the bent line.



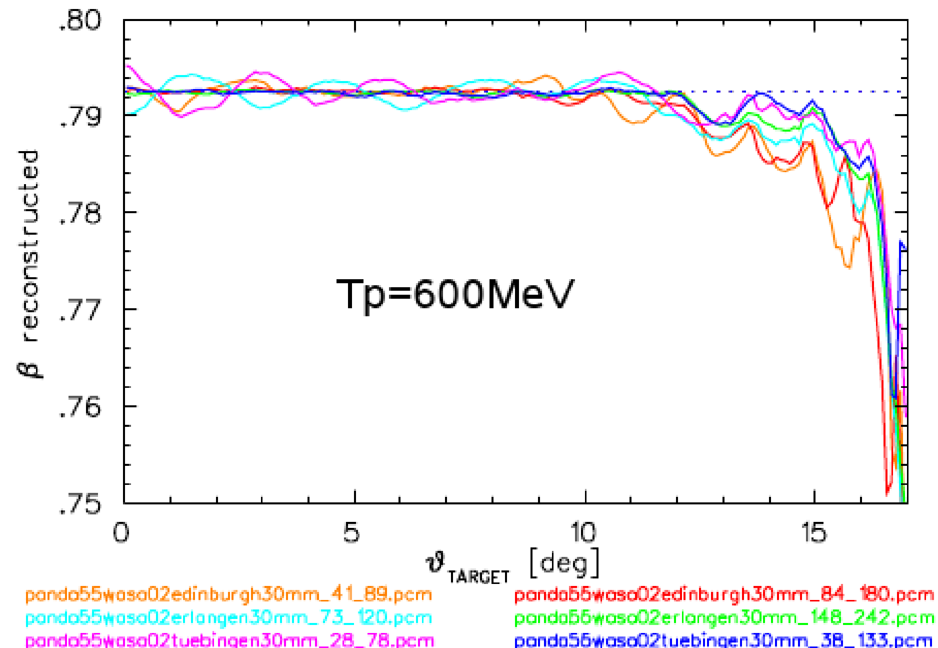
after the 20 degrees bent Cherenkov photos are much more forward-facing

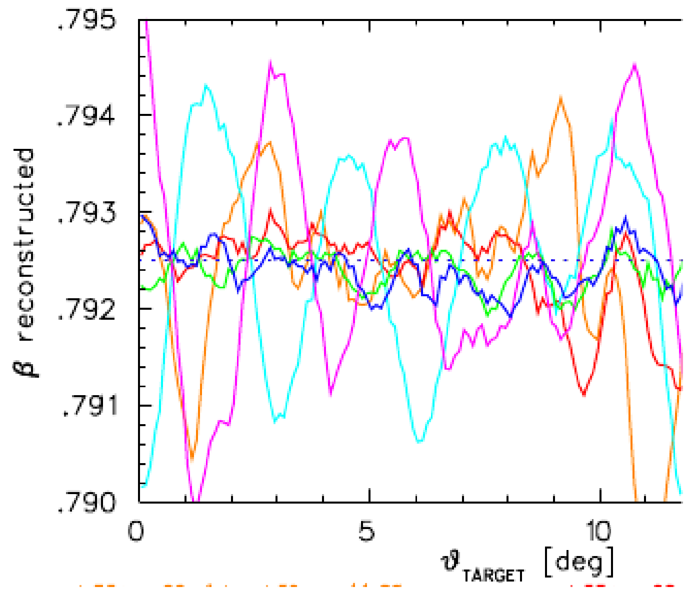


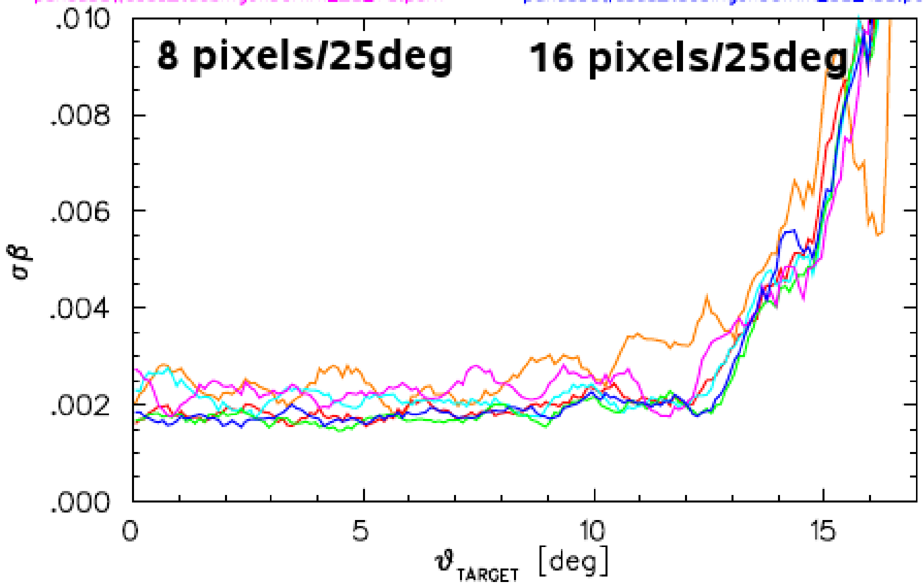
circumstances make use of a lense more suitable


COSY option ...
hit pattern
π
p

Systematic Effect in Analysis



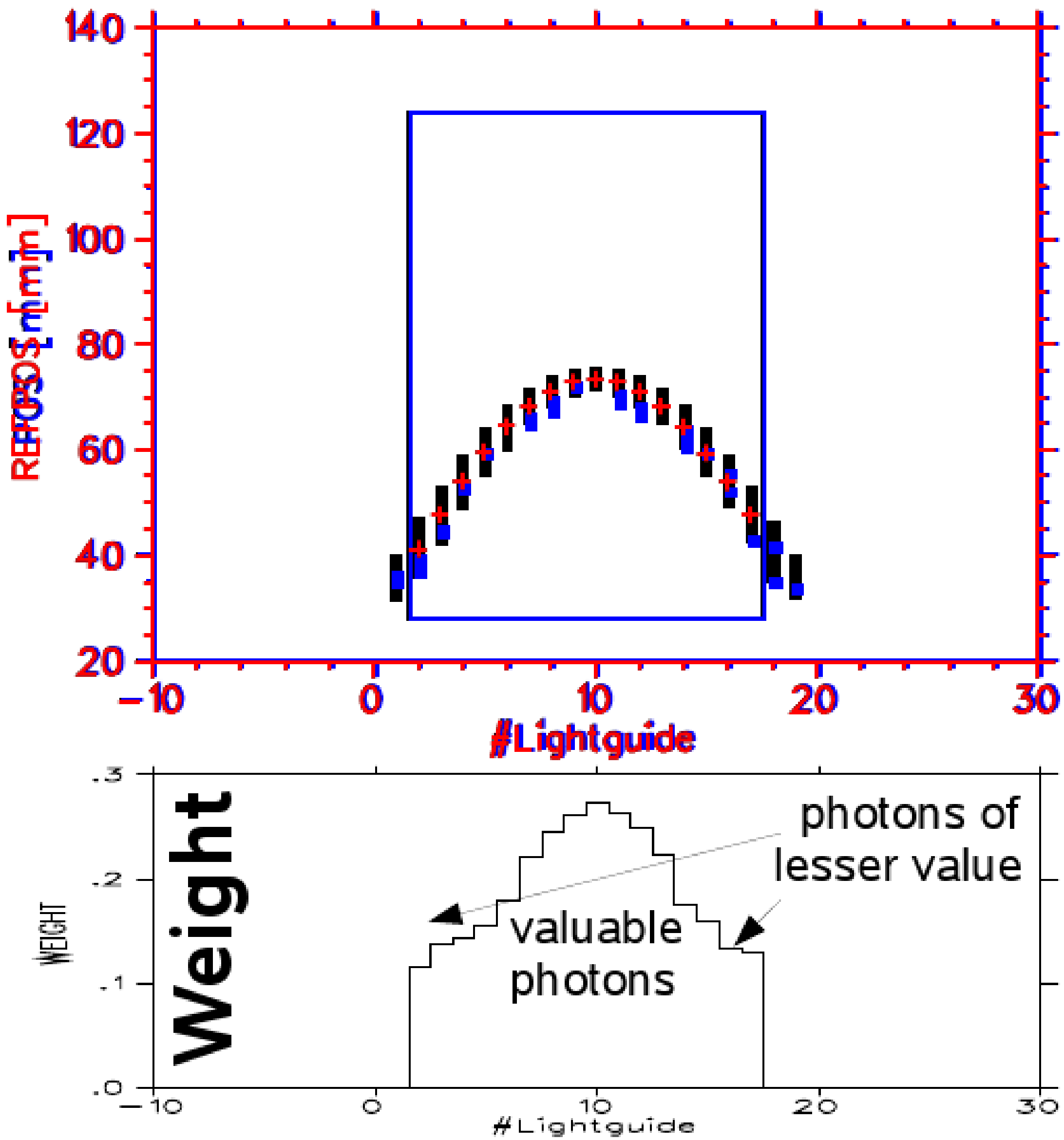




The analysis is proof of principle.

Apart from the pixel size value contributing to the fitting weight, the analysis algorithm is not explicitly aware of the pixel discretisation, hence the reconstructed β shows bias.

