The WASA FLG Disc DIRC

Focussing Light Guide

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JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

HIC for FAIR
Helmholtz International Center

Bundesministerium für Bildung und Forschung

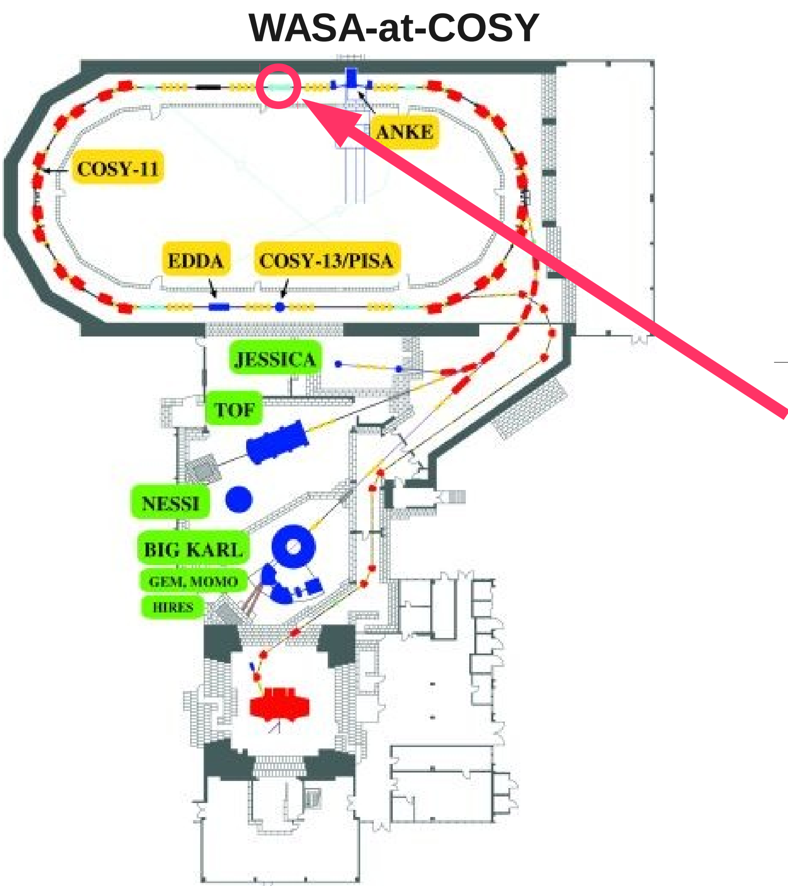
Contents

- Why a DIRC for WASA at COSY in Jülich?
- Which DIRC design are we going for?
- What prototypes are we building?

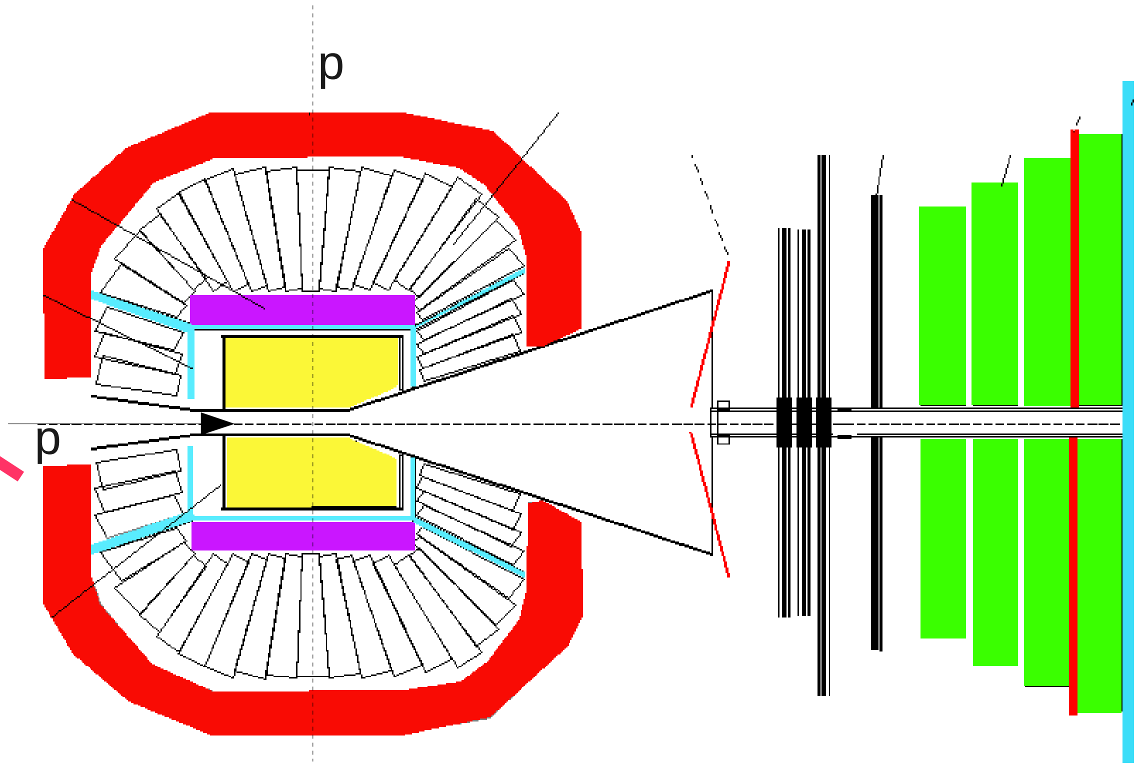
DIRC-at-WASA group with people from:

- Bonn University
- Erlangen University → *talk Adrian Schmidt*
- Gießen University
- Jülich Research Centre
- Tübingen University → *talk Evgueny Doroshkevich*

WASA experiment at COSY, Jülich



COSY in Jülich
(COoler SYnchrotron)
proton storage ring



WASA experiment at COSY

WASA forward direction $\vartheta = 3^\circ \text{ to } 17^\circ$

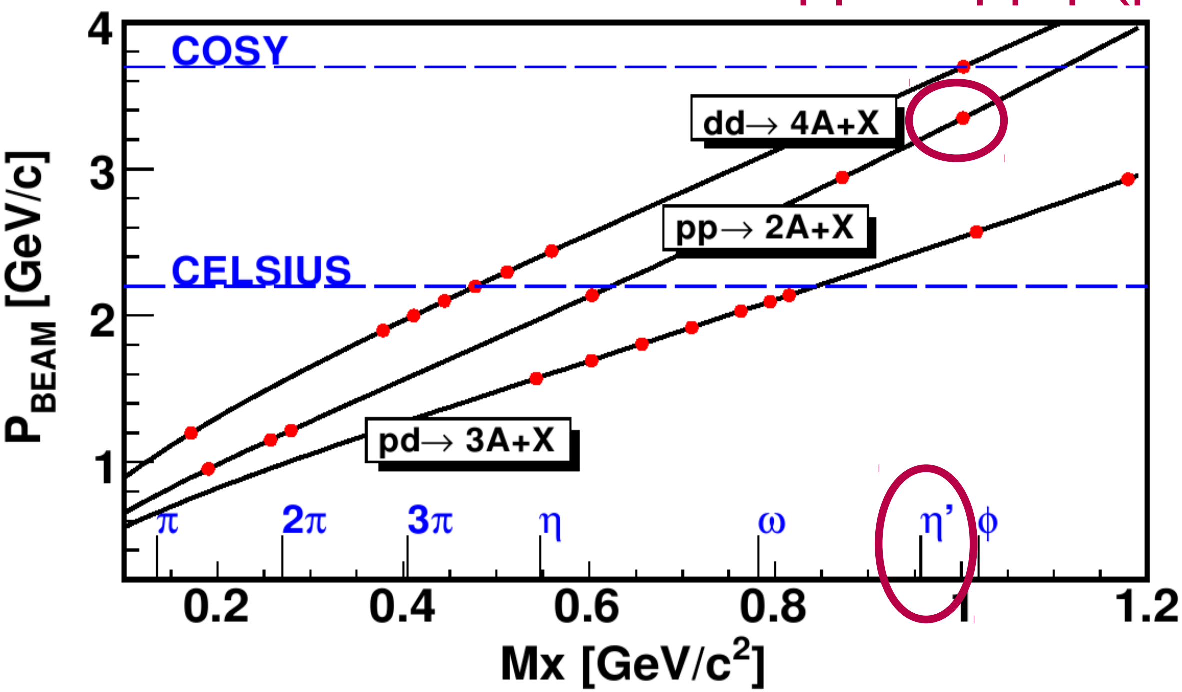
WASA – from CELSIUS to COSY

Higher energies → demanding requirements

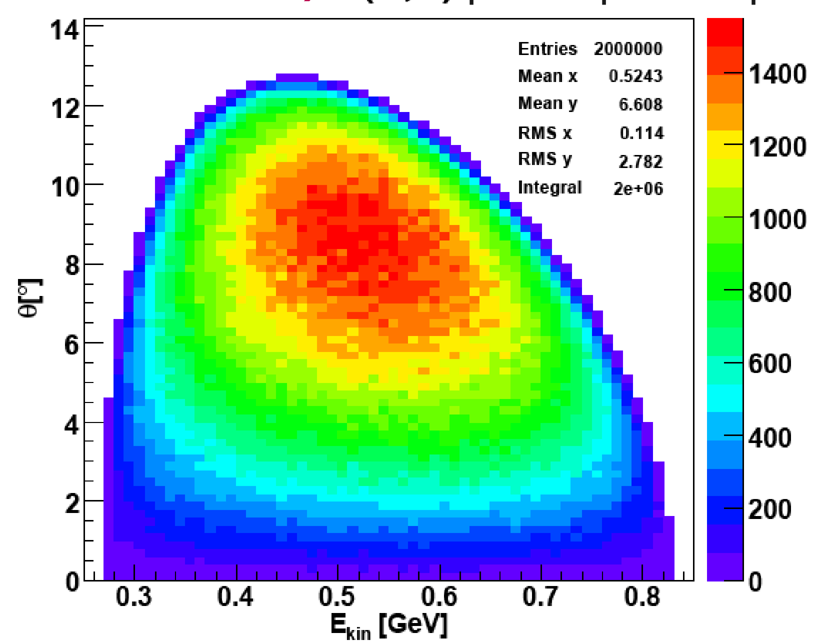
- Upgraded detectors
  - Energy reconstruction improved by 10-20%
  - Better granularity; Faster response

just above production threshold

pp → ppη' (p=3.35GeV/c)



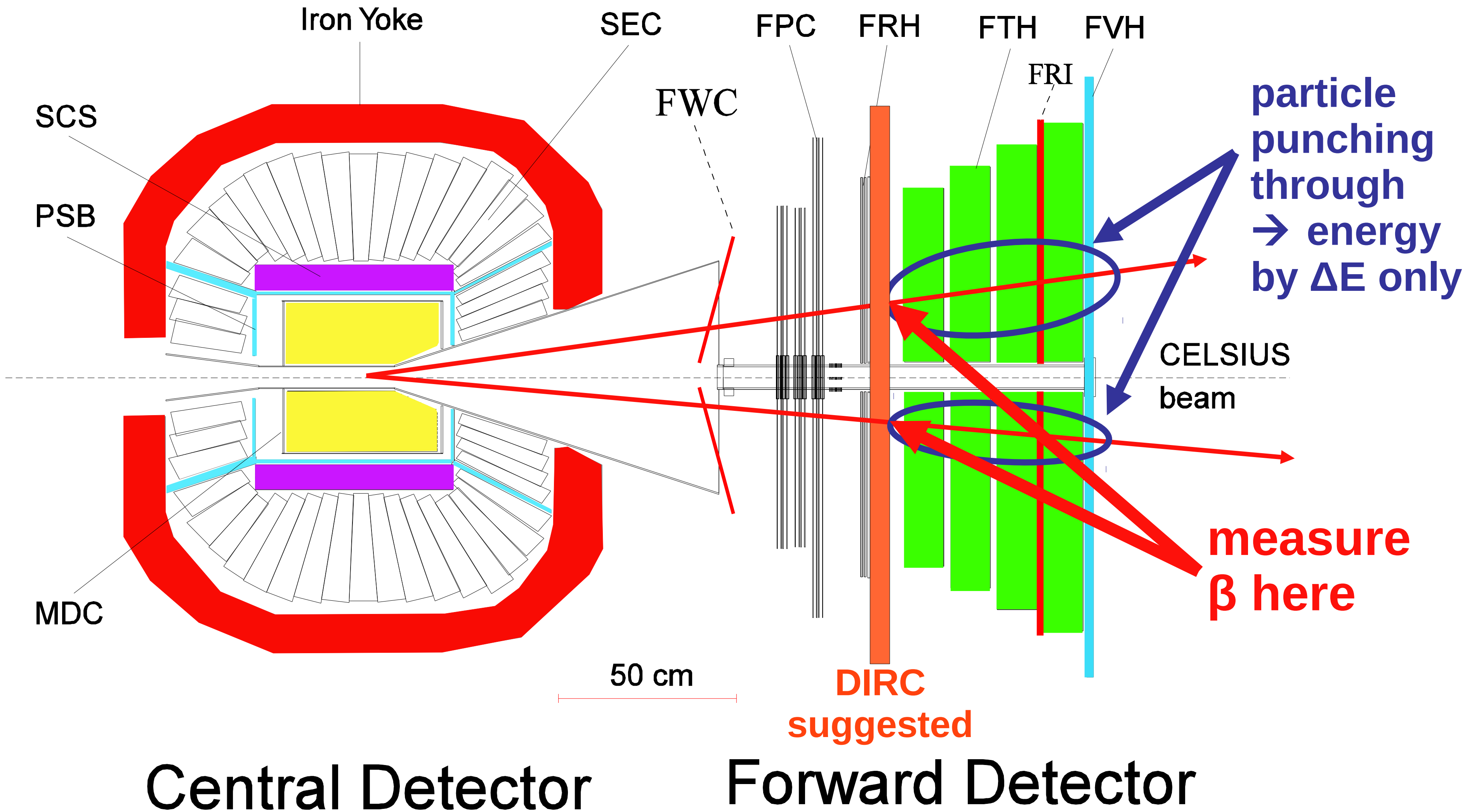
(T, θ) proton phase space



(β = 0.70 – 0.85)

