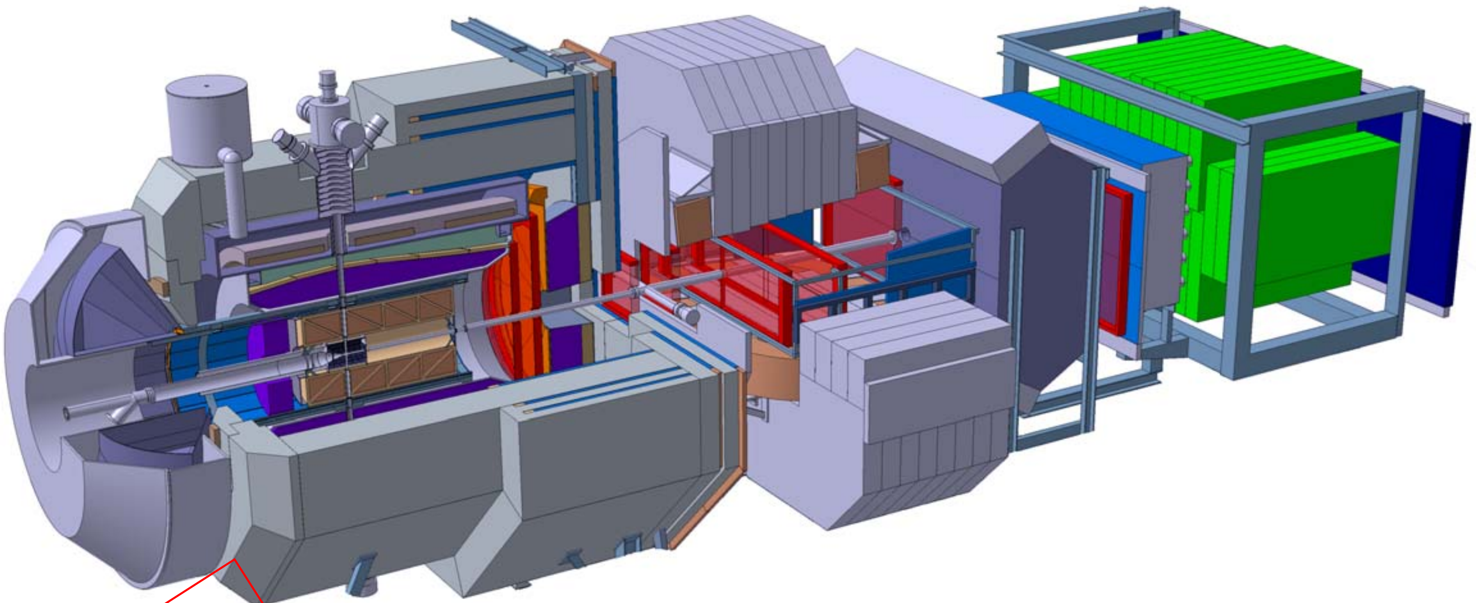
The DIRC projects of the PANDA experiment at FAIR



rough-egdes version
(isn't it great to have
had a fire-alarm today)