Photon pattern analysis



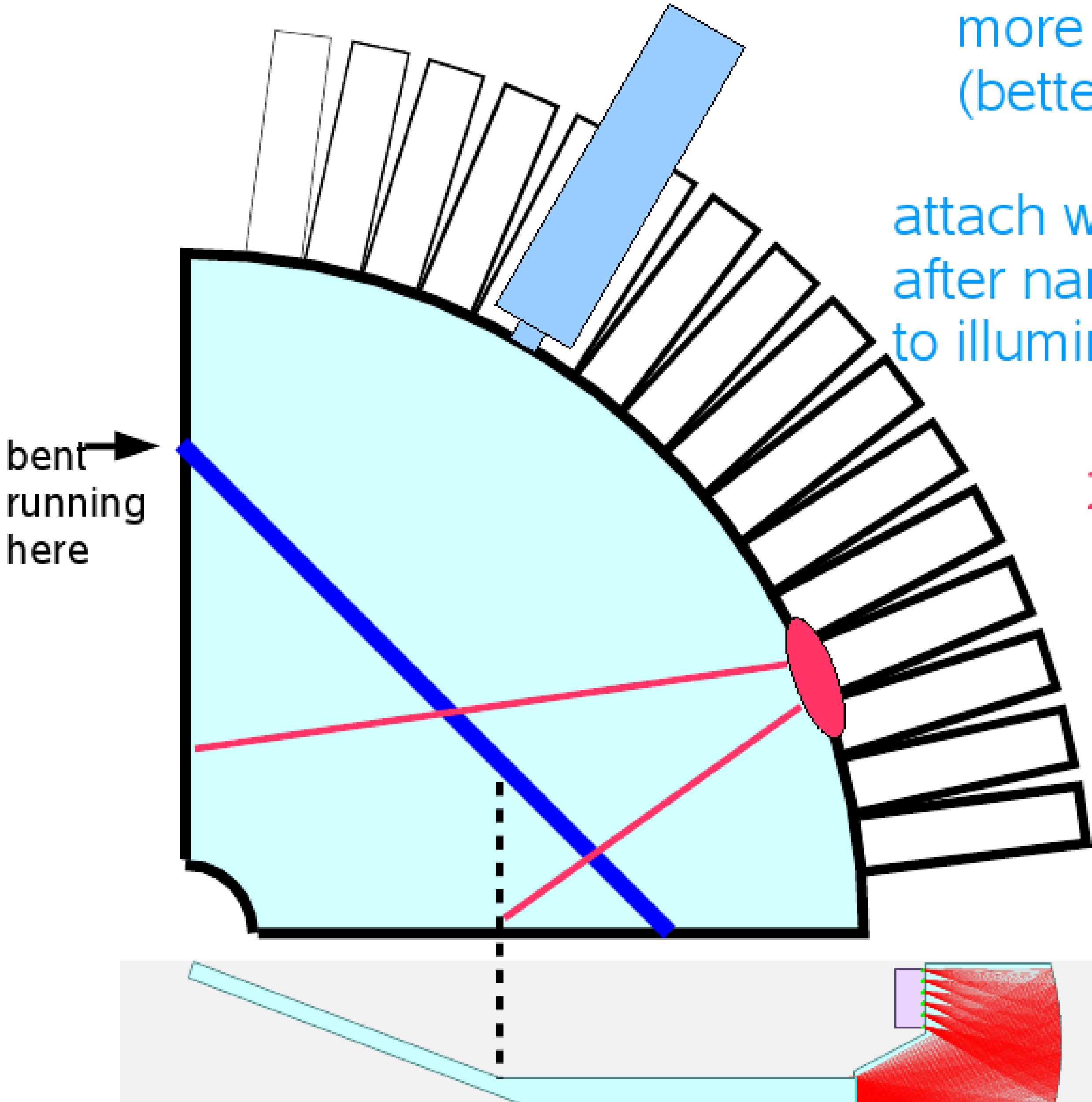
photons come with different levels of appreciation:

if photon rate is too high (i.e. for phototubes) then

1) make the photons more valuable (better phi resolution)

2) keep photons that for a given phi range smear less in theta

Increasing value per photon



1) make the photons
more valuable
(better phi resolution)

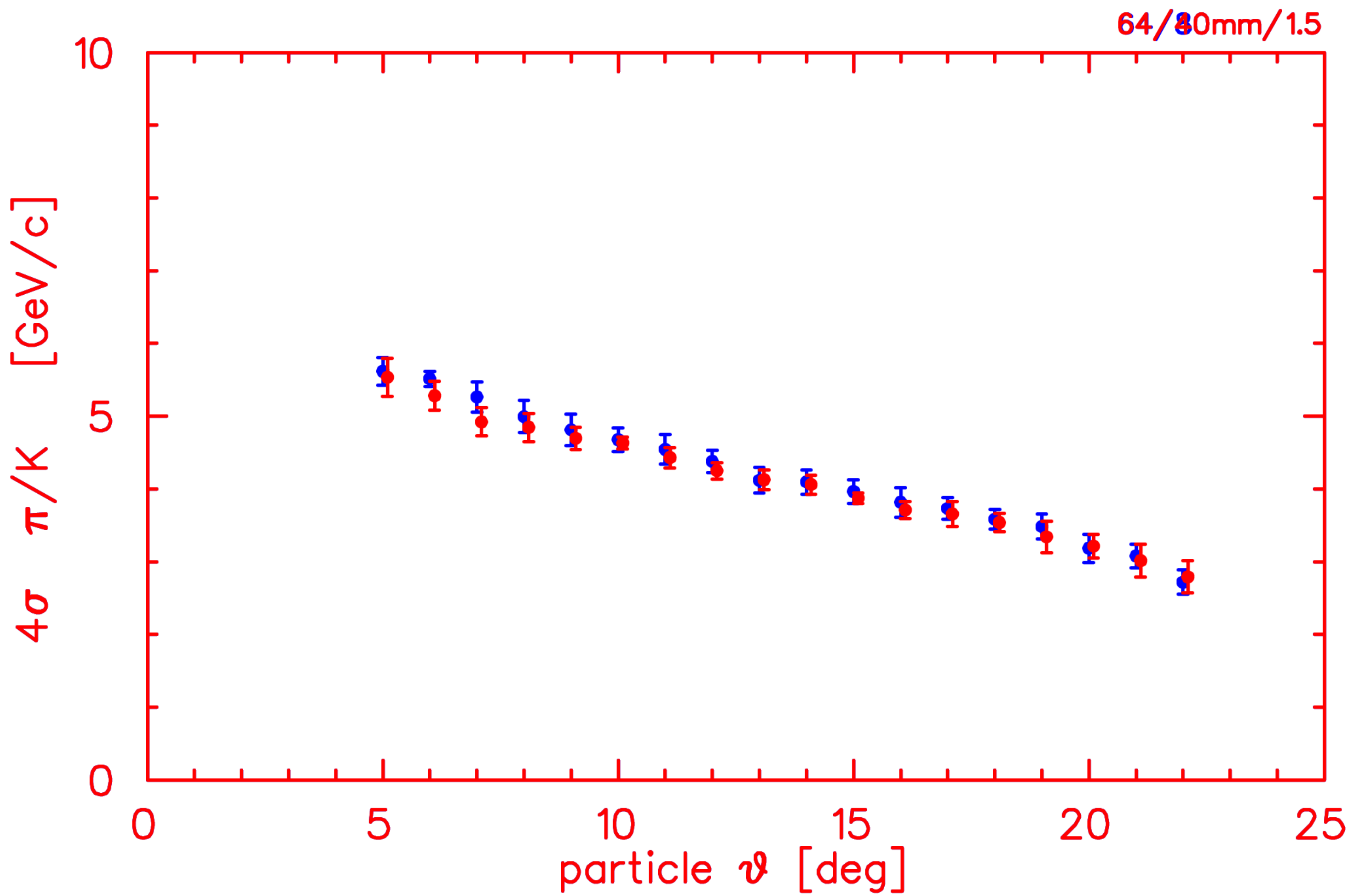
attach wider light guide
after narrow passage
to illuminate entire PMT

2) keep photons that for
a given phi range
smear less in theta

use image size of lense

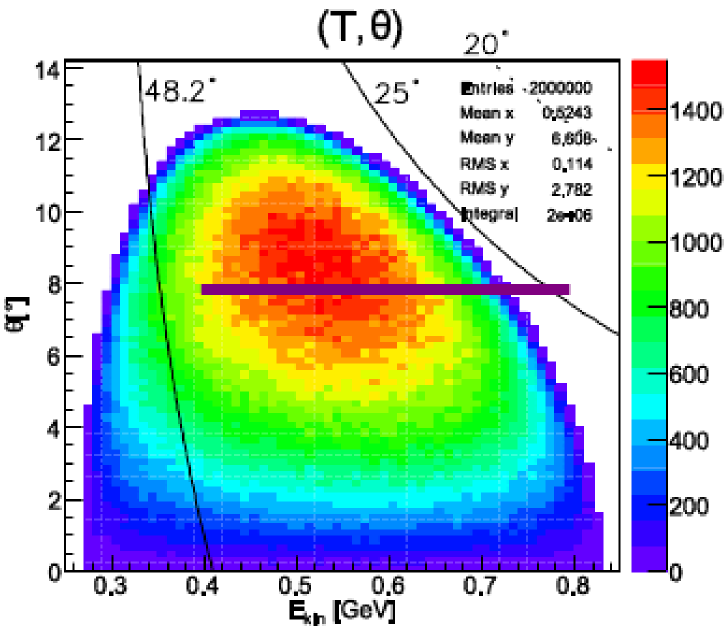
only photons from a
narrower angle range
arrive on the focal plane