WASA at COSY

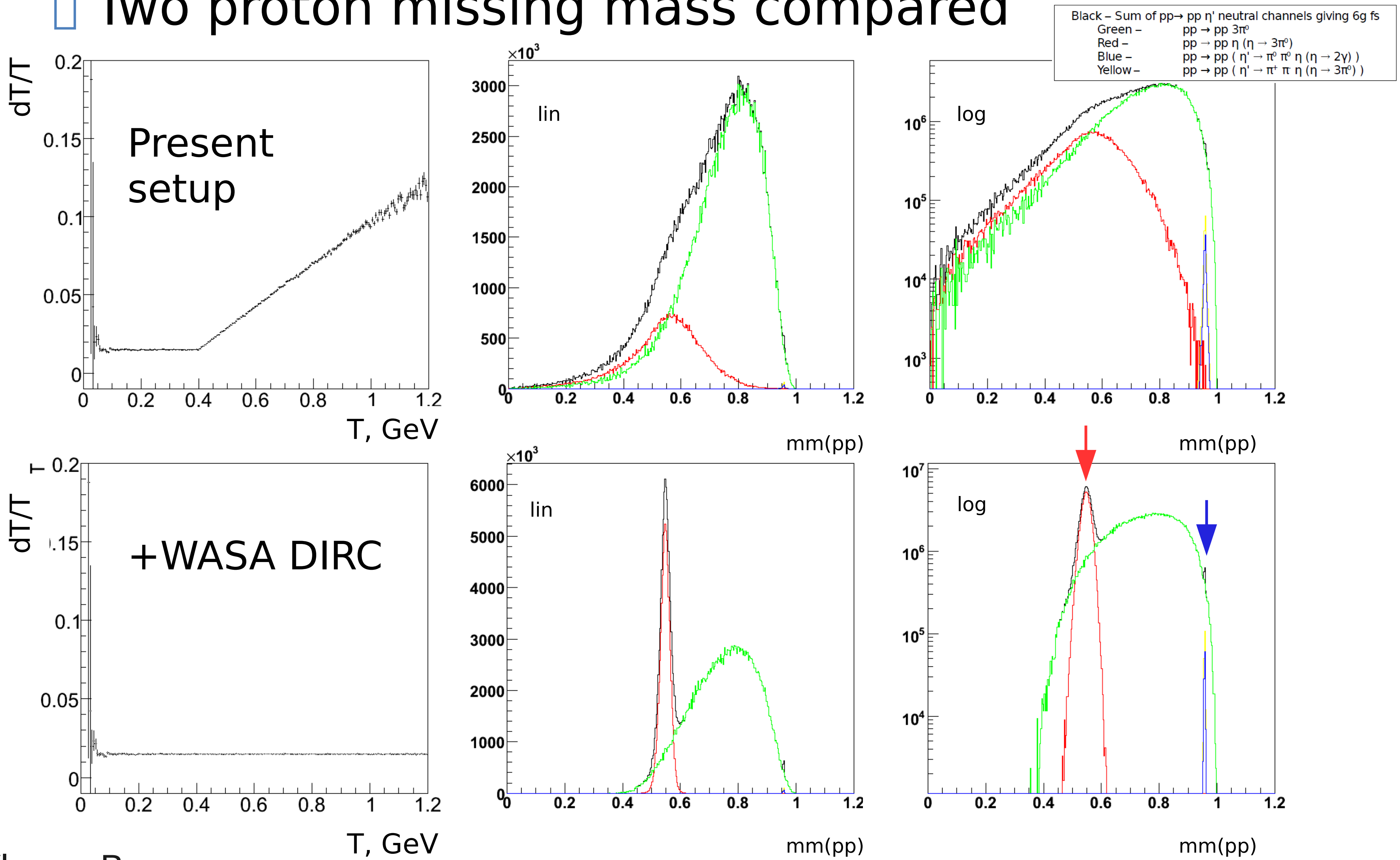
COSY allows higher energies than CELSIUS where WASA resided in the past



measure beta for energy determination

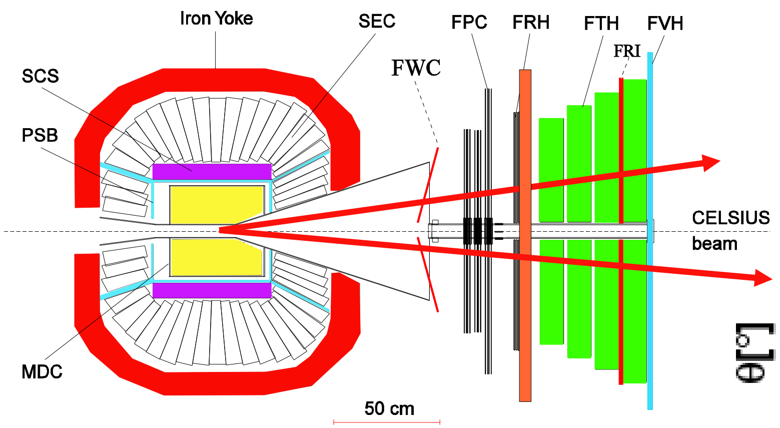
Fast Simulation. Signal/Background

- Two proton missing mass compared

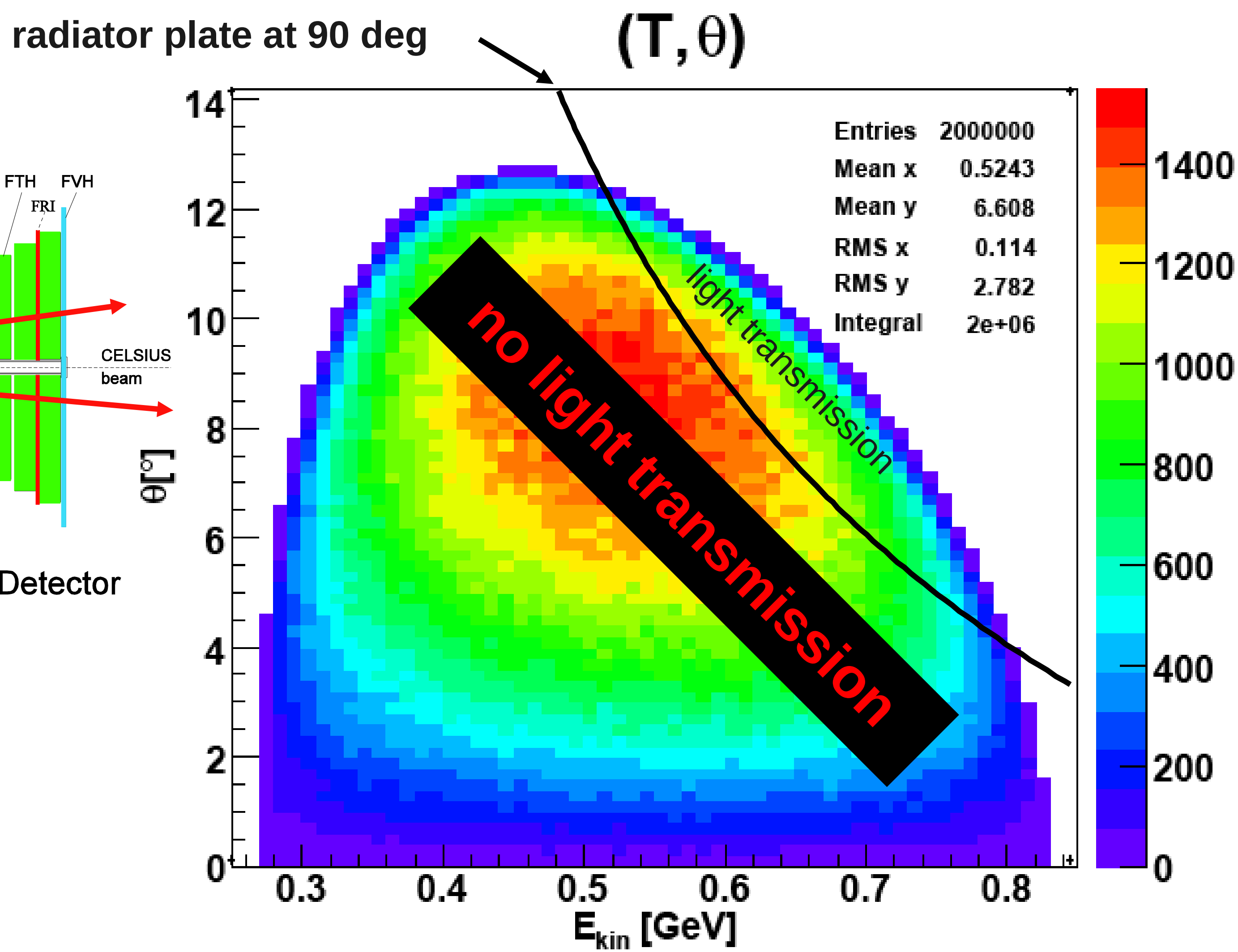


Petr Vlasov, Bonn

Eta’: pp → ppη’ (p=3.35GeV/c)



Central Detector Forward Detector

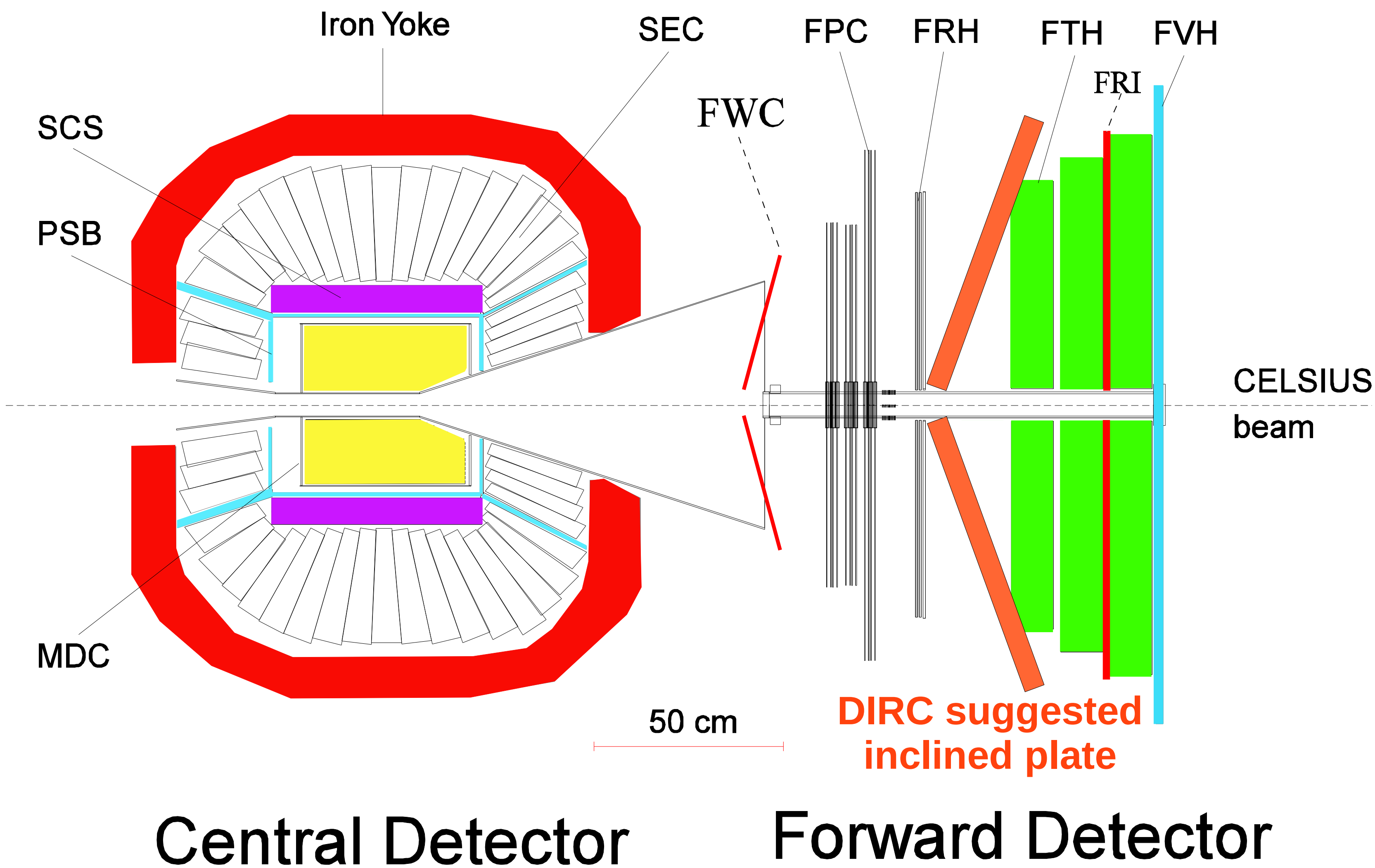


entire range is punch-through energies

most energies below light transmission threshold for vertical radiator disc

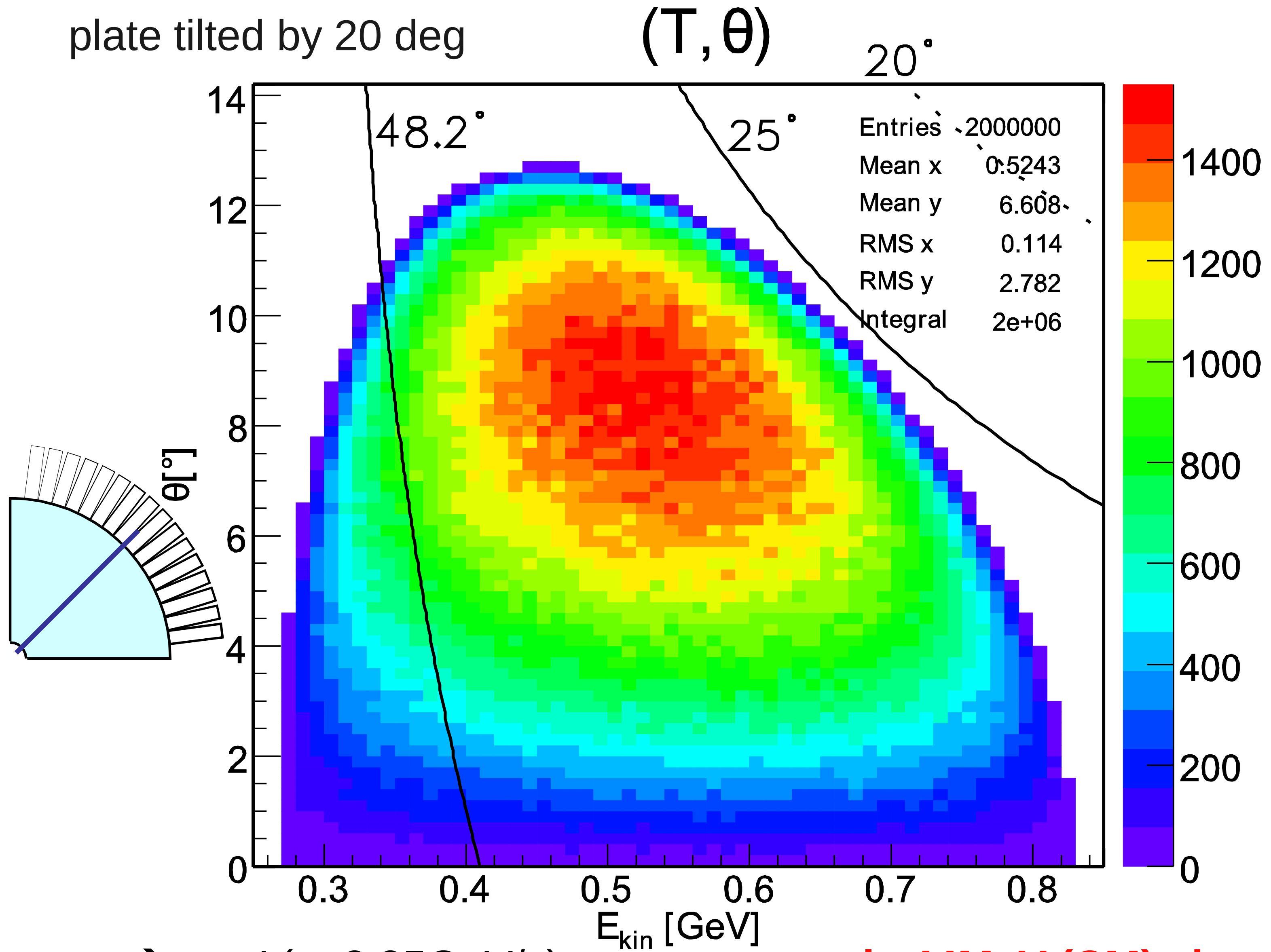
WASA at COSY

COSY allows higher energies than CELSIUS where WASA resided in the past



Phase Space & Detector Thresholds

plate tilted by 20 deg



pp → ppη' (p=3.35GeV/c)

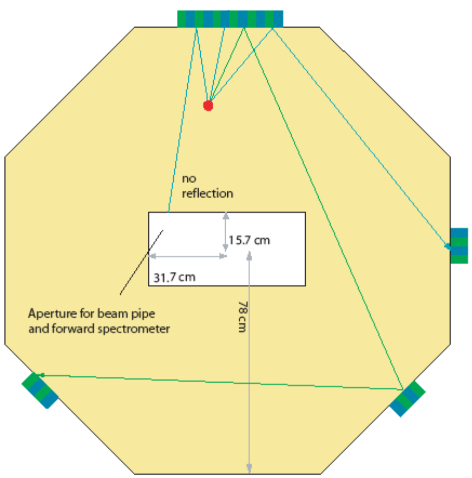
only 44MeV (CM) above threshold

How to build DIRC-at-WASA?