Klaus Föhl on behalf of PANDA Cherenkov Group

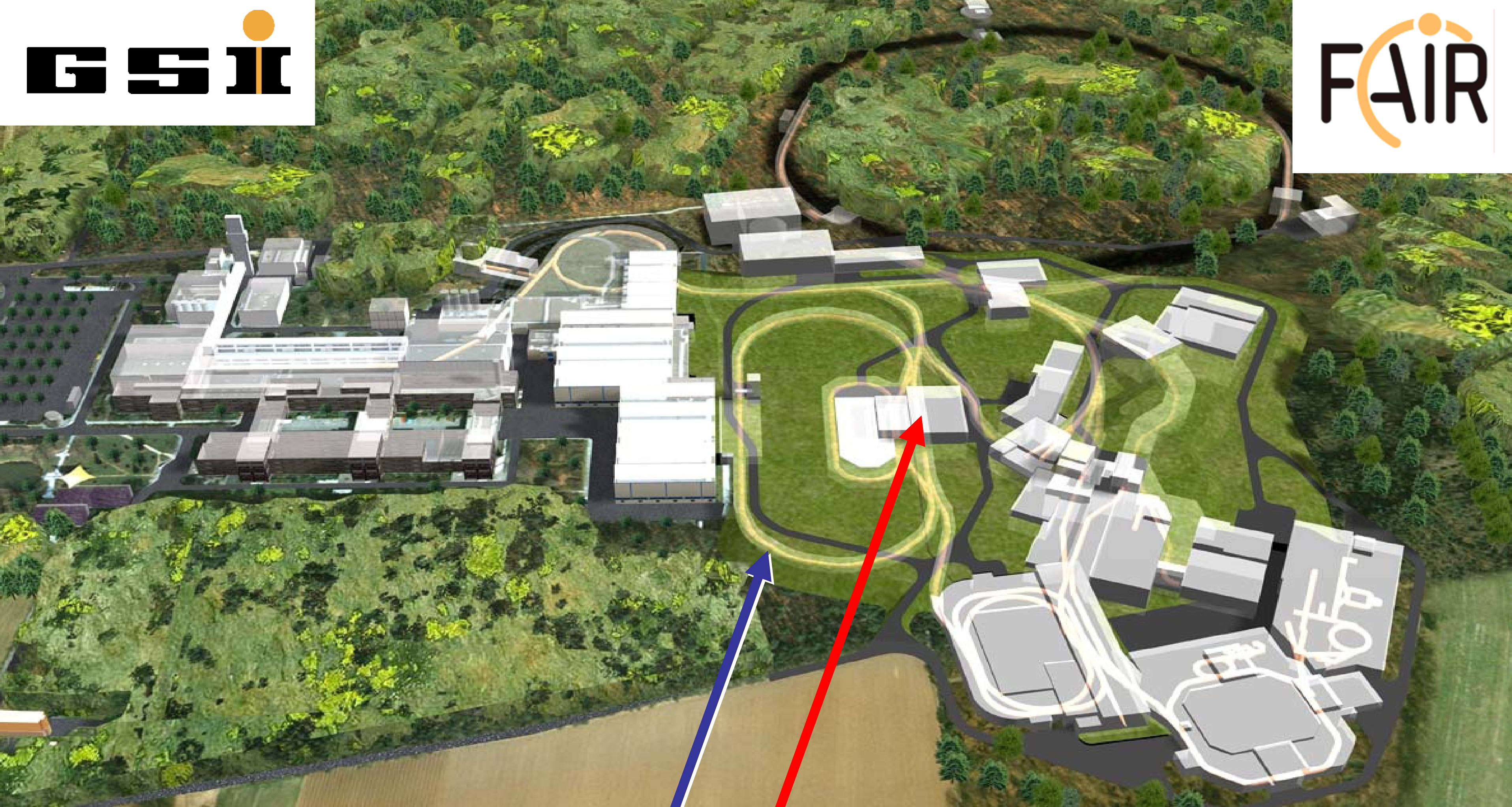
RICH2007 Trieste

18 October 2007

Gliederung

- quick FAIR & PANDA overview
- DIRC detectors
  - Barrel
  - Disc Focussing
  - Disc Time-of-Propagation
- Challenges
- Summary

- **Gesellschaft für Schwerionenforschung** in Darmstadt, Germany
- German National Lab for Heavy Ion Research
- Highlights:
  - Heavy ion physics (i.e. superheavies)
  - Nuclear physics
  - Atomic and plasma physics
  - Cancer research