FLG thicknesses 80mm and 40mm

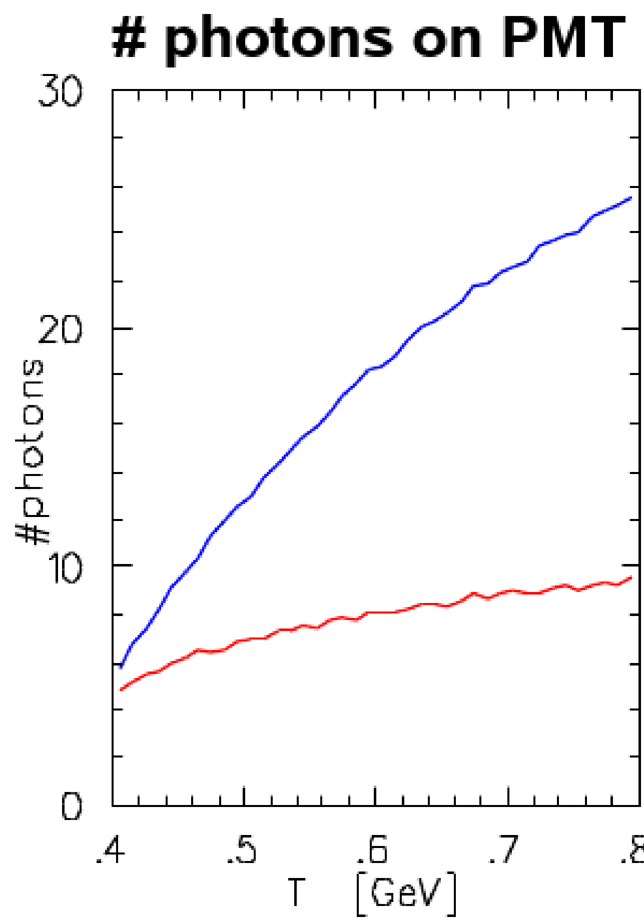


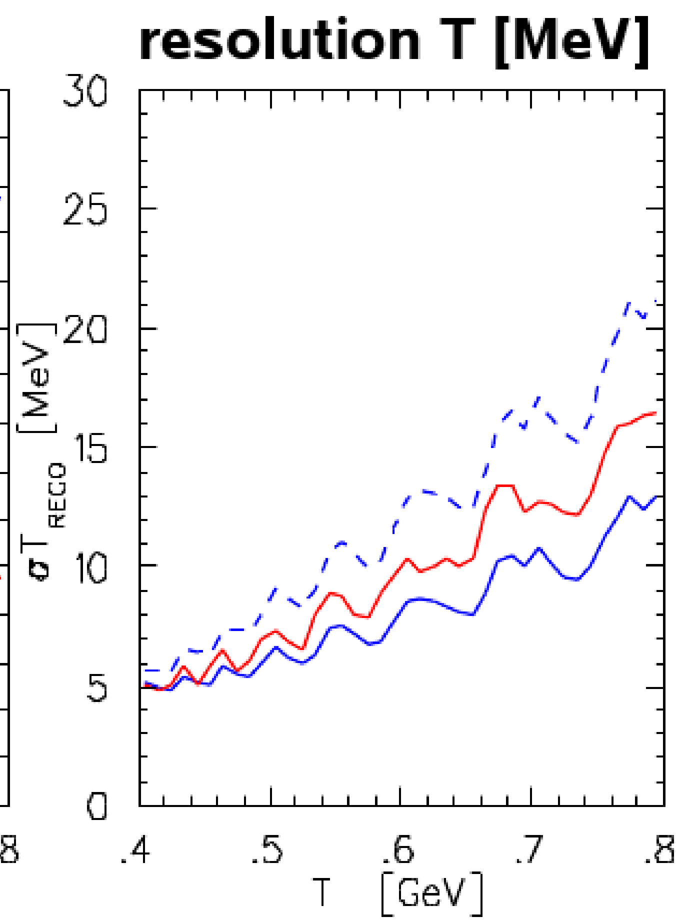
PANDA DIRC simulation

Performance with limited angular range



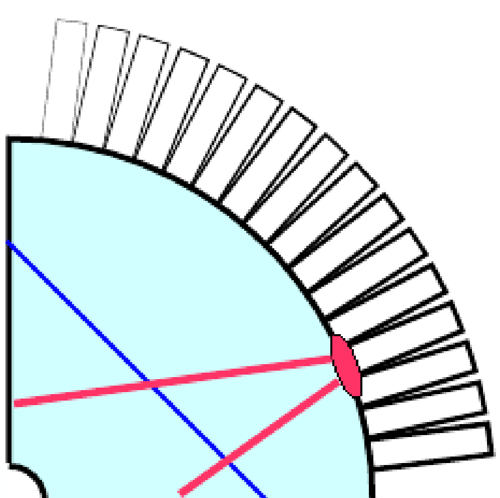
simulations shown for 8 degrees
T_proton = 400MeV to 800MeV