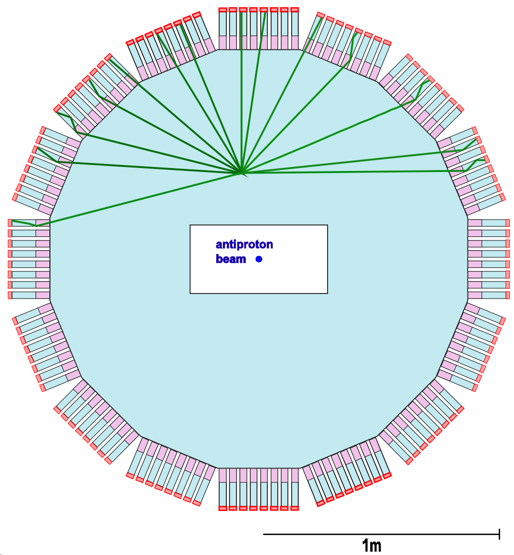
lots of candidates

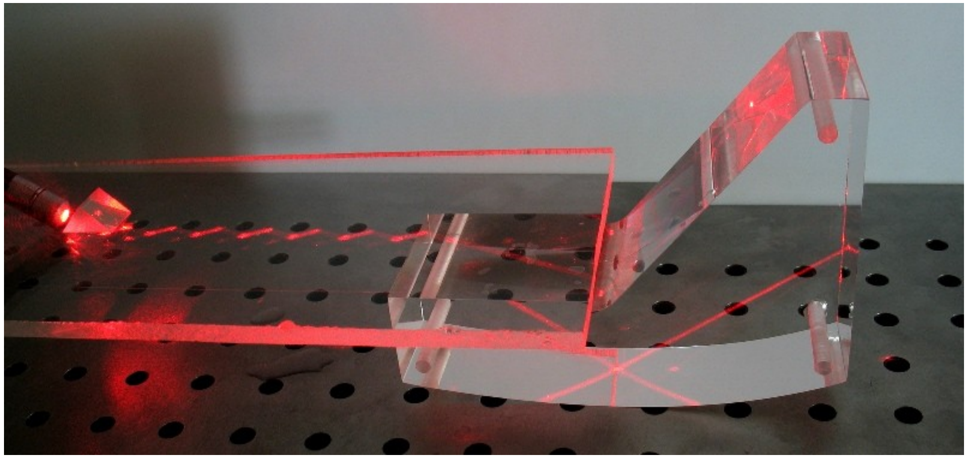
Disc DIRC designs for PANDA & WASA

Time-of-Propagation

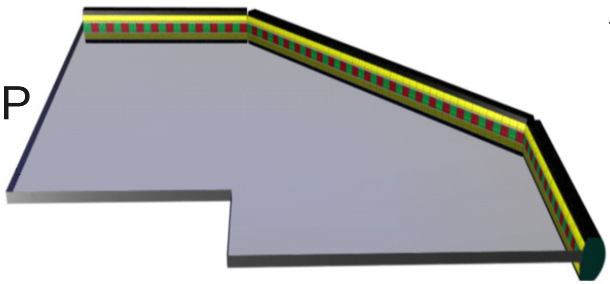


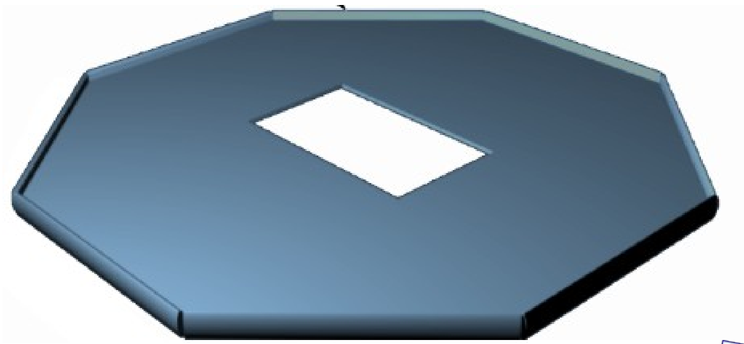
Focussing Lightguide

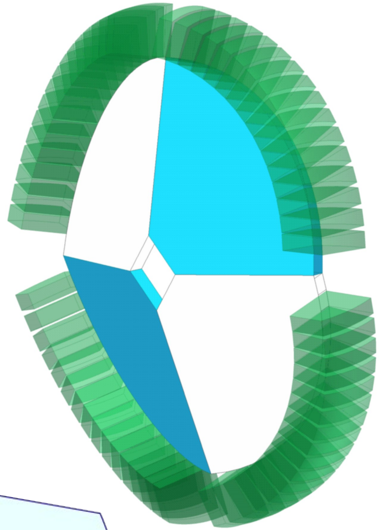


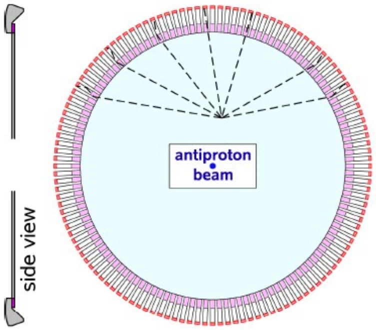


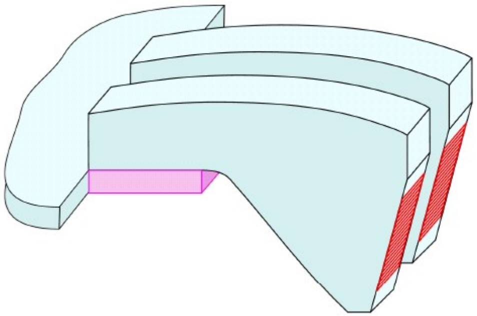
3D-ToP

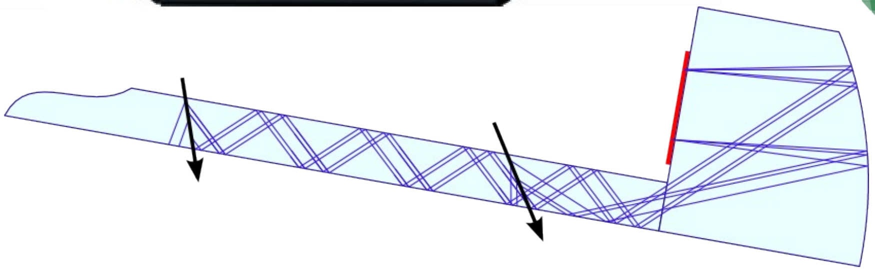












use Lightguides ?

with focussing and chromatic correction

total internal reflection angle independent of λ

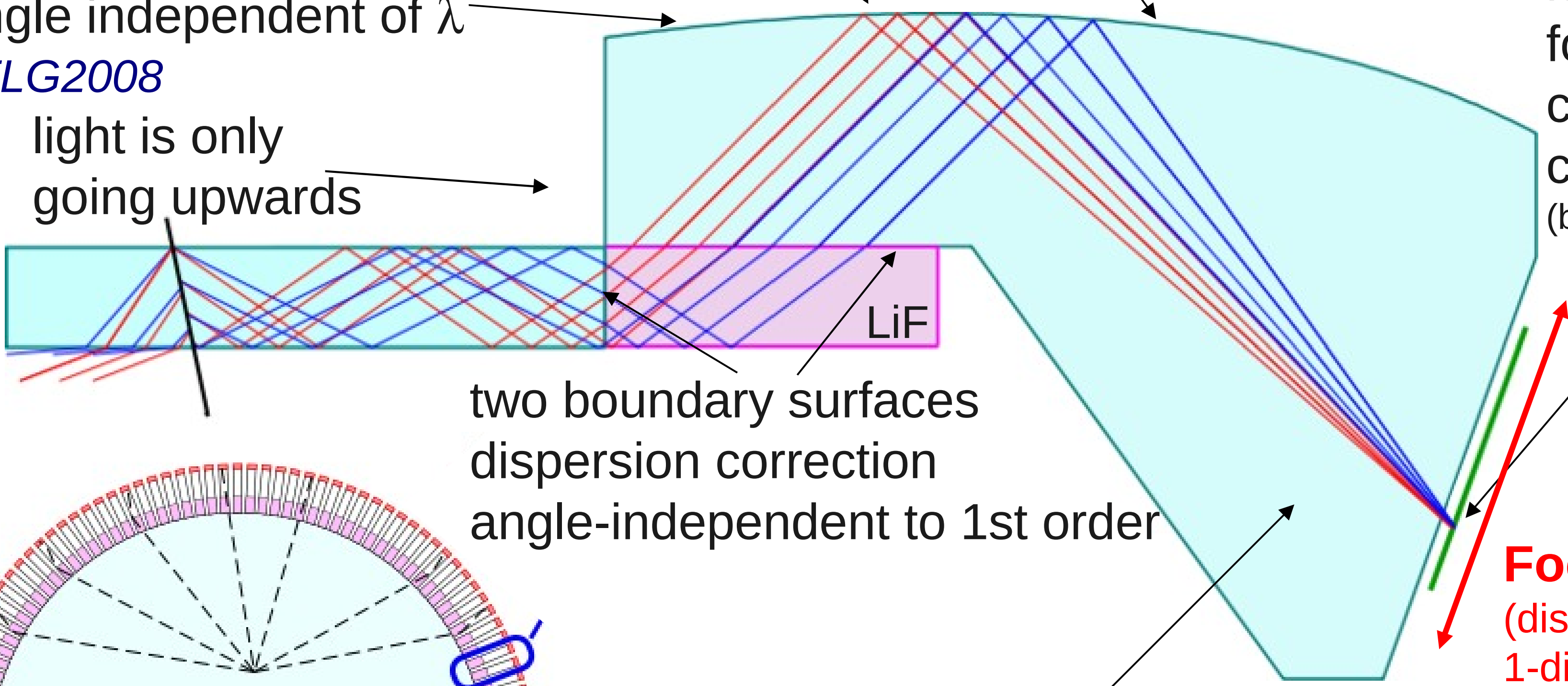
FLG2008

no mirror coating

1-dim aspheric surface

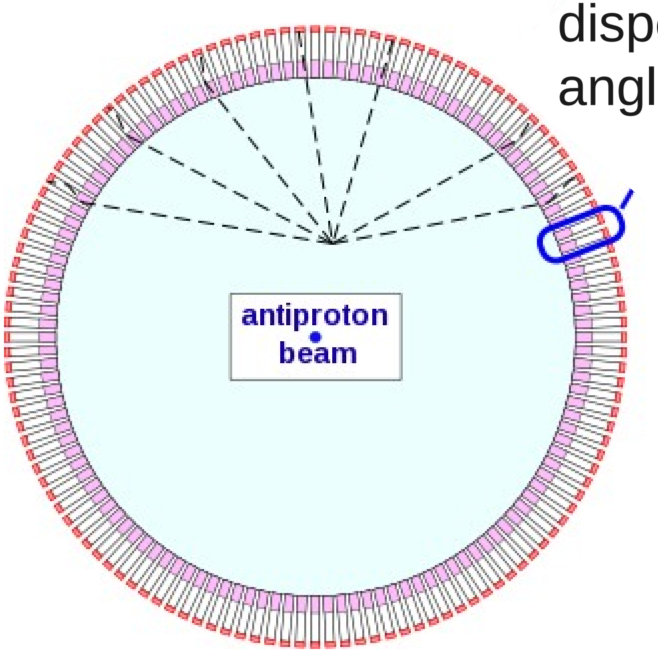
light is only going upwards

not-perfect focussing as curvature is compromise (but good enough)



two boundary surfaces
dispersion correction
angle-independent to 1st order

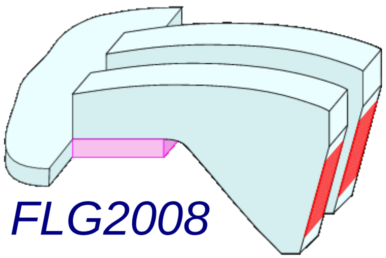
Focal Plane
(dispersive direction)
1-dimensional readout