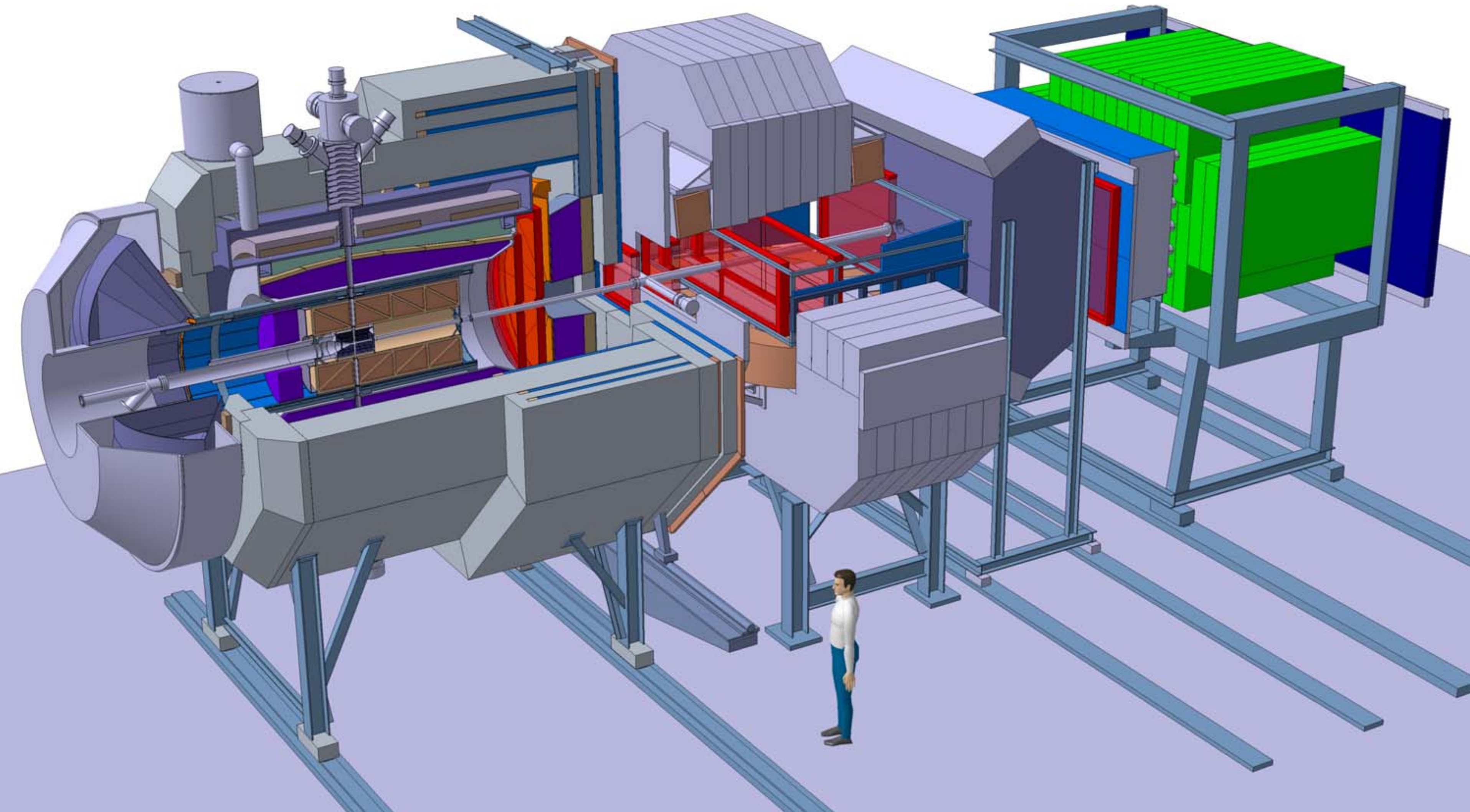
HESR

Rare-Isotope Beams
N-N Collisions at High Energy
Ion Beam Induced Plasmas
Antiprotons panda

Nuclei Far From Stability
Compressed Nuclear Matter
High Energy Density in Bulk
Hadron Spectroscopy