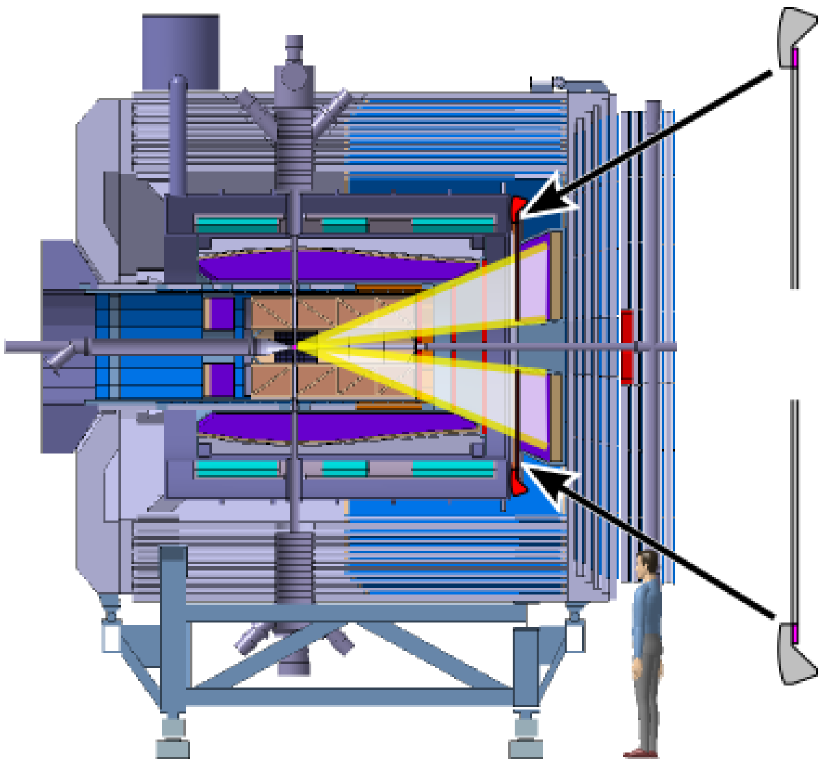
standard lightguide optics

only |tan phi|<1/6 into optics

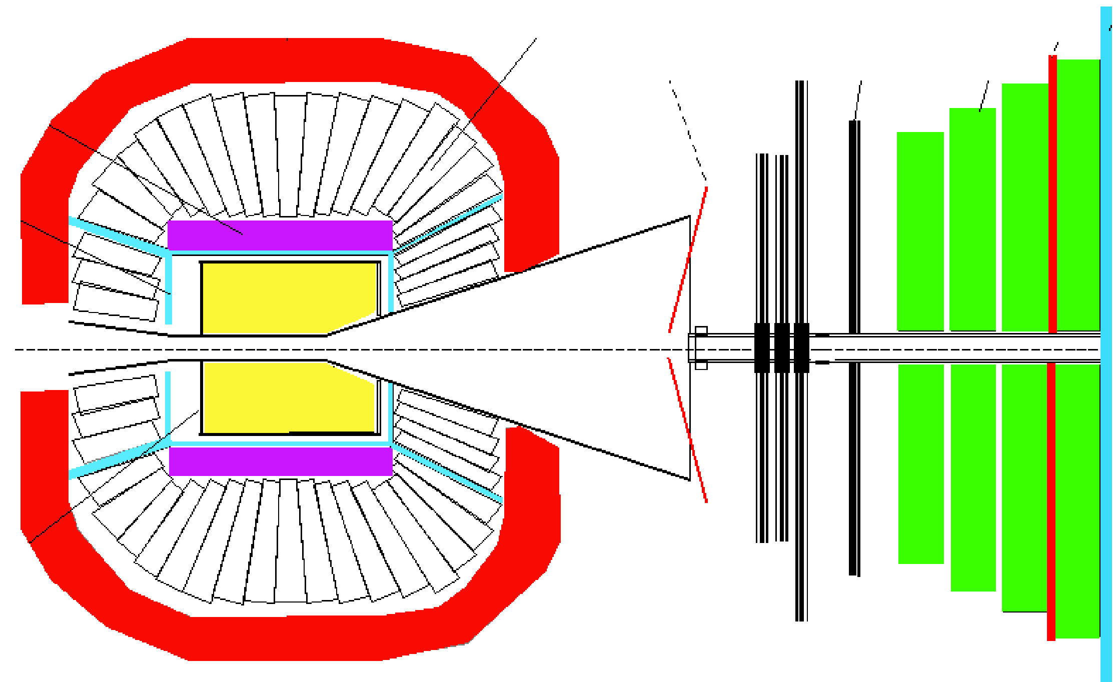


WASA DIRC simulation

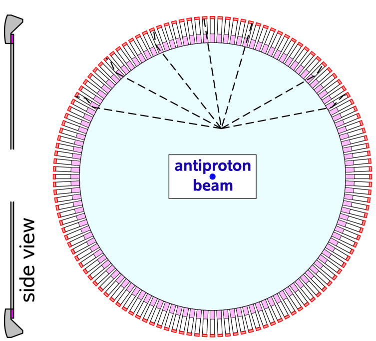
Disc DIRCs for PANDA and WASA



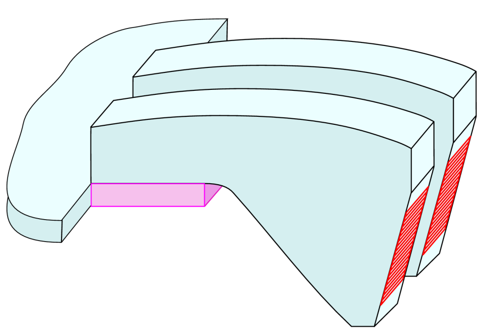
PANDA Target Spectrometer



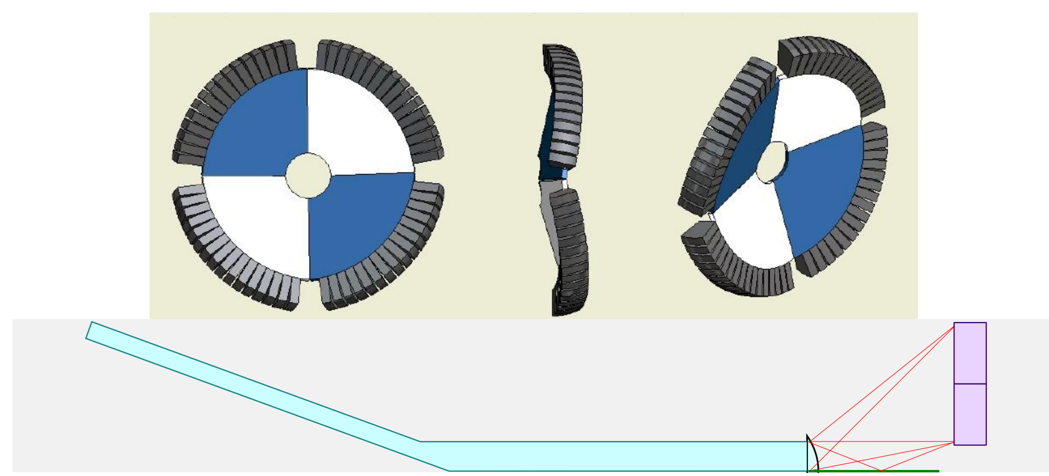
WASA experiment at COSY



Disc DIRC seen from target