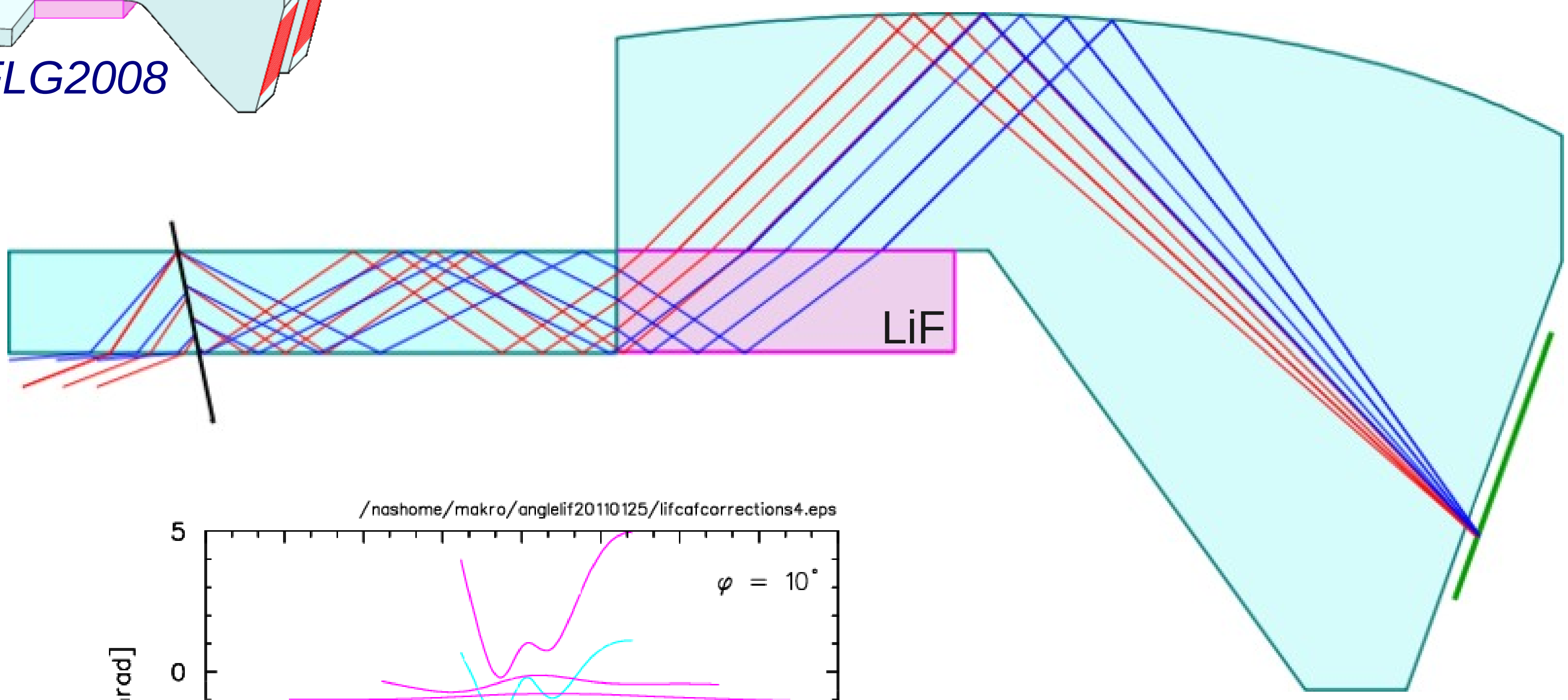
light never leaves dense optical medium
➔ good for phase space

focal plane oriented perpendicular to magnetic field vector
➔ MCPs can be used

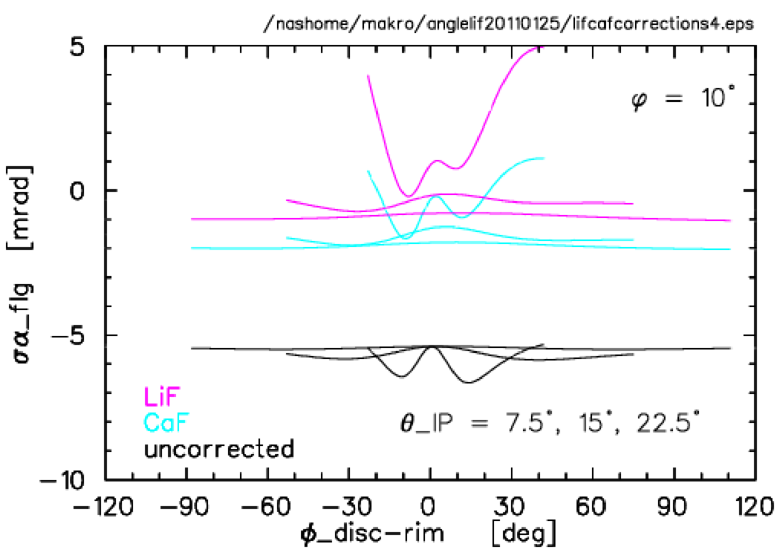
Focussing & Chromatic Correction



FLG2008



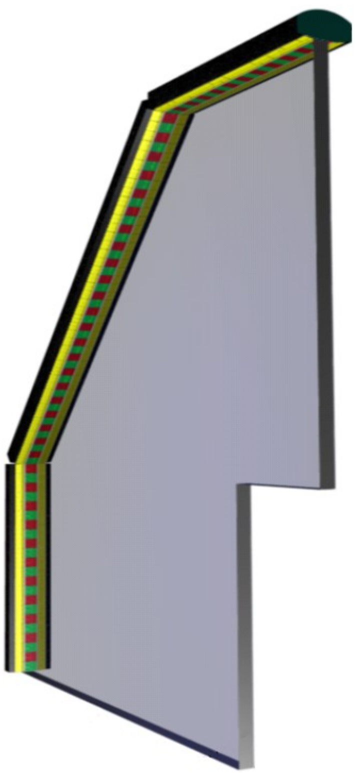
FLG2008



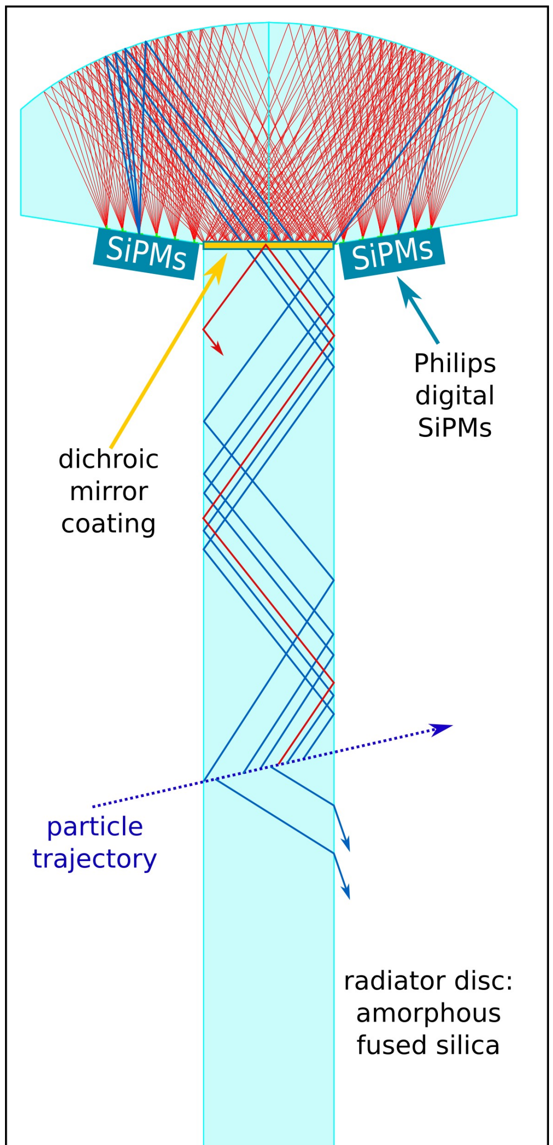
(300nm vs 600nm converted into sigma error)

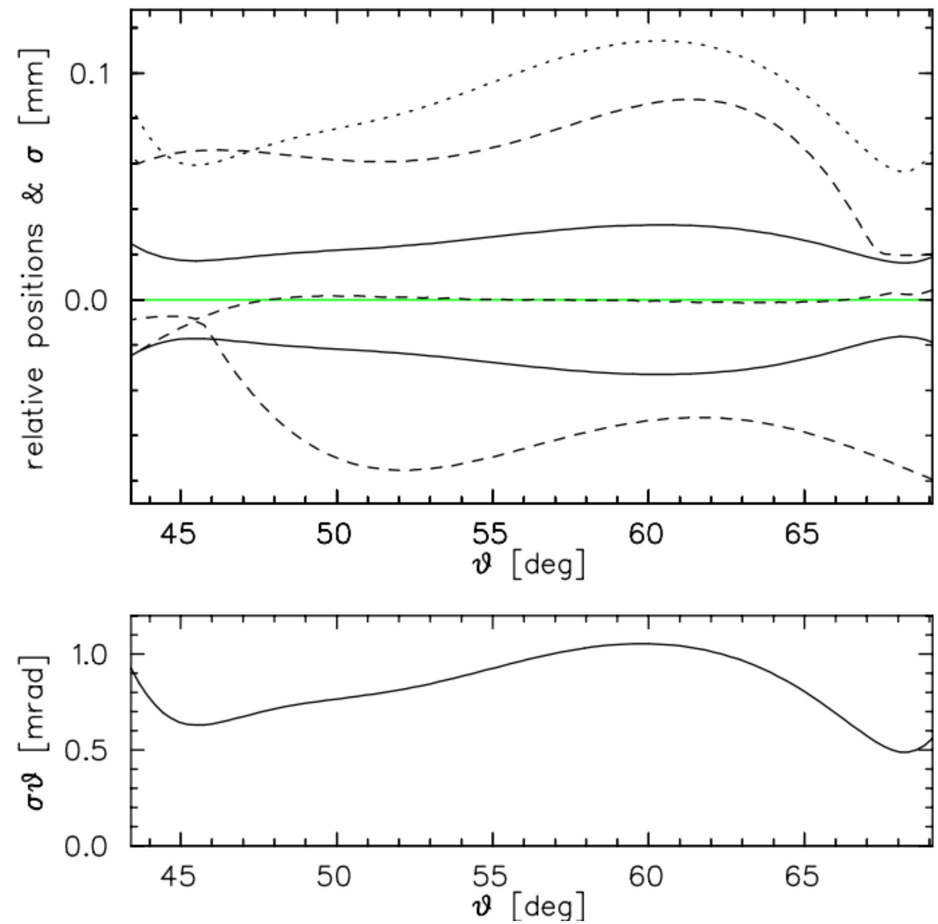
- high performance
  - 1mrad (uncorrected 5mrad)
  - (we want 16 pixel for 0.5sr)

use 3D Disc DIRC ?



3D2011





light guide imaging resolution

Performance values

	Error source	*Error value* [σ in mrad]		
$\sim \frac{1}{\sqrt{N}}$	focussing spot size	0.5÷1.1	0.9÷4.3	~2
	detector granularity (θ component)	0.6	3.1÷6.2	**11**
	finite FLG width (φ component)	<1.7÷4.8	2.9 ; 11.5	**~5÷20**
	chromatic error	1.5	<1.5 (5*)	2.5
	blurring by angular straggling	0.5	0.5	1.5÷2.0
	TOP smearing	5.3	-	-
	TOP detector resolution σt =60ps	8.2	-	-
	path length uncertainty	2.2	-	-
~ 1	RMS shift: angular straggling	0.8	0.8	**2.4÷3.2**
	tracking precision upstream of DIRC	0.4	0.4	0.8 (2)
	track curvature in B field	0.1	0.1	0
		3D2011	*FLG2008*	***DIRC-at-WASA***

3D2011 Error value [σ] Error source
0.5÷1.1 mrad finite spot size of focussing light guide curvature, 20 mm radiator thickness
0.6 mrad detector granularity of 64 µm pixel size (θ component only)
<1.7÷4.8 mrad finite FLG width (15mm) effect (φ component) (θ=7.5◦ and 15◦), octagon
1.5 mrad ca. chromatic error (ranges 400nm÷500nm; 500nm÷700nm
0.5 mrad angle blurring by angular straggling p = 4 GeV/c (∝ 1/p)
5.3 mrad TOP smearing (FLG & 400-500nm, d=20mm, 1m 2D path length)
8.2 mrad TOP detector resolution σt =60ps (1m 2D path length)
2.2 mrad path length smearing (1m 2D path length, AOI 30◦ 15mm FLG
0.8 mrad RMS shift: angular straggling for p = 4 GeV/c (β=1, SiO2 , d=20mm)
0.4 mrad tracking precision upstream of DIRC radiator disc for p = 2 GeV/c
0.1 mrad track curvature in B field, p = 2 GeV/c and θ = 18 degrees at target vertex

FLG2008 Error value [σ] Error source
0.9÷4.3 mrad finite spot size of focussing lightguide curvature, 15 mm radiator thickness
3.1÷6.2 mrad detector granularity of 1.5 mm pixel size (θ component only)
2.9 ; 11.5 mrad finite FLG width (50mm) effect (φ component)
5 mrad chromatic error uncorrected (constant PDE for λ=300nm÷600nm)
<1.5 mrad maximum chromatic error with LiF correction plate
1.4 mrad angular straggling of saturated particle p = 2 GeV/c
numbers for circle shift and smearing
0.4 mrad tracking precision upstream of DIRC radiator disc for p = 2 GeV/c
0.1 mrad track curvature in B field, 2GeV/c and θ = 18 degrees at target vertex

Use something simpler !

Favourable Conditions at COSY

compared to the PANDA situation

- Plexiglas can be used
  - radiation level <100 Gy (so I have been told)
  - plexiglas stands 100 Gy irradiation (Cobalt 60 source)
- photon sensors **not** in magnetic field
  - standard multi-anode PMT technology feasible
- less demanding requirements:
  - 35 degrees range with 16 pixels $\rightarrow$ 11 mrad sigma
  - hence use off-the shelve MA-PMTs (i.e. H8500)
- cost aspect – resolution scaling with 1/sqrt(#ch)
  - also limit from upstream tracking precision

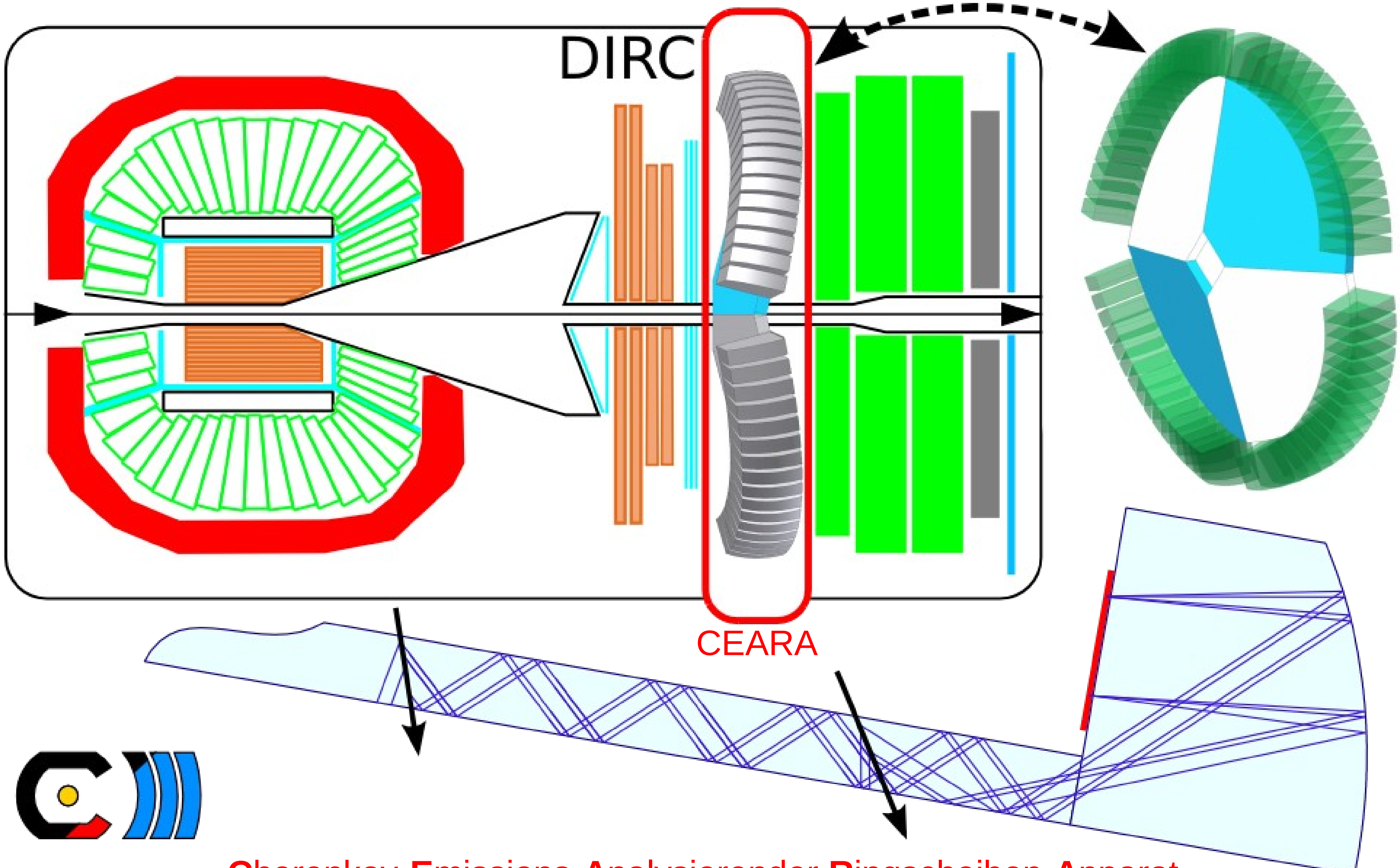
Favourable Conditions at COSY

- Plexiglas can be used (so I have been told)
- photon sensors **not** in magnetic field
- less demanding resolution requirements

- Tübingen can machine plexiglas well
- Erlangen has experience with H8500
- Jülich has or will have electronics
  - 512 channels for Phase I
- staged approach possible

and certainly I have forgotten something...