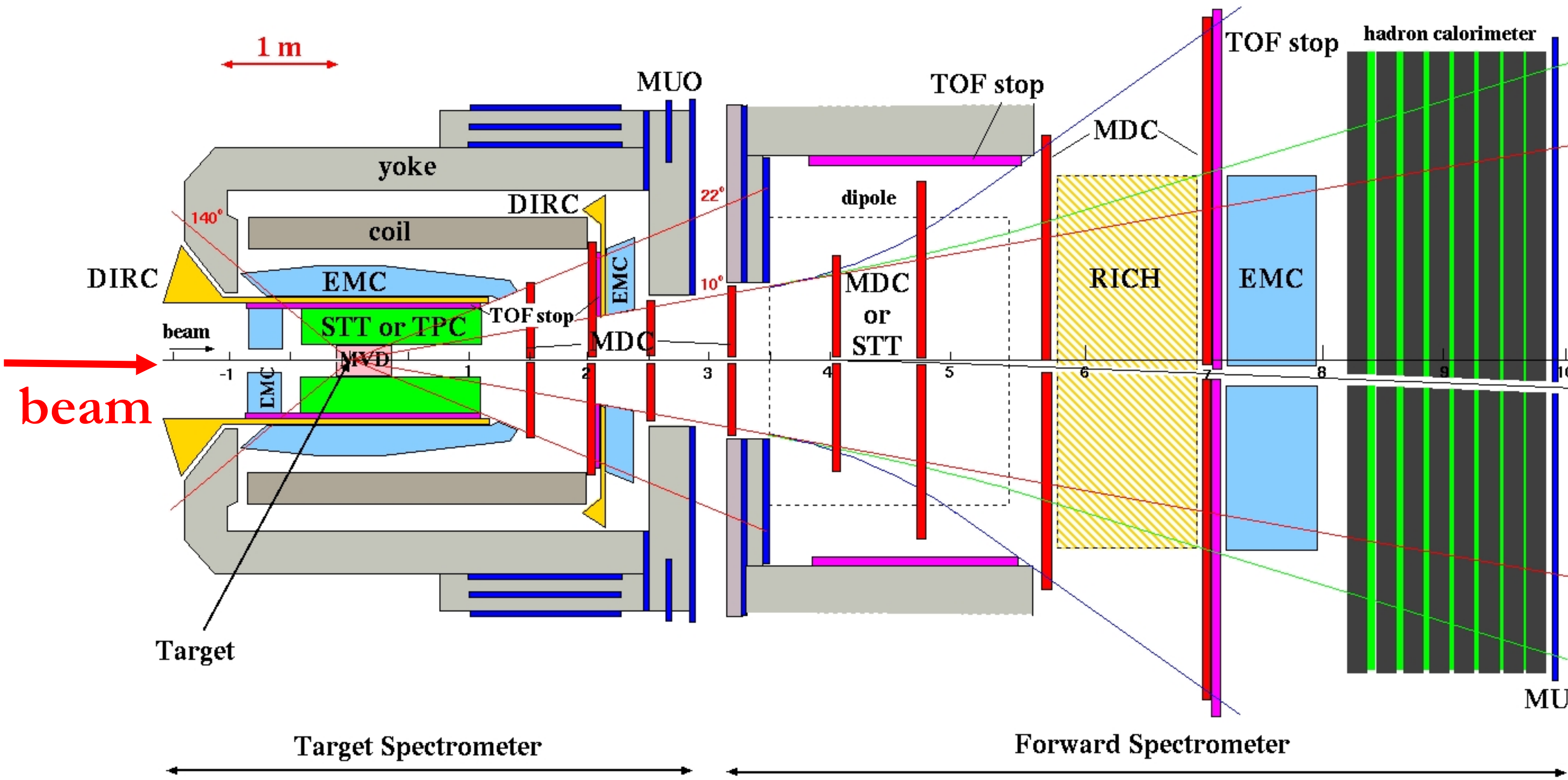
A View of PANDA

Pbar **AND A**   Anti**P**roton **AN**ihilations at **DA**rmstadt