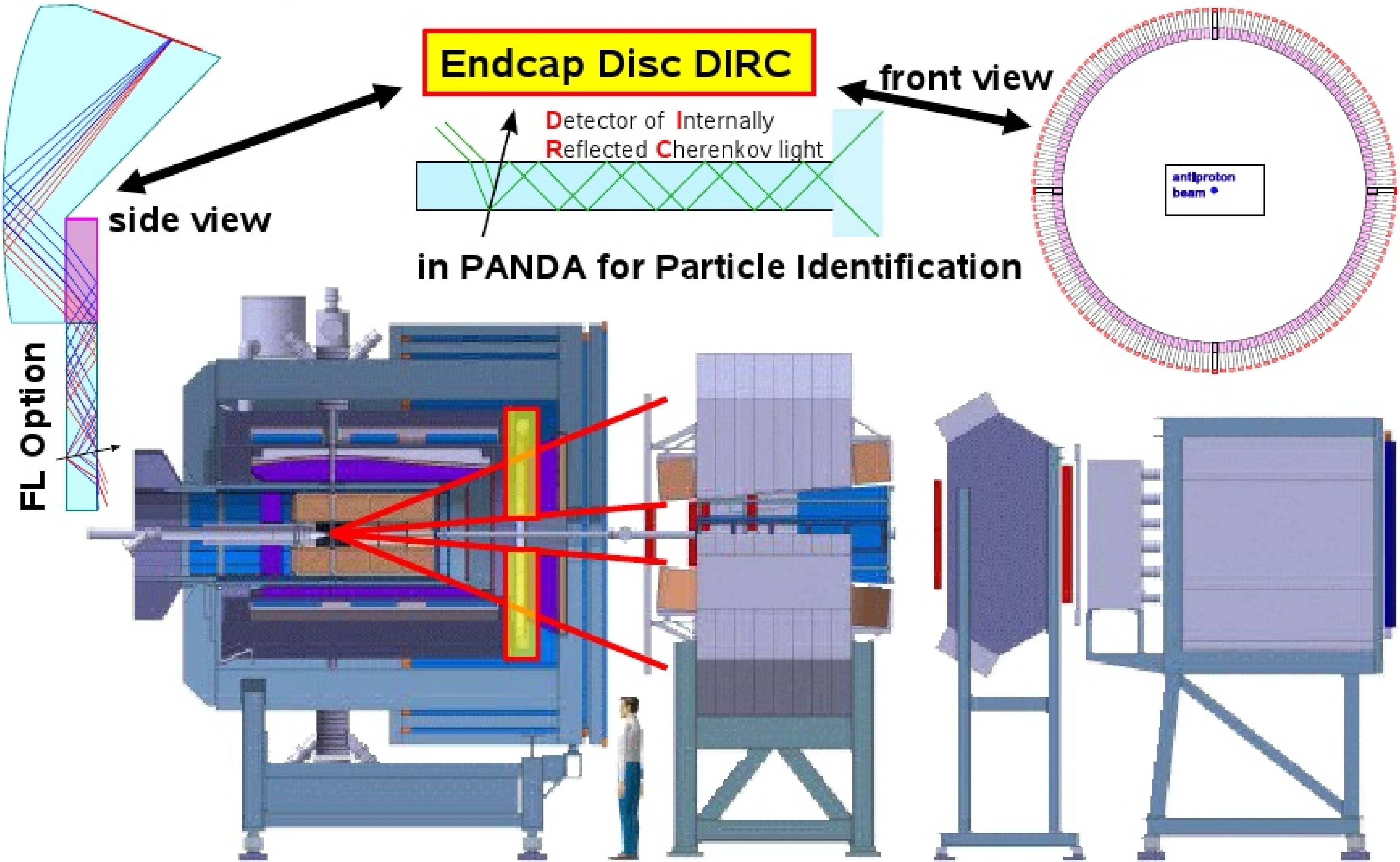
Lightguides with LiF - 3D visualisation



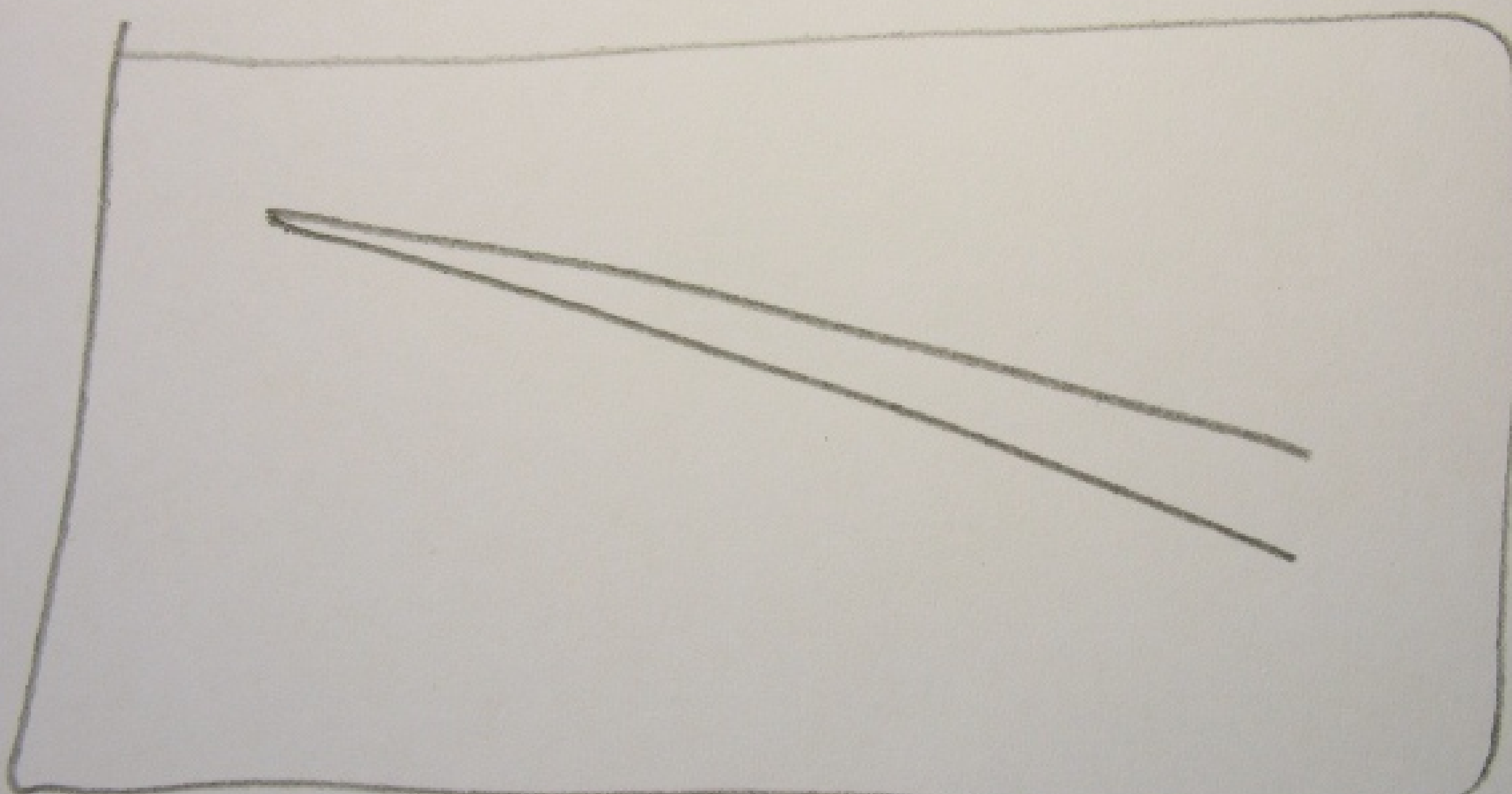
Summary

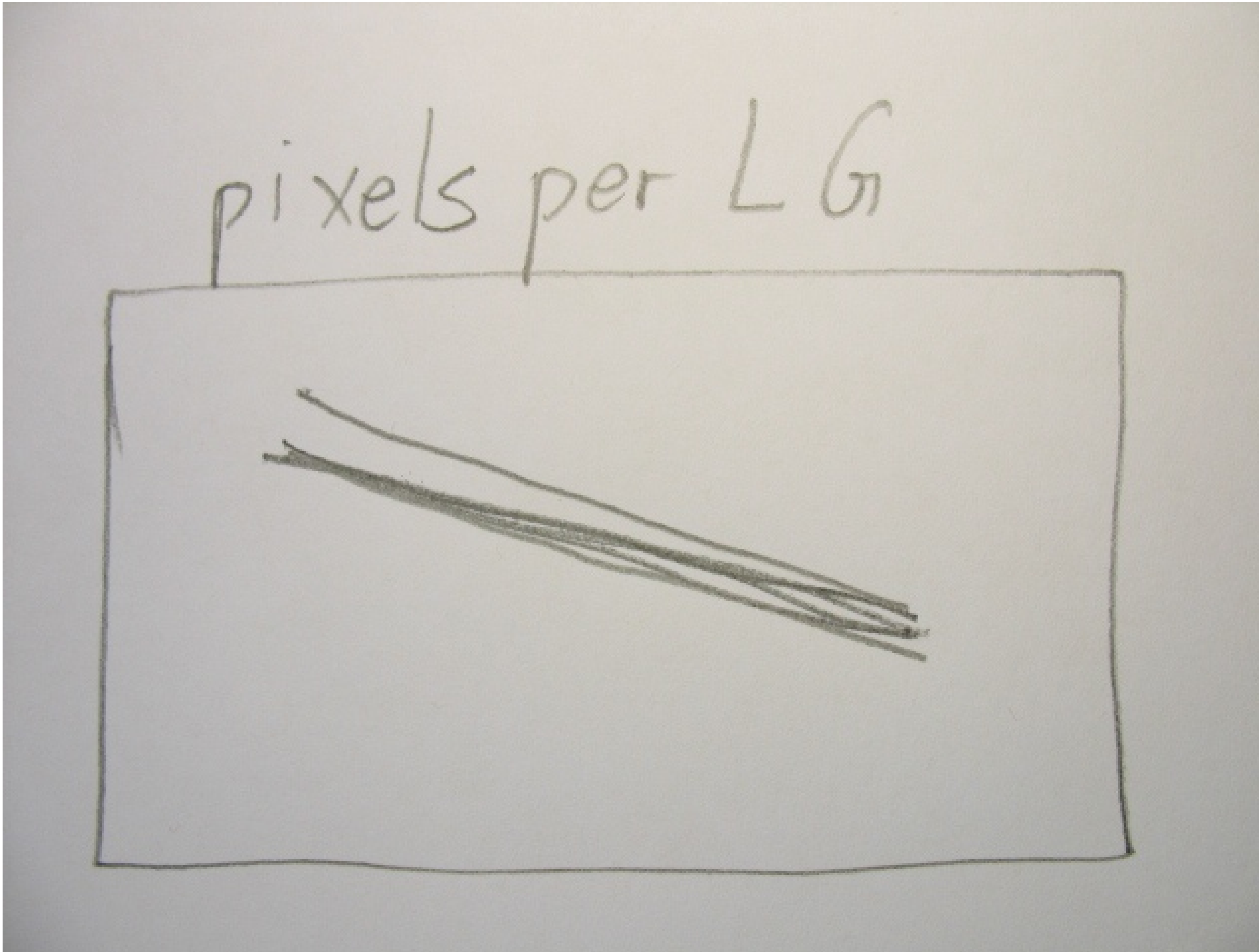
- Focussing Light Guide disc DIRC design presented
- looked at some optical aspects
- DIRC performance assessed in simulations
- forward angular range in
  - PANDA: PID detector
  - WASA: energy resolution improvement
- layout can be fine-tuned to experimental needs