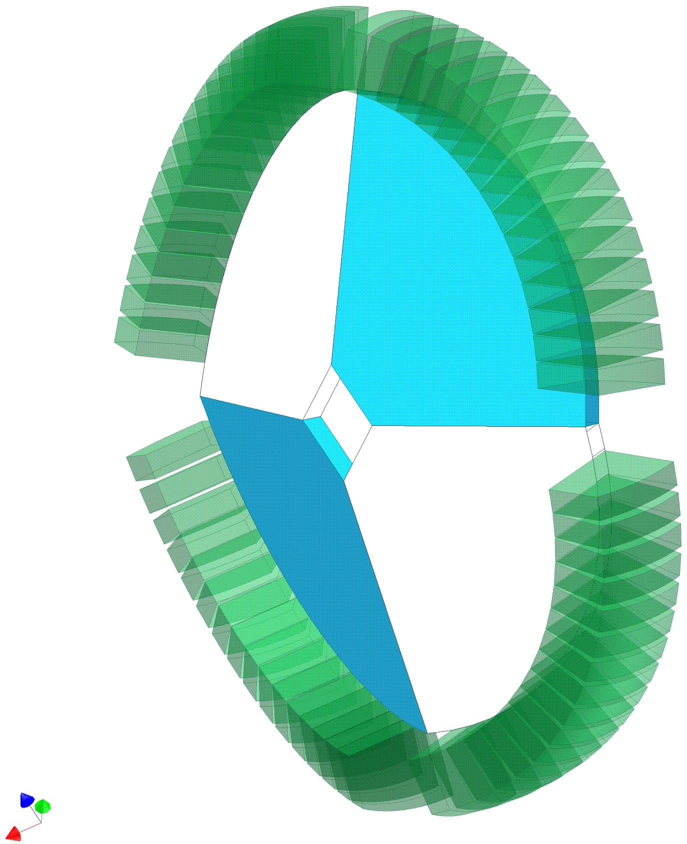
DIRC replacing FRH layers and FRI



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

Current Design Choices

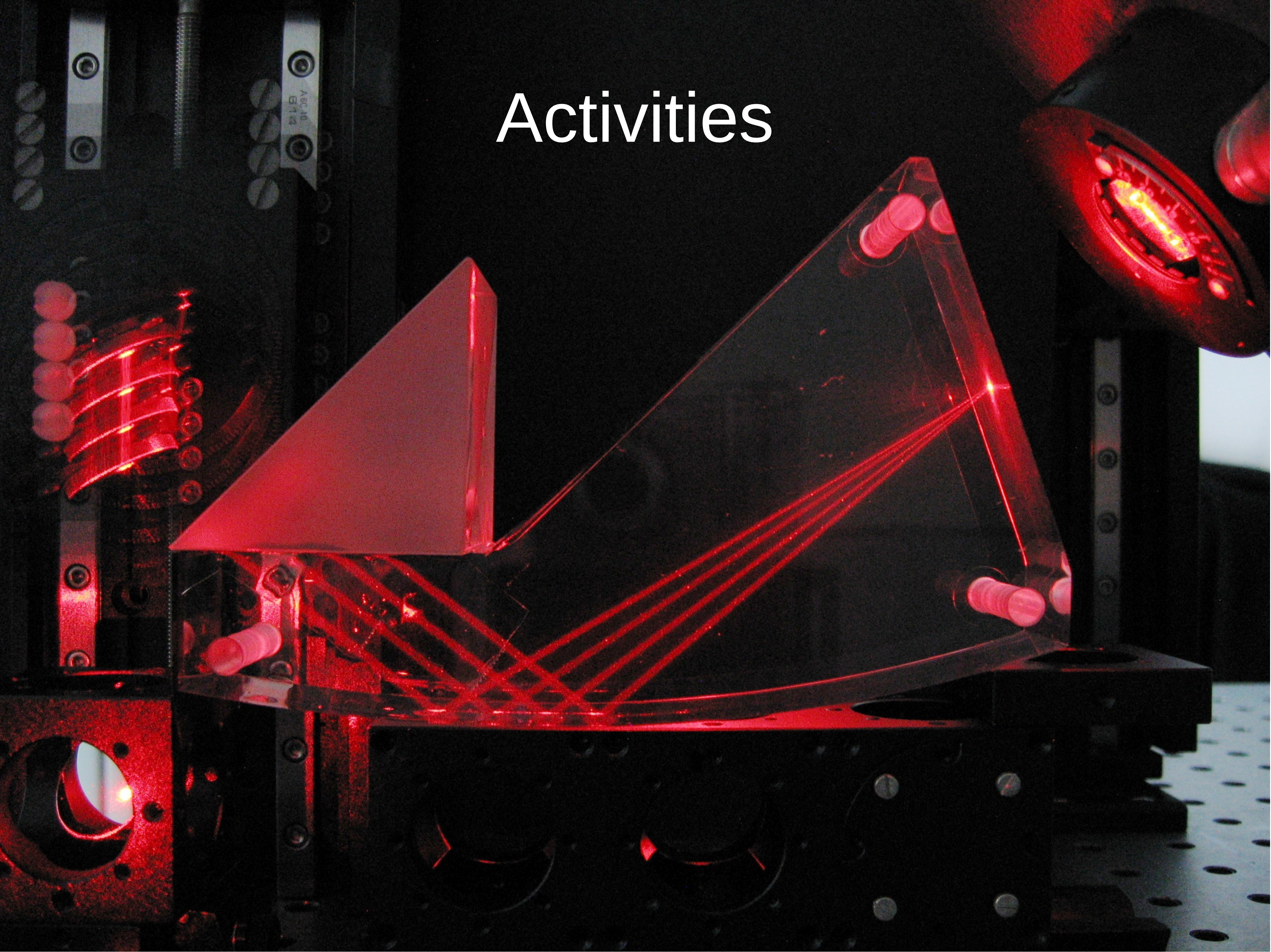
- 4-fold rotational symmetry
- DIRC radiator tilted by 20°
- *available width 310mm*
- plexiglas radiator material
- no dispersion correction
- MaPMTs 64x(6mm)^2 pixels



- 4x 16 Focussing Light Guides, range 15°-50°
- 2 PMTs per FLG, worth 128 pixels 6mmx6mm

(initial idea was 8x1 pixels = 1 superpixel → 16 superpixels per FL)

Activities

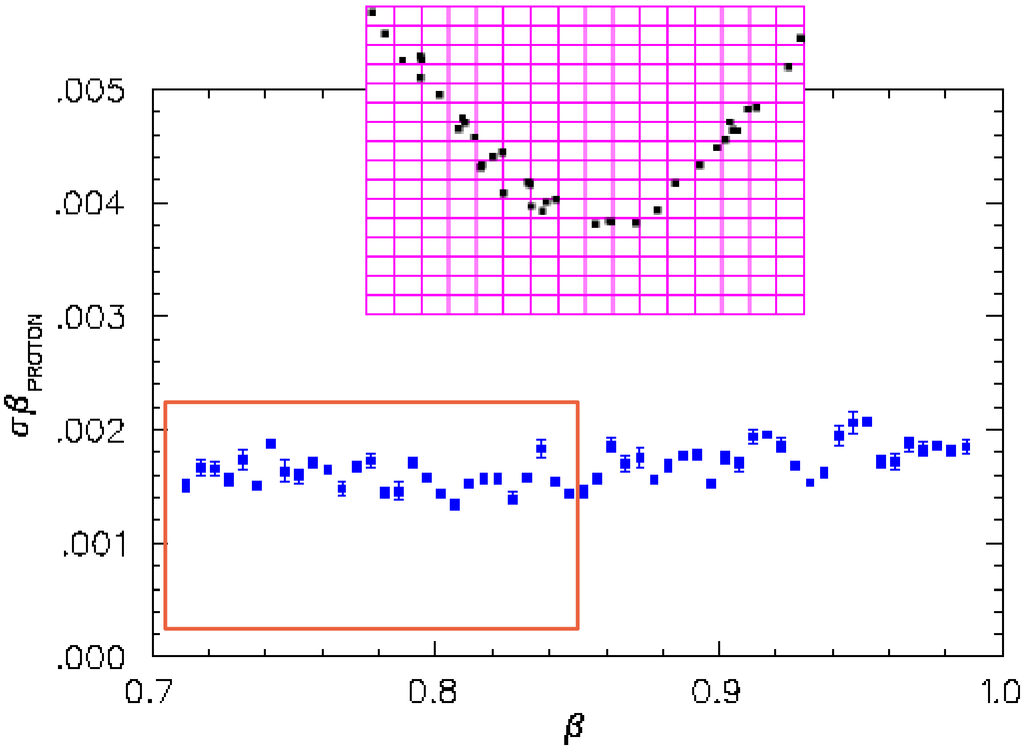


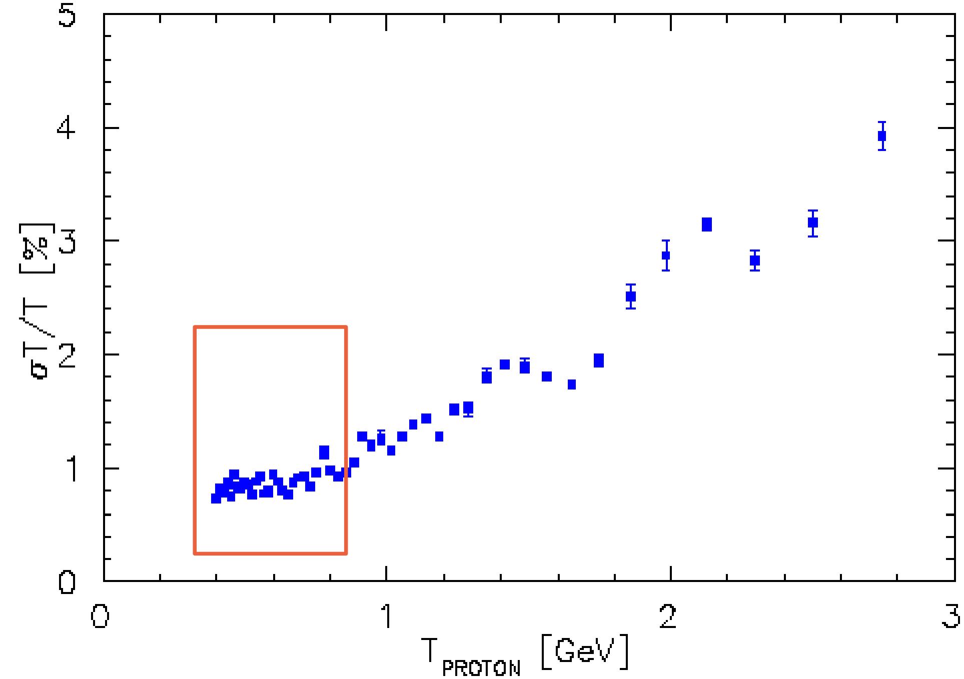
Activities

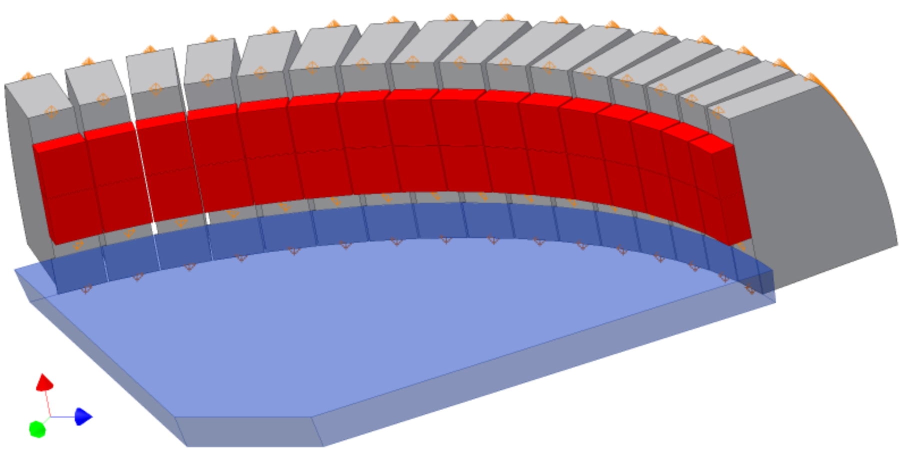
- Simulations (PHYSICA and GEANT4)
- Radiation hardness
- Optical surface quality tests
- Radiator geometry mapping
-
- sensors
- electronics
- mechanics
- ...