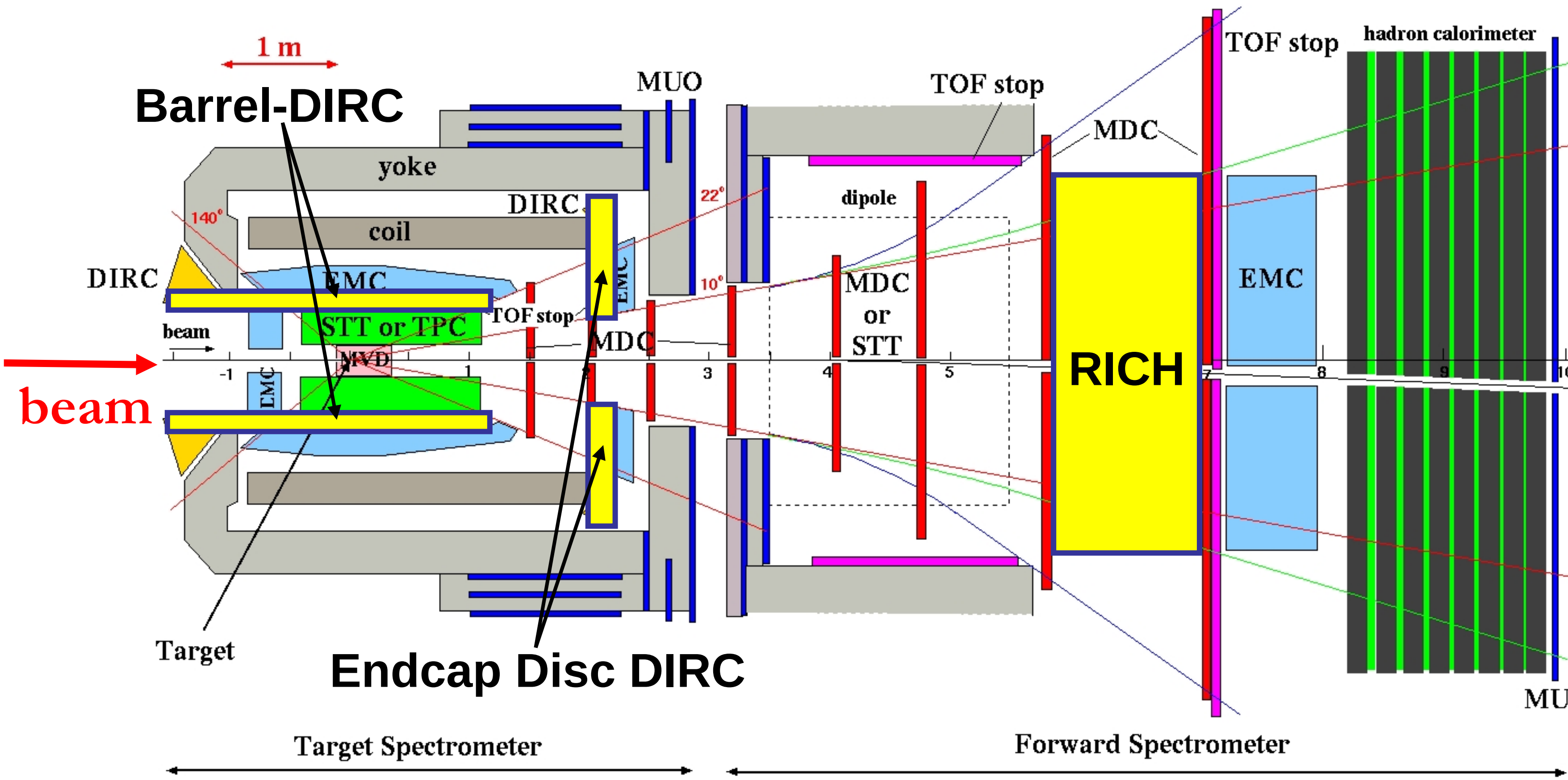
PANDA Detector

Top View



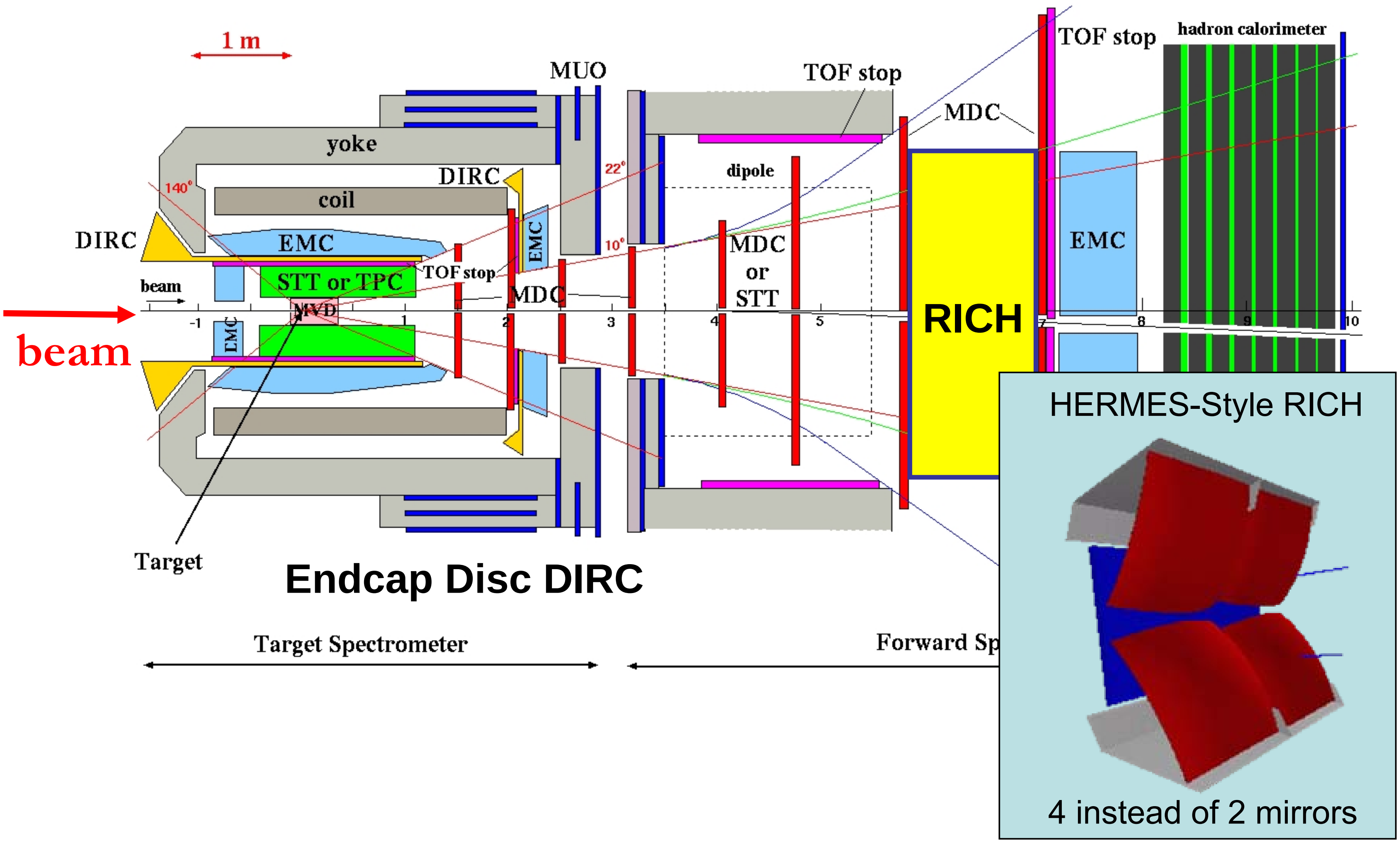
PANDA Detector

Top View