p̄anda Detector Setup



number of LGs




pixels per LG

(external) boundary conditions

available space

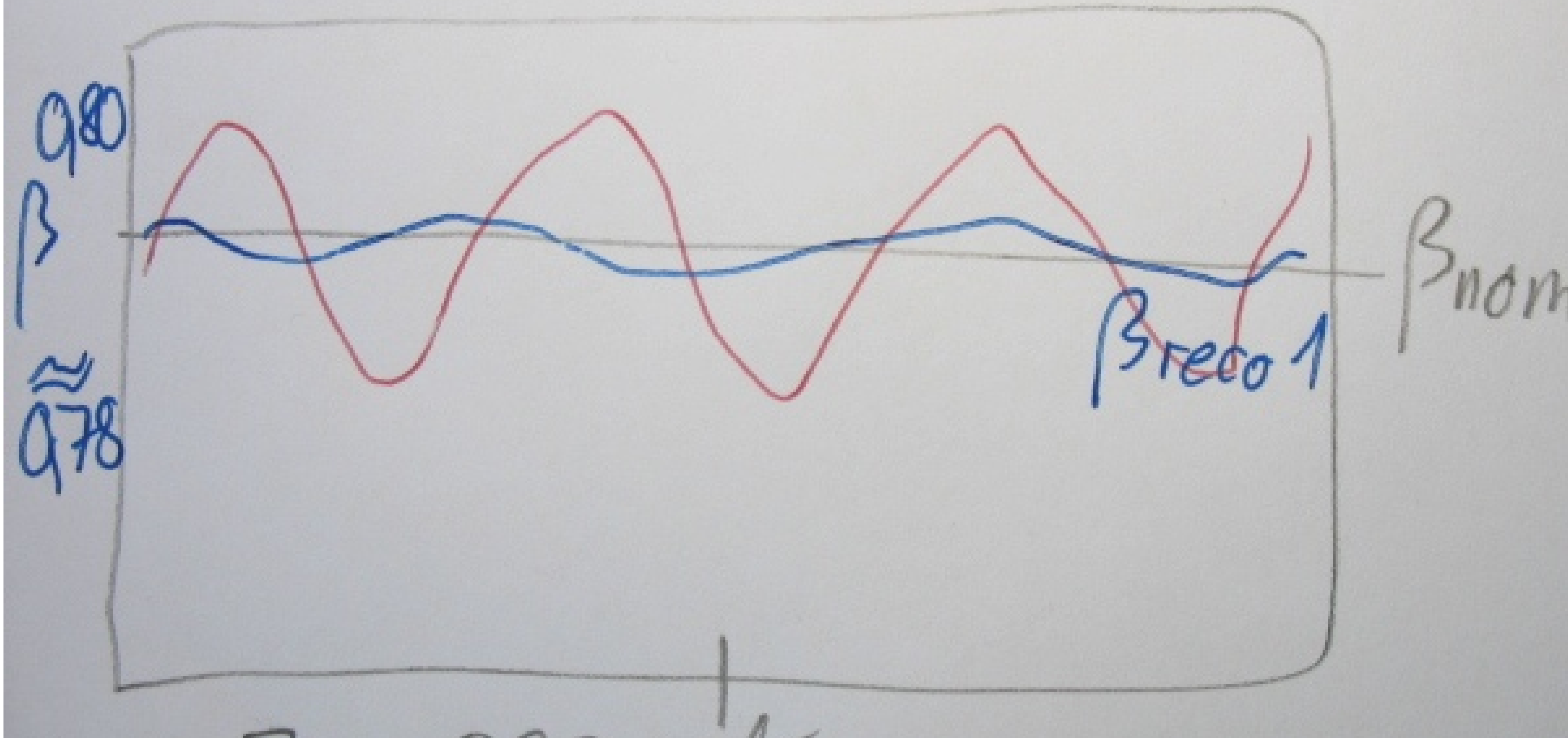
money

X allowed

PMT lifetime

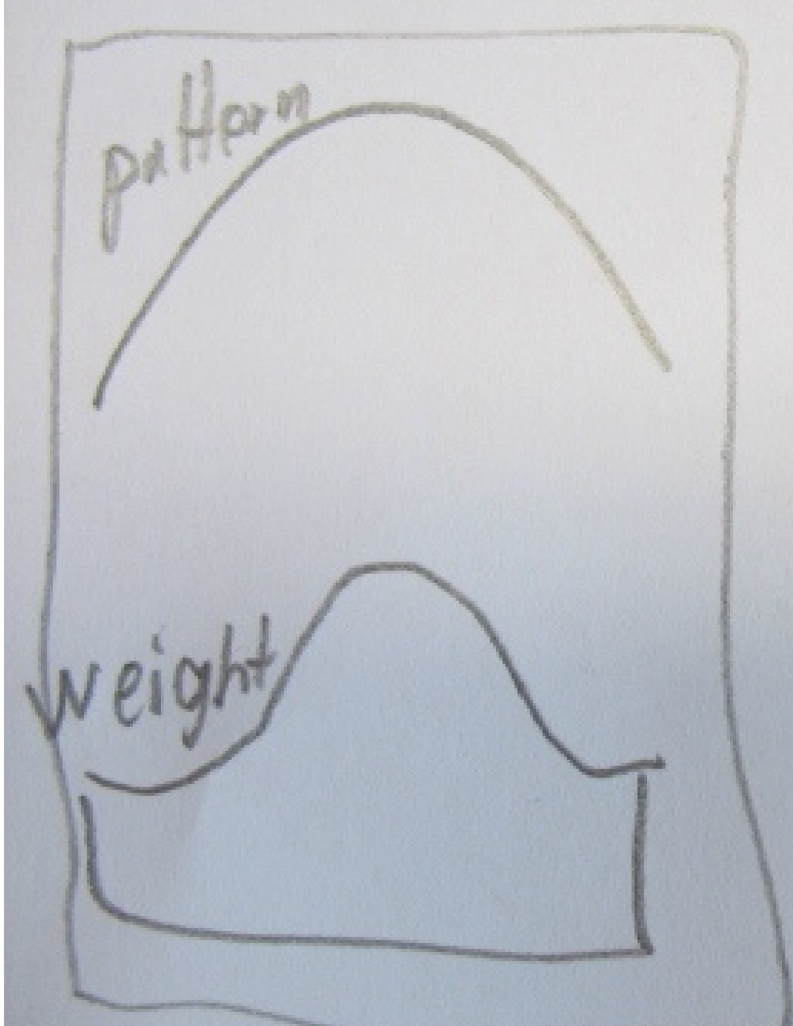
maximise info per photon

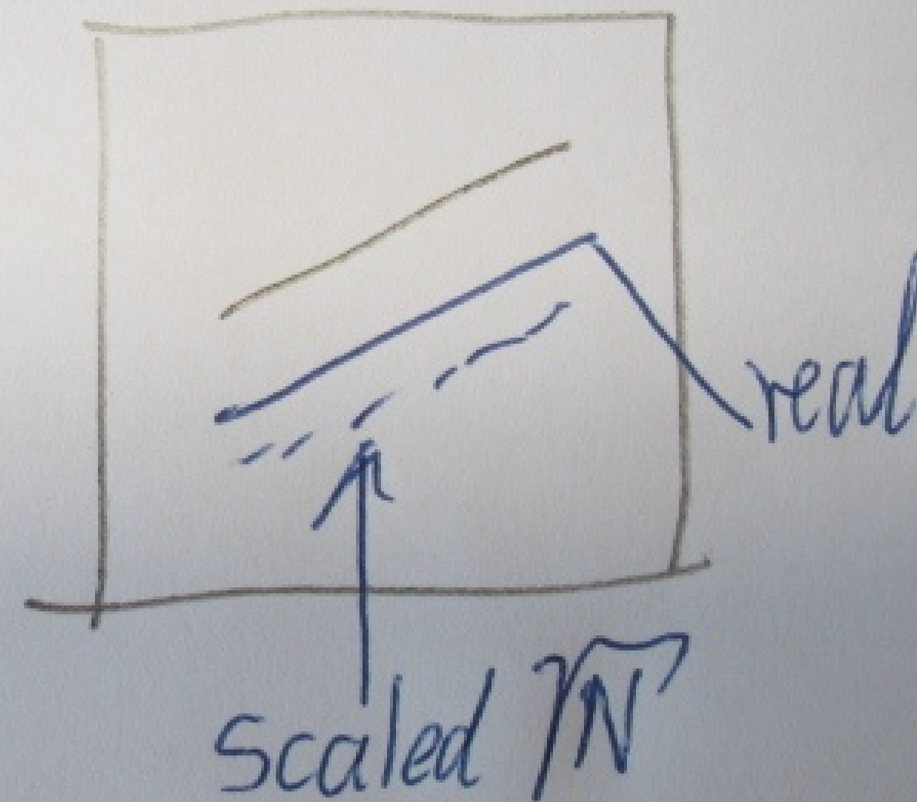
systematic effects

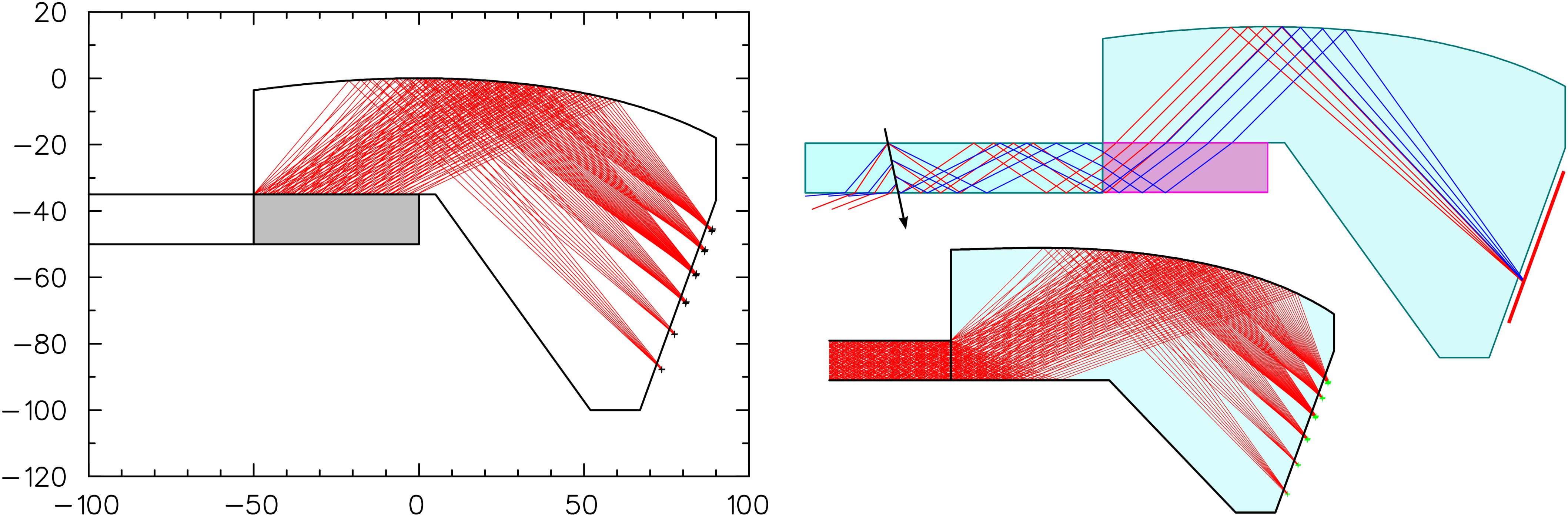