see further talks

DIRC-at-WASA performance

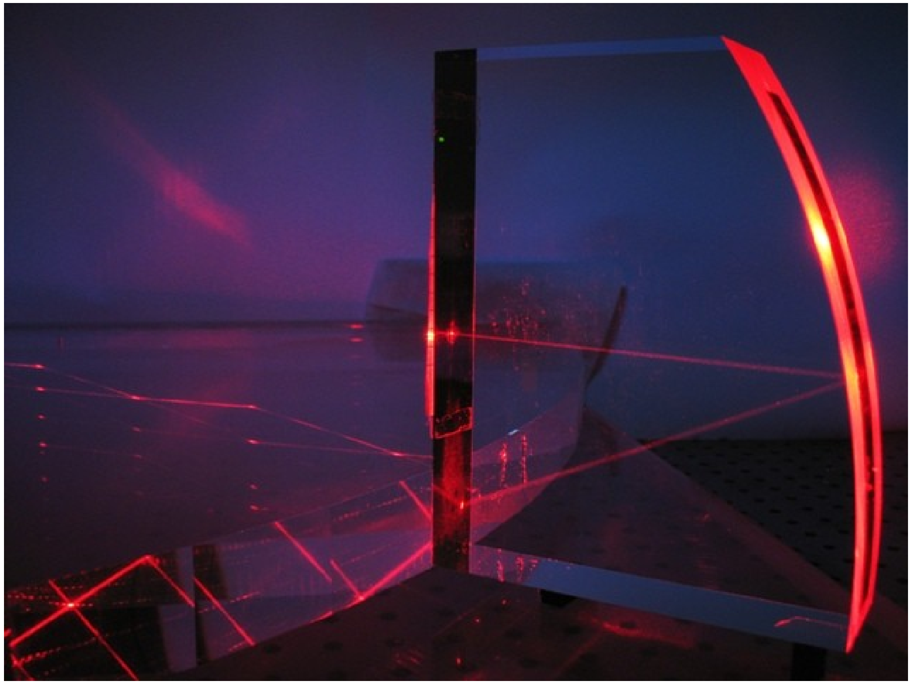


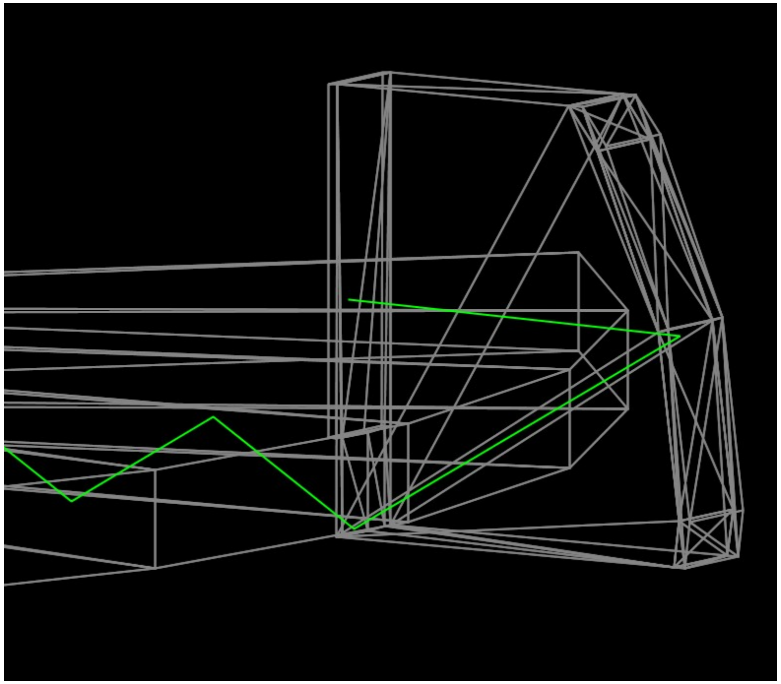




Performance Studies

- Geant4 model ready

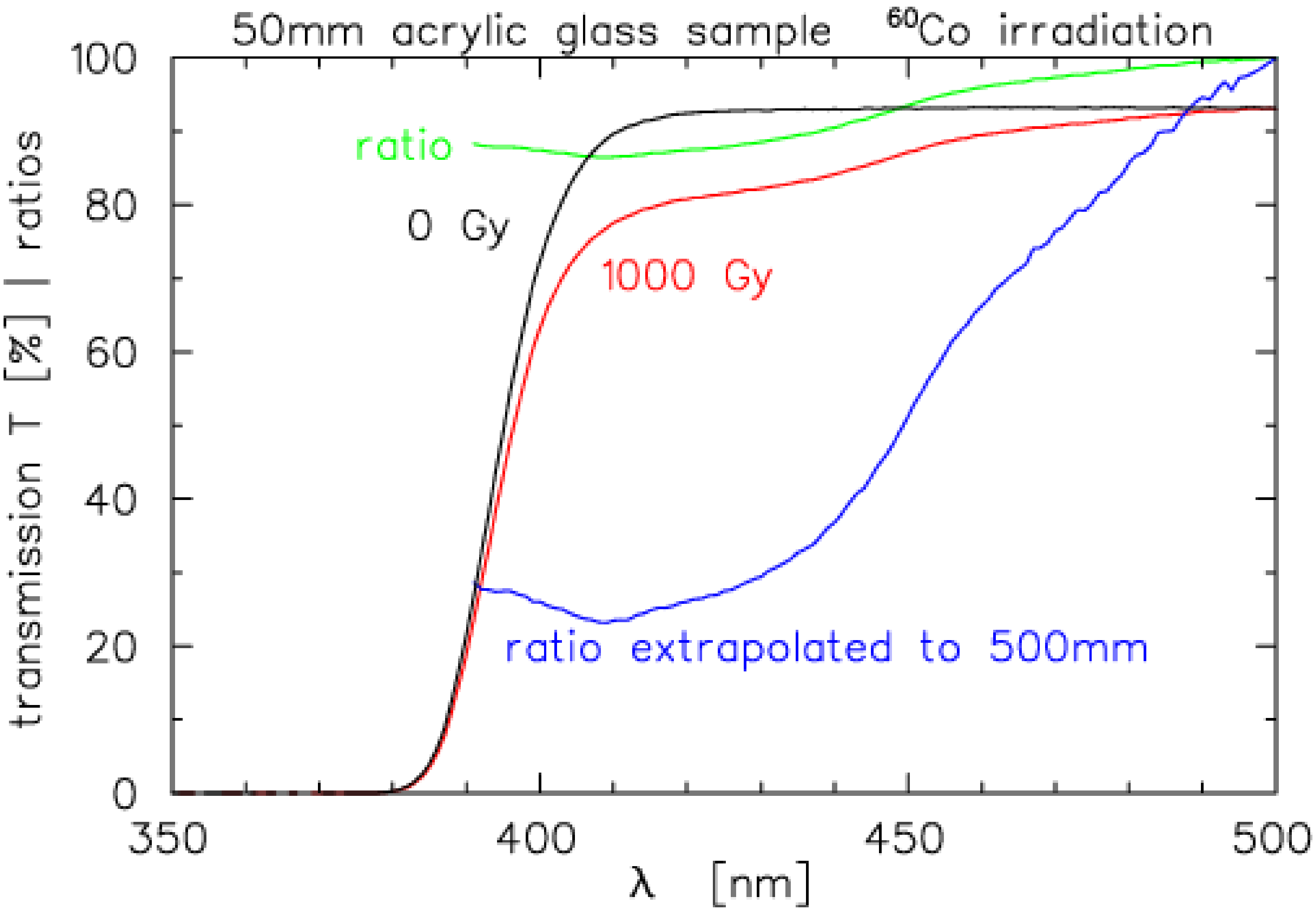




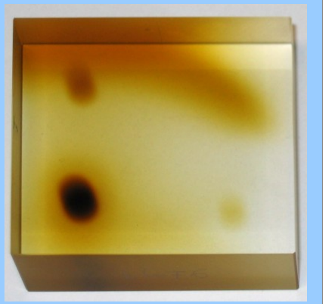
Optical table in Giessen (K.Föhl)

Geant4 visualization

Plexiglas Radiation Hardness



motivation:

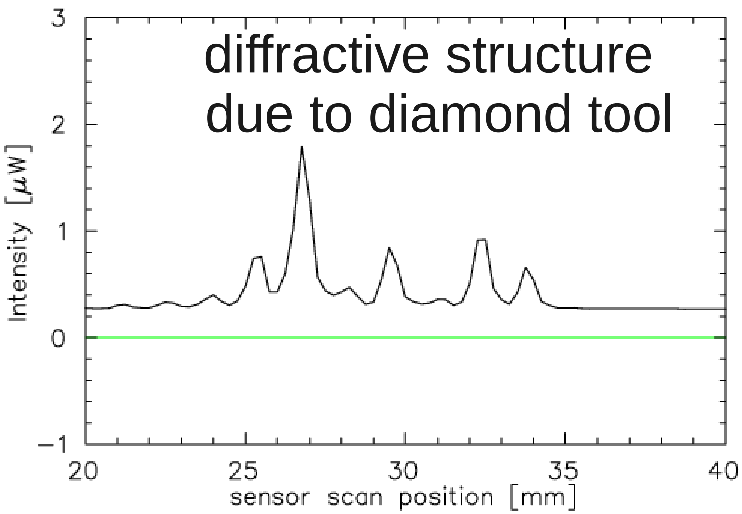


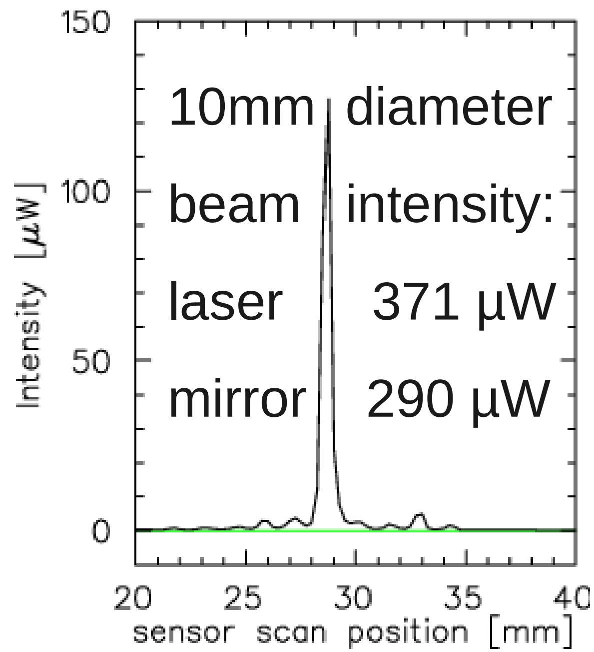
irradiated lead glass sample

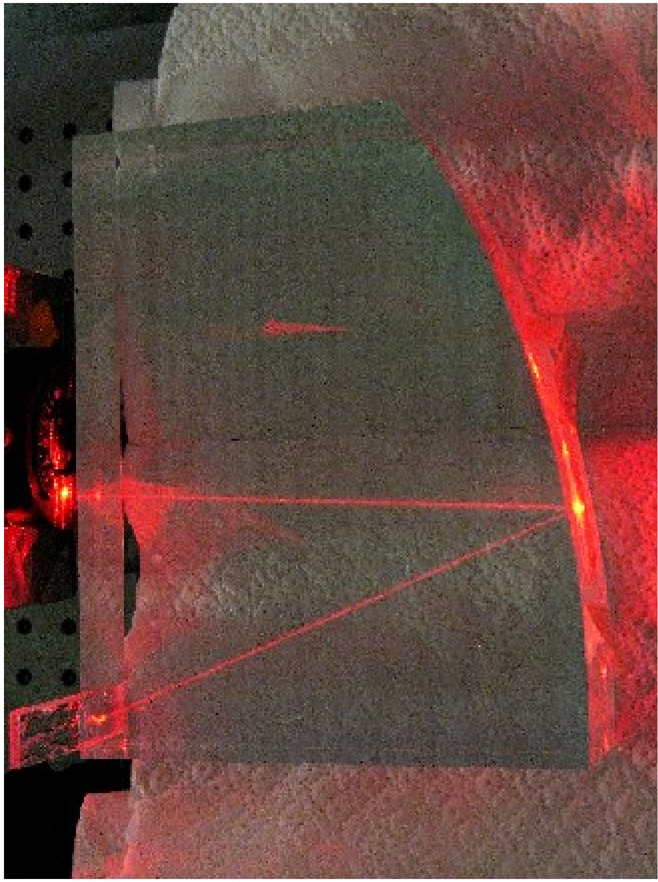
- LLF6,
- p 200MeV

Nils Stöckmann

Light Guides and VM2000 foil

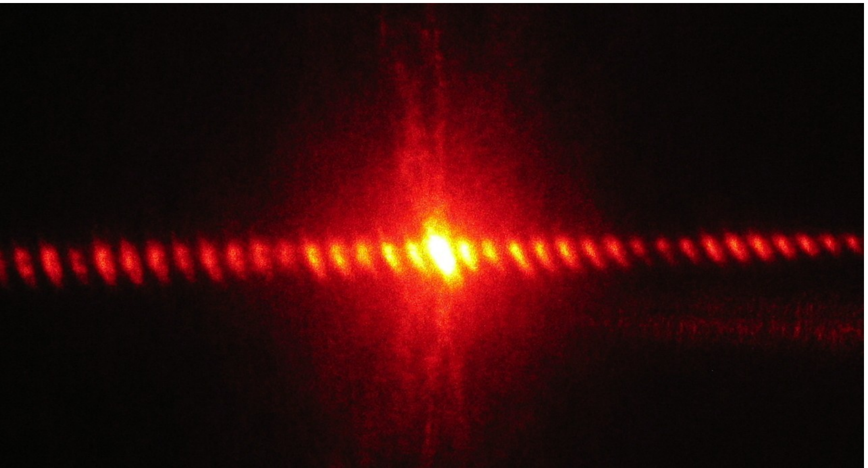


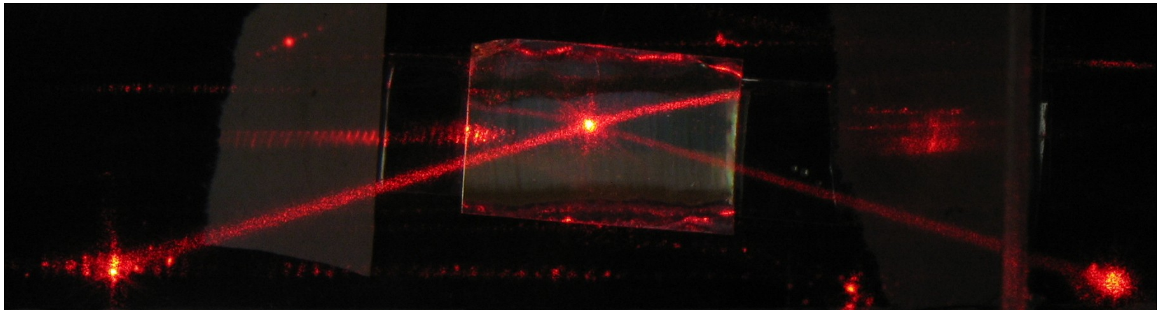




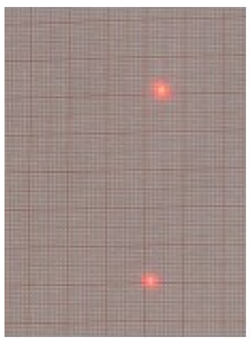
- VM2000 foil

Marko Zühlsdorf, KF

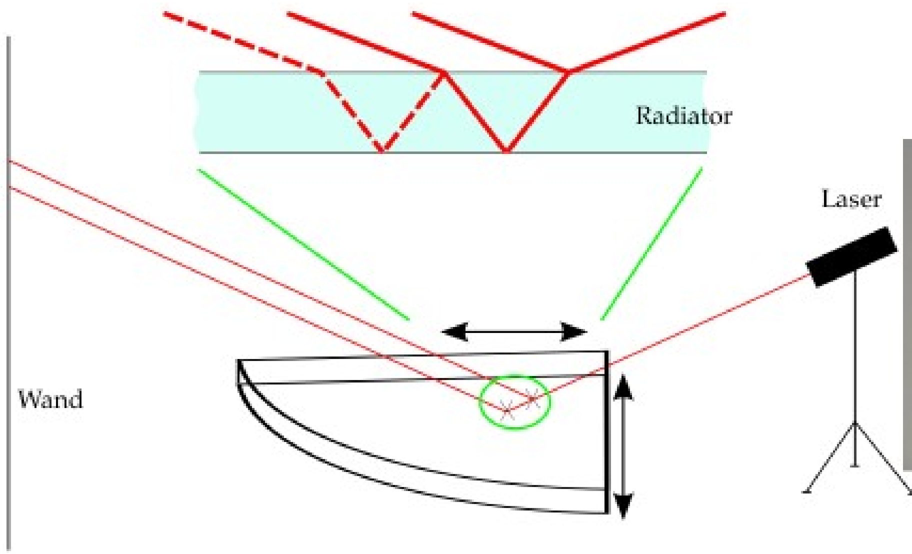




Radiator thickness mapping

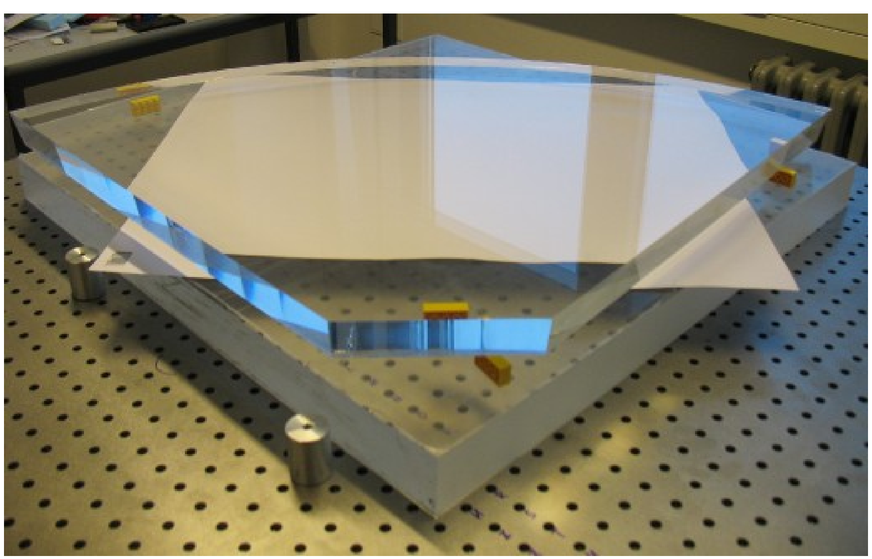


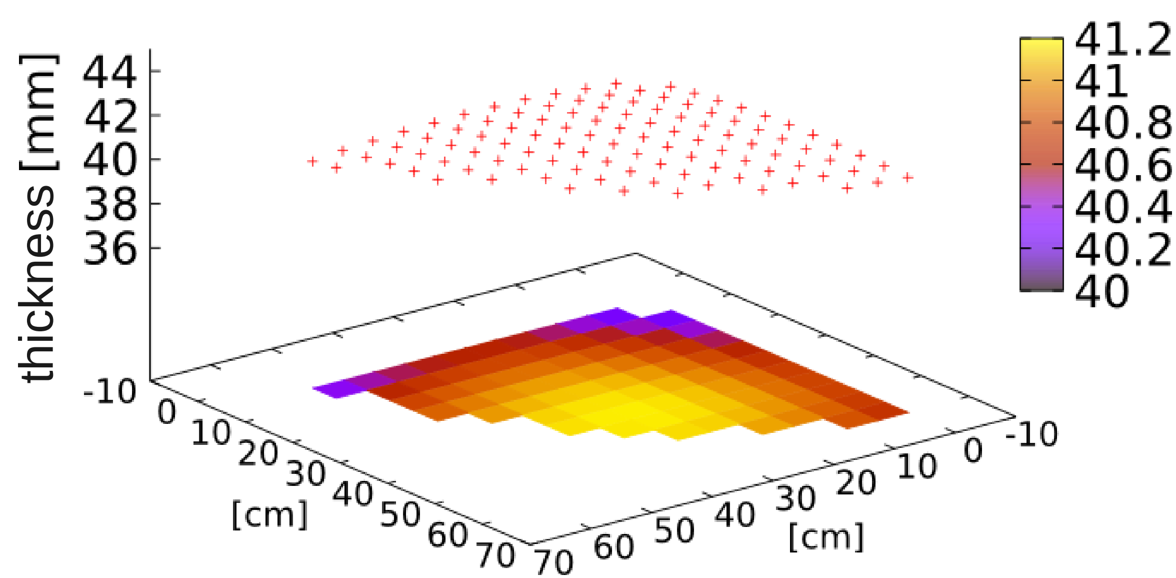
screen



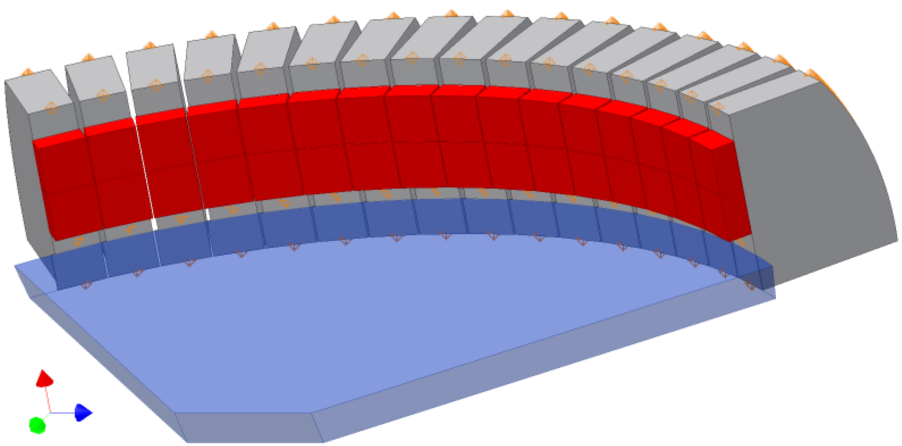
laser stand

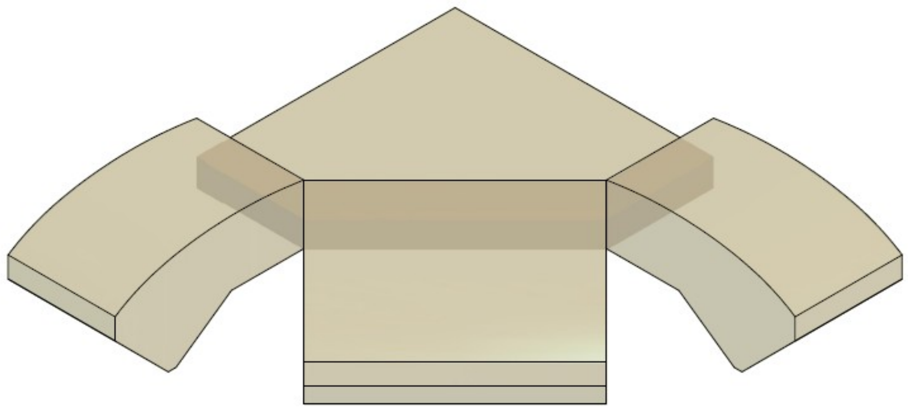
Marko Zühlsdorf & KF





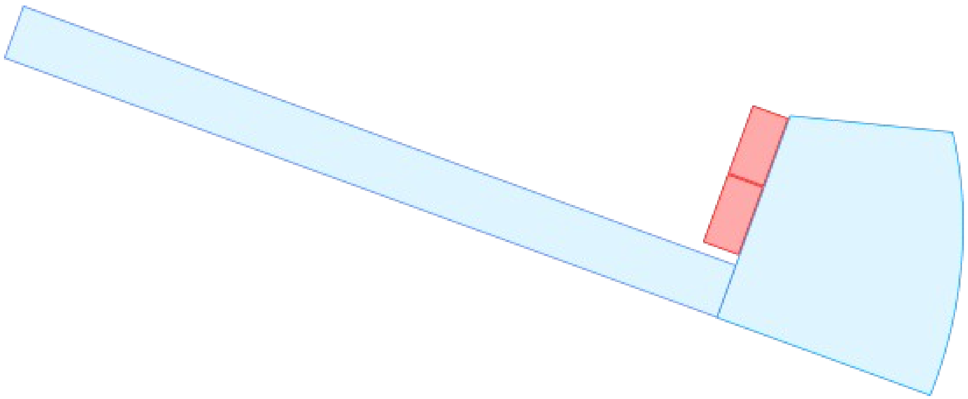
Constructing Prototypes

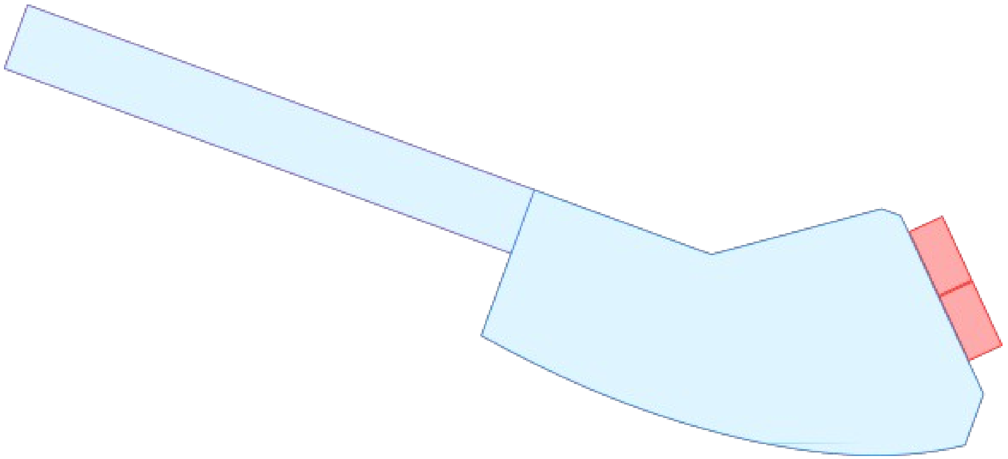




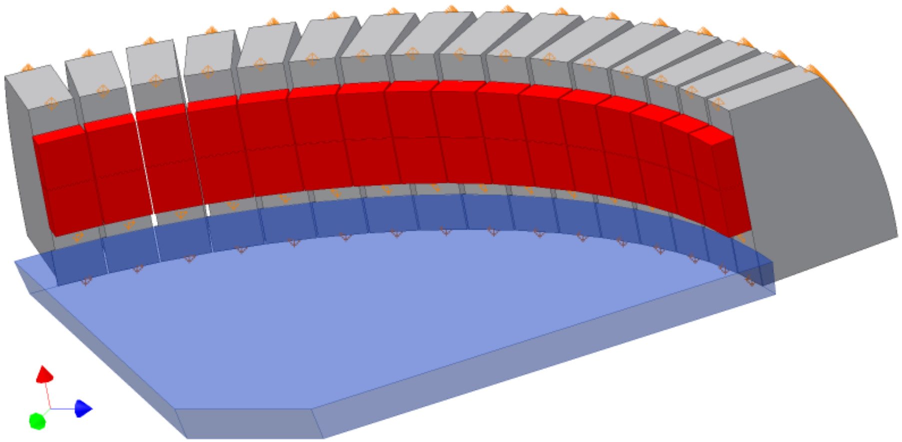
Tübingen prototype

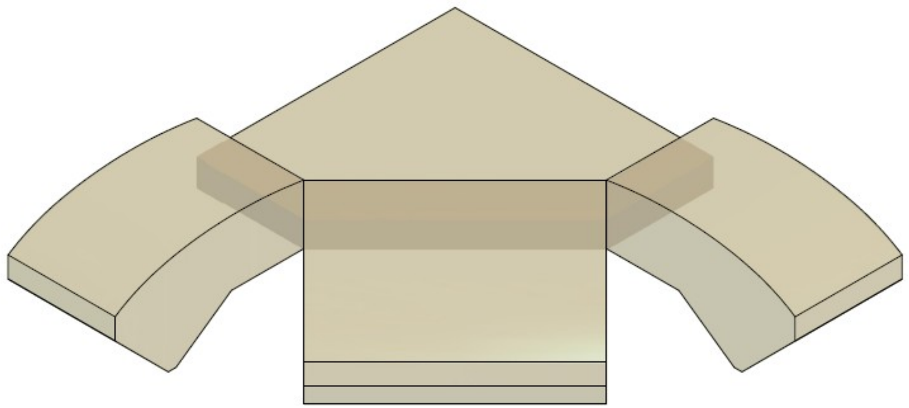
Erlangen prototype

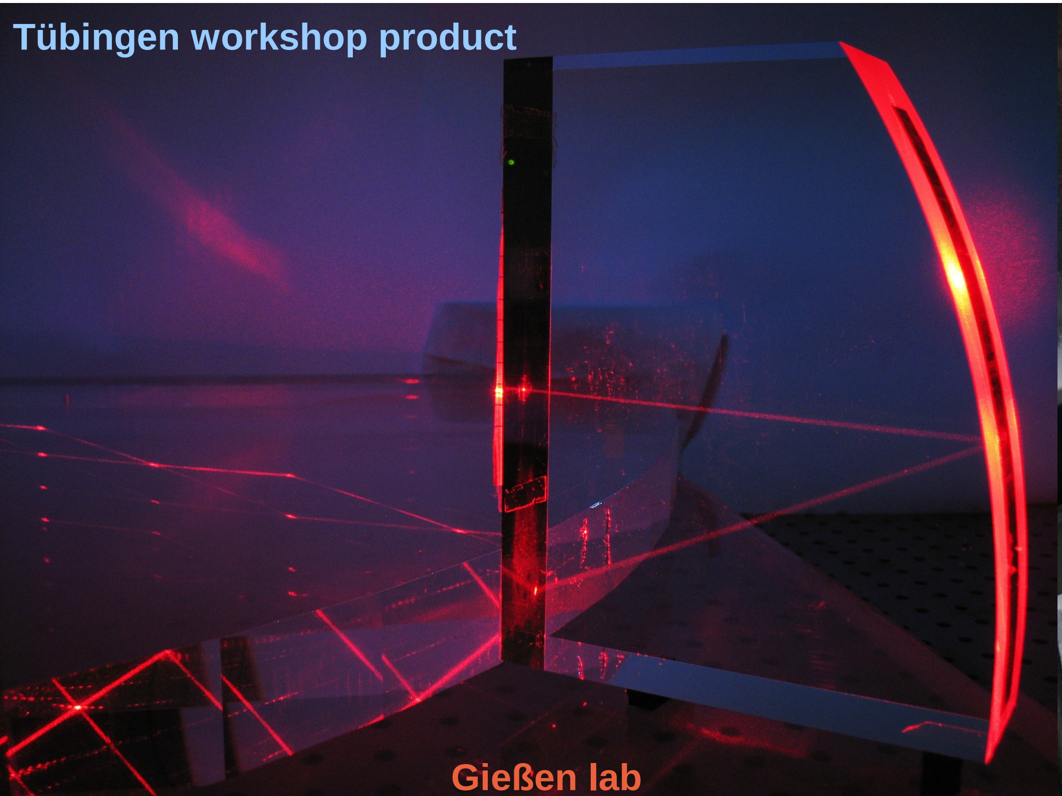




Constructing Prototypes

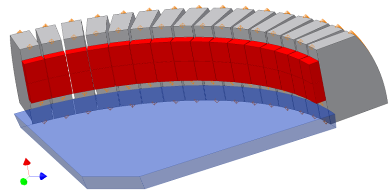






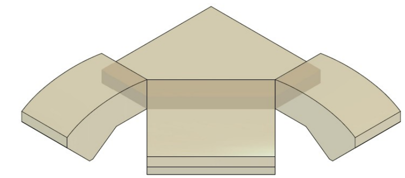
Prototype Comparison

- Tübingen:



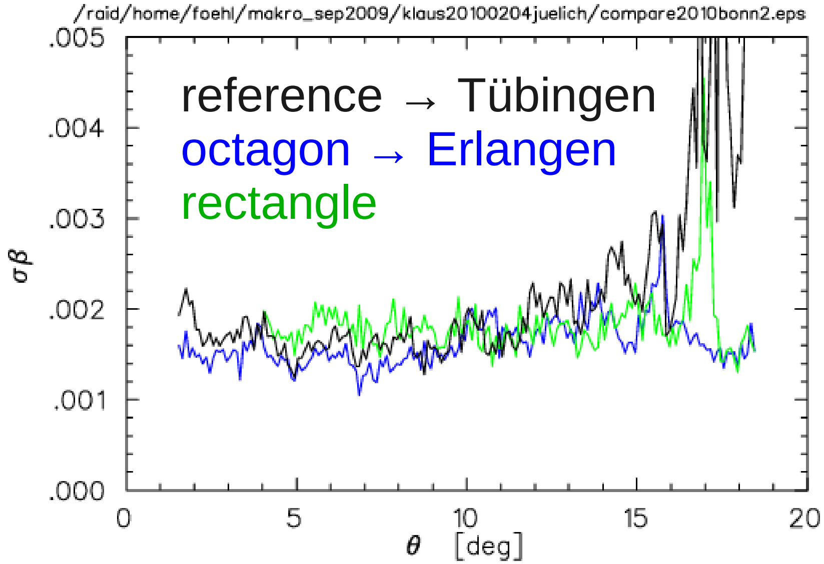
- r=650mm, d=40mm
- theta=15-50 degrees
- FLG „Erlangen/Siudak++“
  - 16x 50mm
  - VM2000 mirror coating
  - 2 mrad optical (sigma)
  - 11 mrad pixel equiv.
- 282mm width needed

- Erlangen:

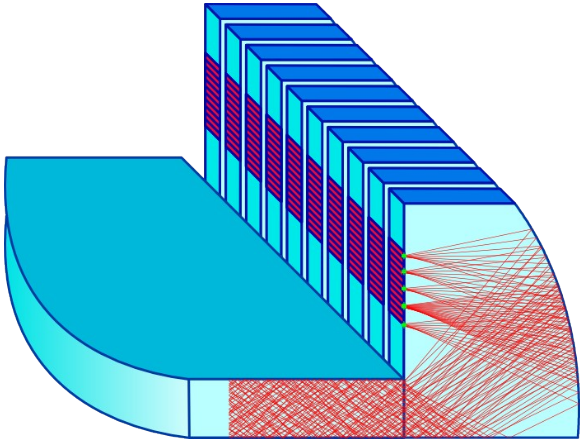


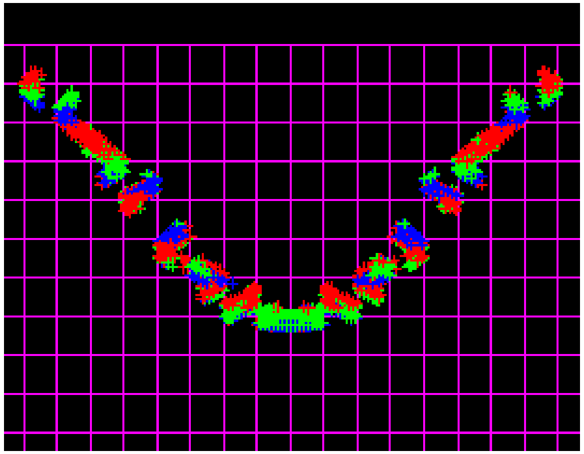
- r=500mm, d=50mm
- theta=25-50 degrees
- FLG „Edinburgh“
  - 2x200mm, 1x400mm
  - total internal reflection
  - 7 mrad optical (sigma)
  - 8 mrad pixel equiv.
- 333mm width needed

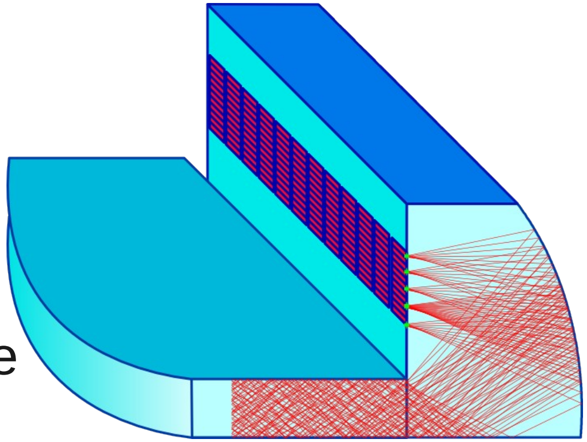
Design Comparisons

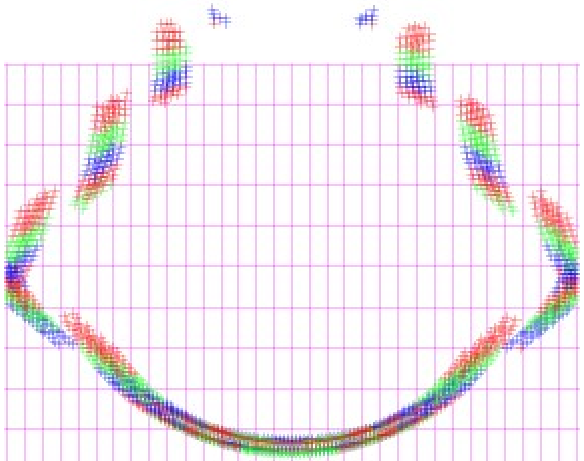


T(proton)=600MeV









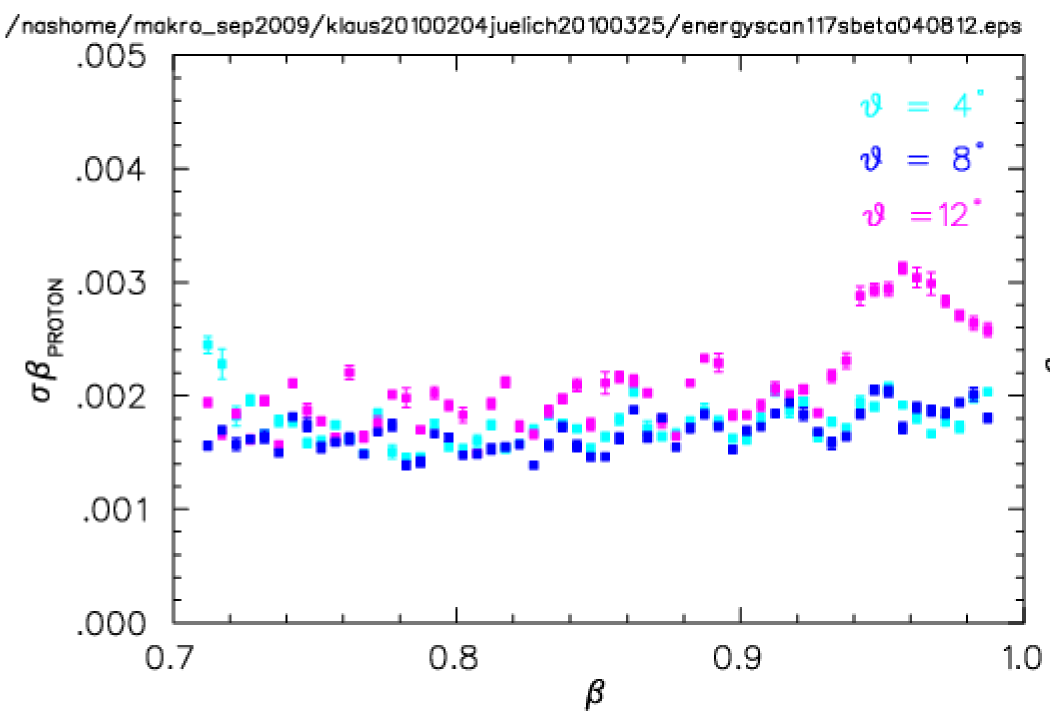
- comparing several
  - plate geometries (quarter, half)
  - rim shapes (circle, octagon)
  - light guides (individual, block)
- small performance differences
- some shapes need analysis fudge

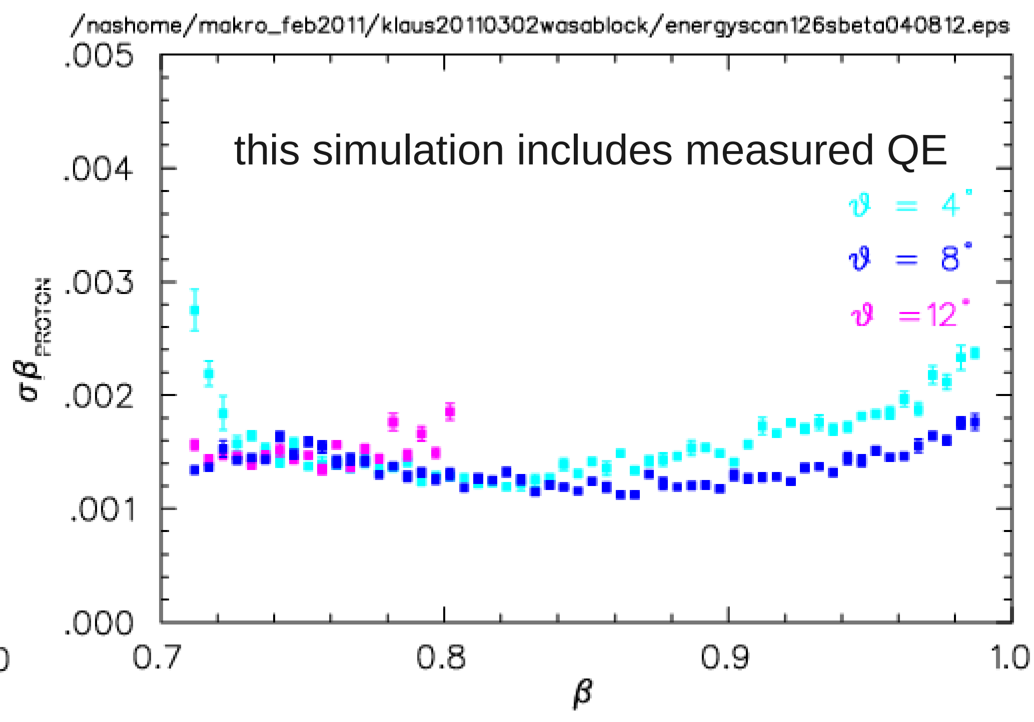
somewhat better performance, but analysis difficulty

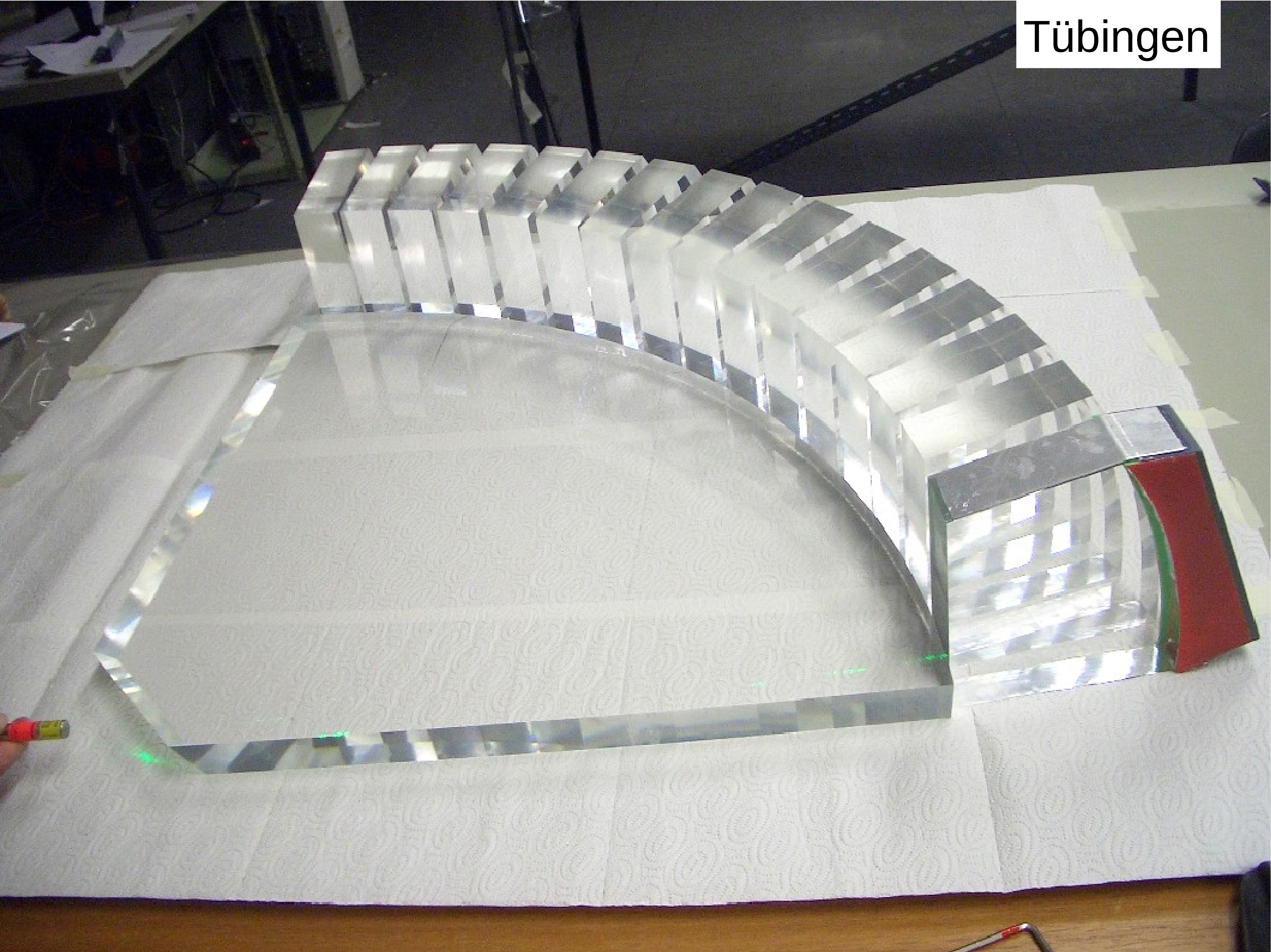
Performance Comparison

- Tübingen:
- wider beta range
- full 3-17 deg theta

- Erlangen:
- better phi resolution
- sensors further outside
- pattern more complex






Tübingen

DIRC-at-WASA Scheduling

- Phase I
  - quarter plate
  - cupboard electronics 512 ch for 8 PMTs
- Phase II
  - quarter plate, full 32x H8500
  - custom electronics
- Phase III
  - four quarter plates

test beam experiments → Phase I

qualify DIRC for WASA → Phase II

DIRC-at-WASA in WASA@COSY → Phase III

Conclusions

- Cherenkov detector suggested
  - improve WASA energy resolution
  - proof-of-concept for the PANDA Endcap PID
- CEARA detector concept presented
- resolution circa $\sigma\beta$=0.002 in simulations
- prototype construction under way
    - see talks Adrian und Eugene
- *I am eager to see this detector in real*

Thank you to PANDA and COSY folks for information and discussion.