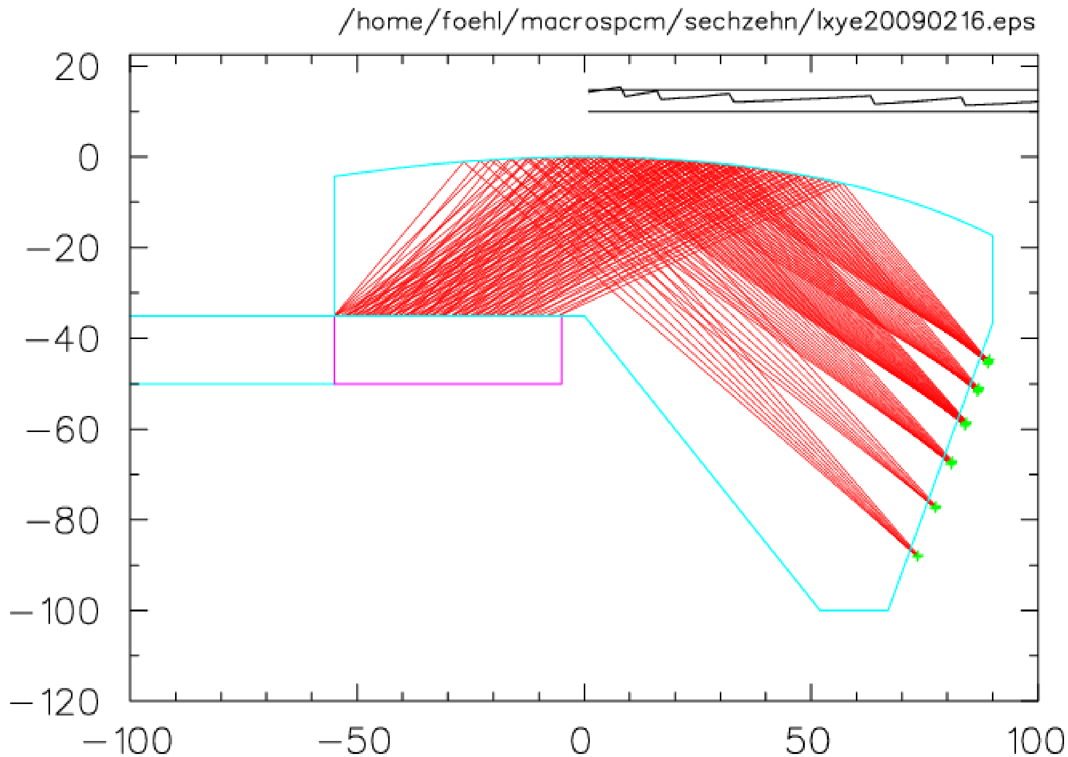
Bsp COSY

info per photon






20
0
−20
−40
−60
−80
−100
−120
−100
−50
0
50
100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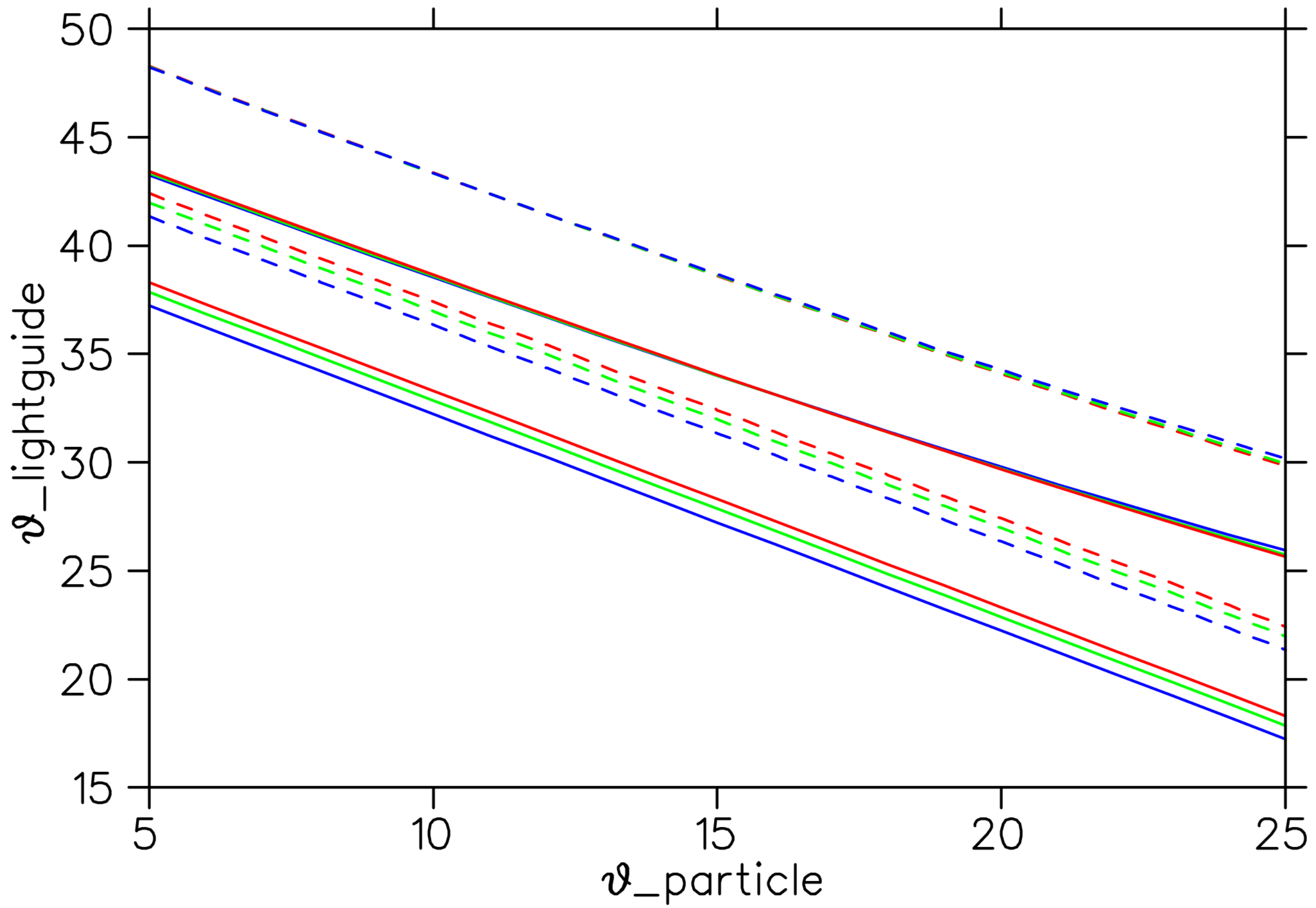
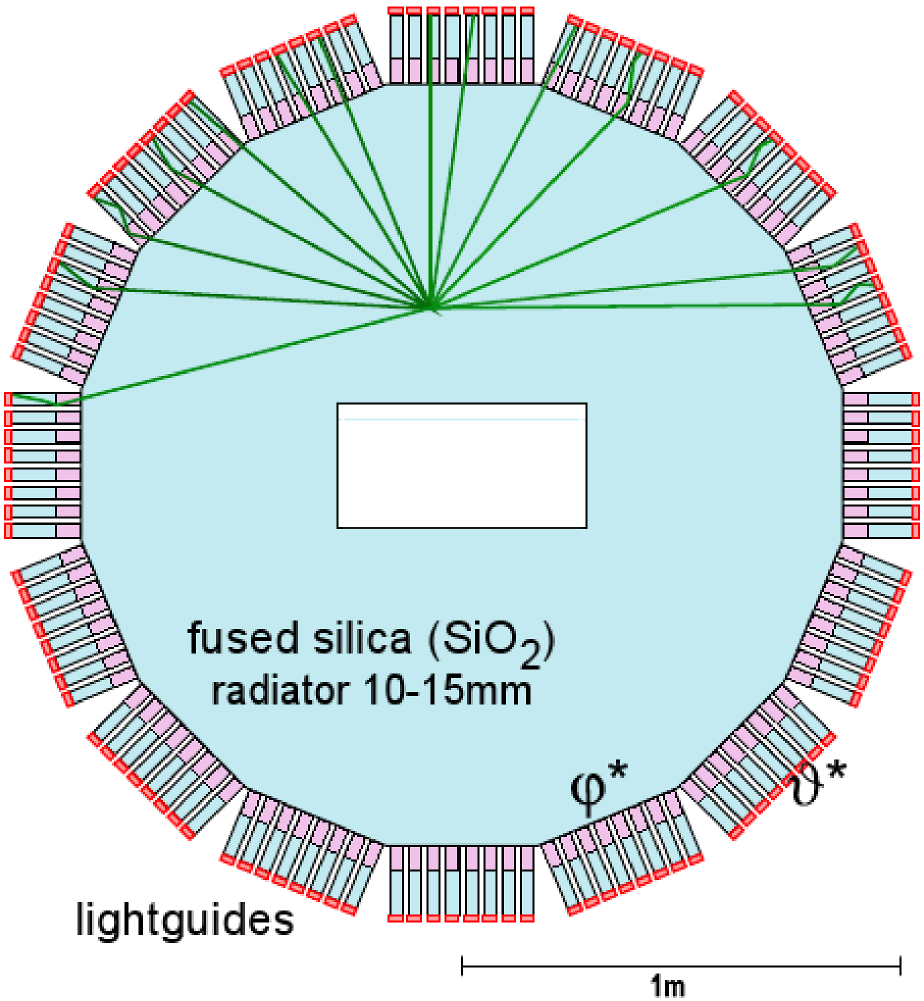
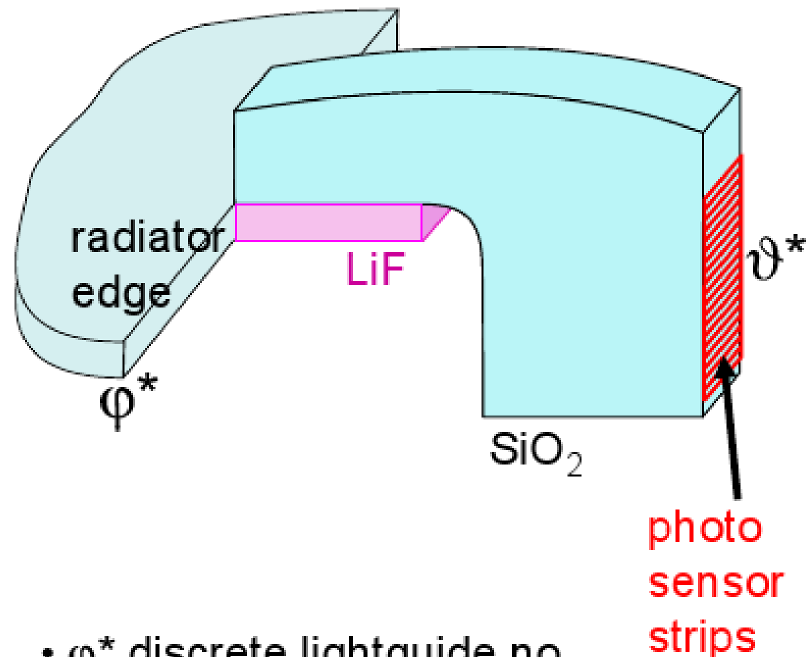
20
0
−20
−40
−60
−80
−100
−120
−100
−50
0
50
100

Dispersion Correction

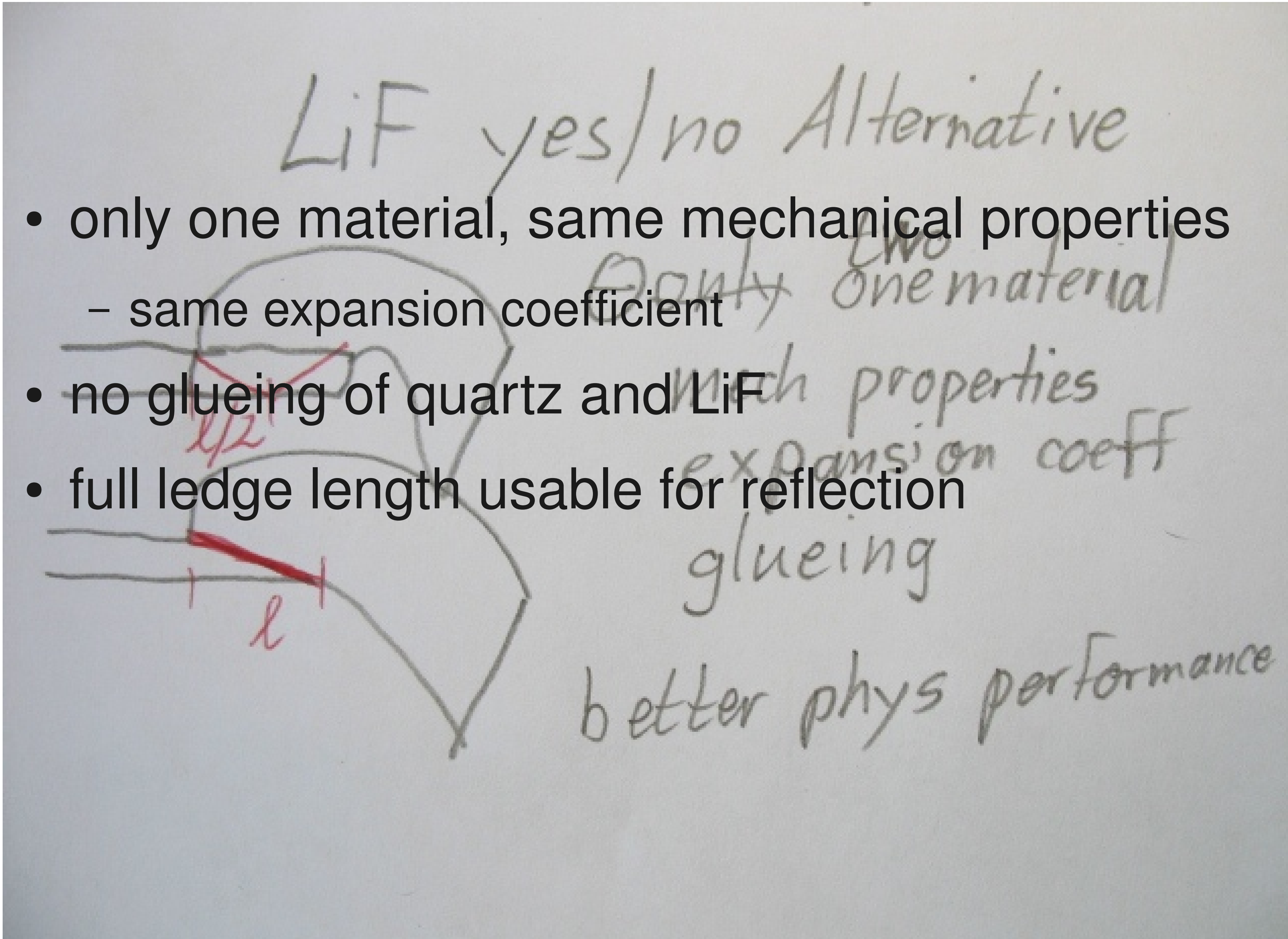


Focussing Lightguide



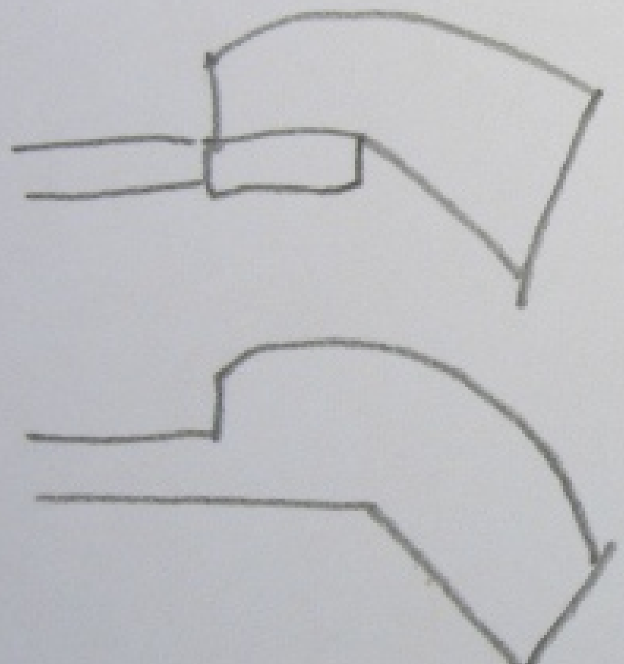


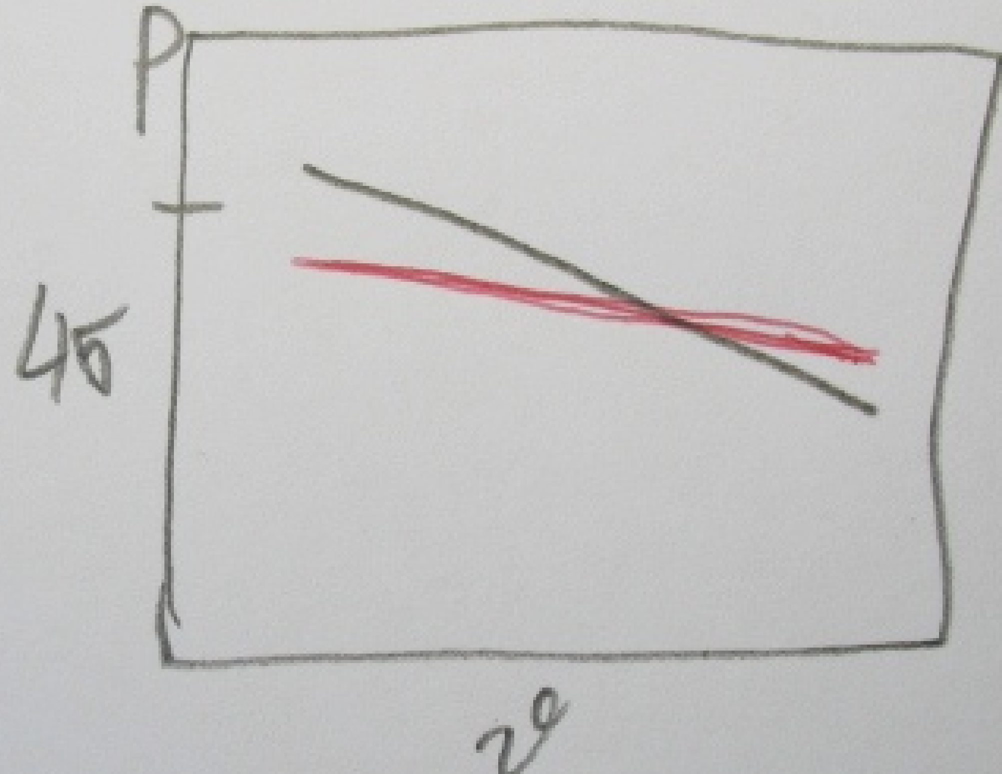
- φ* discrete lightguide no.
- ϑ* angle in (r-z) plane
- LiF for dispersion correction
- photon extraction into lightguide lifts up-down direction ambiguity
- focussing inside lightguide



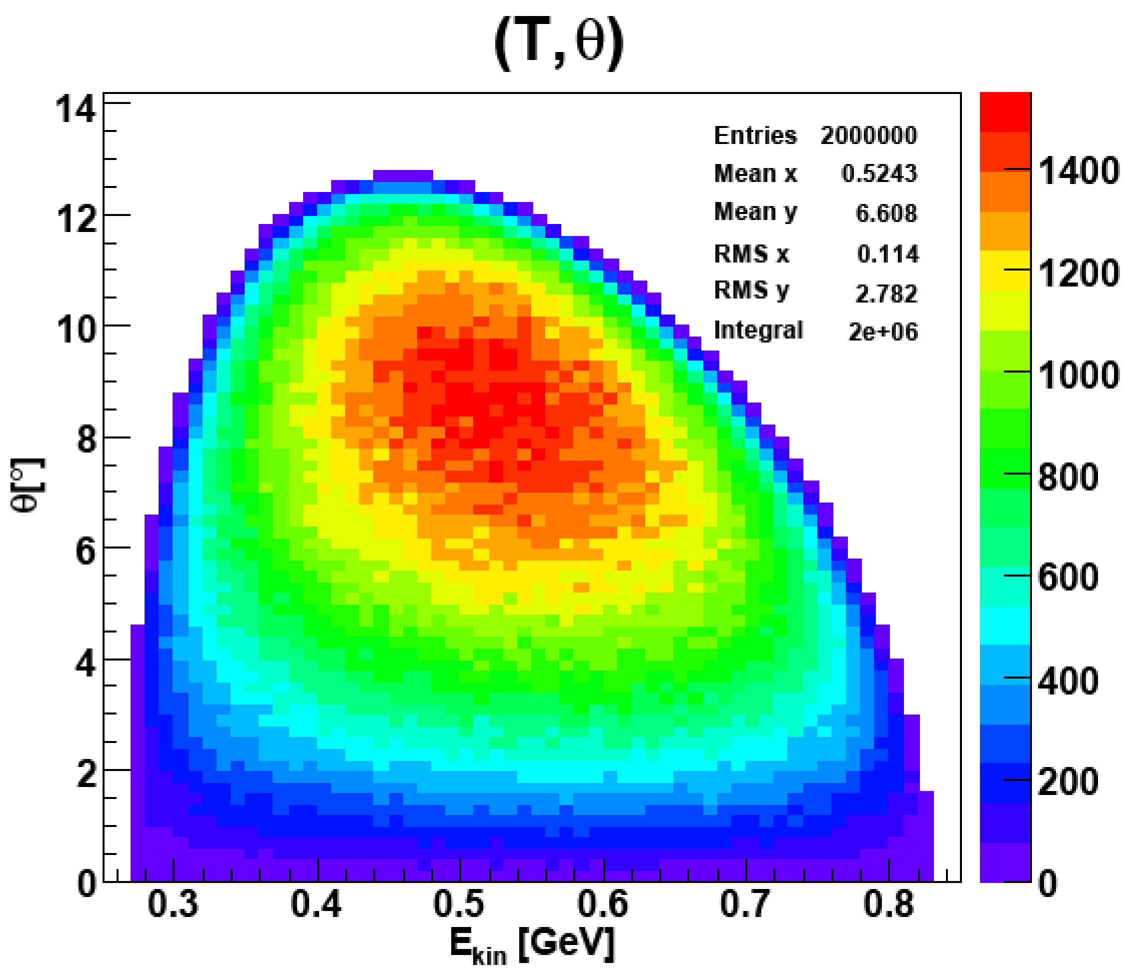
- only one material, same mechanical properties
  - same expansion coefficient
- no glueing of quartz and LiF
- full ledge length usable for reflection

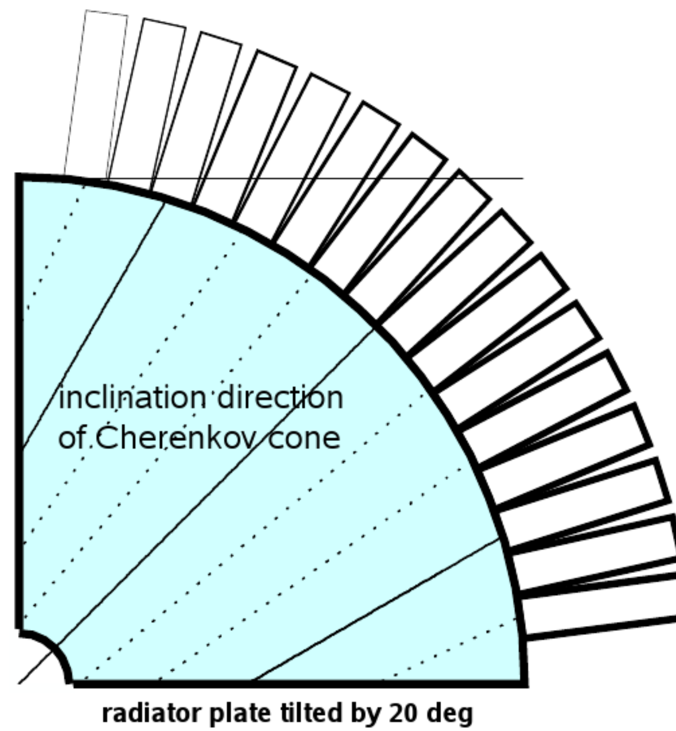
LiF yes/no 2





Eta’: pp → ppη’ (p=3.35GeV/c)





entire range is punch-through energies

most energies below threshold for vertical radiator disc