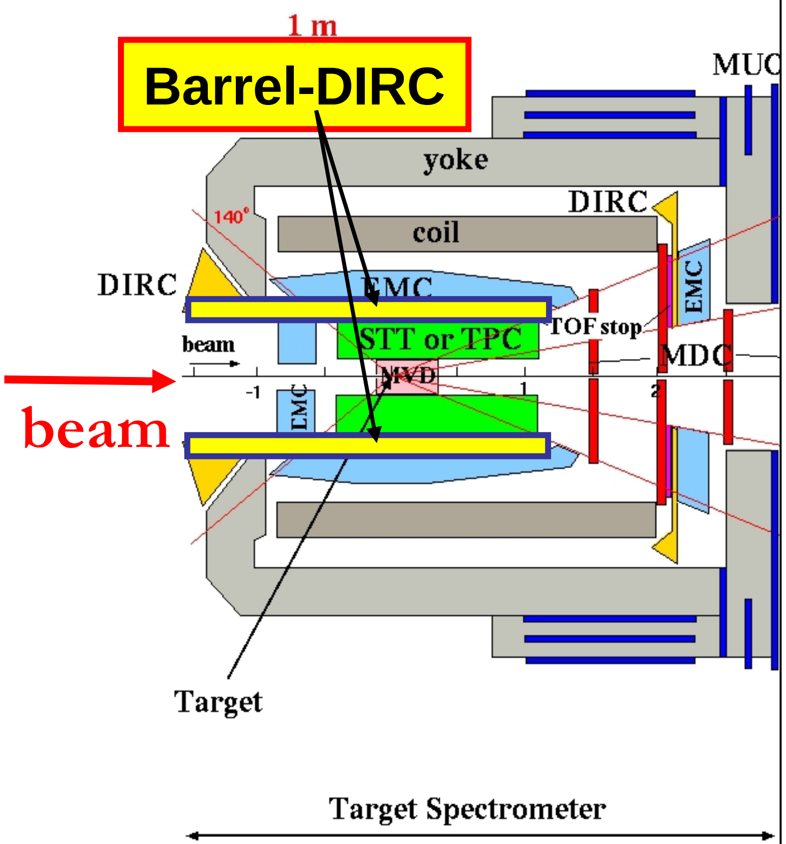
PANDA Detector

Top View

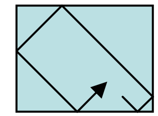


PANDA Detector

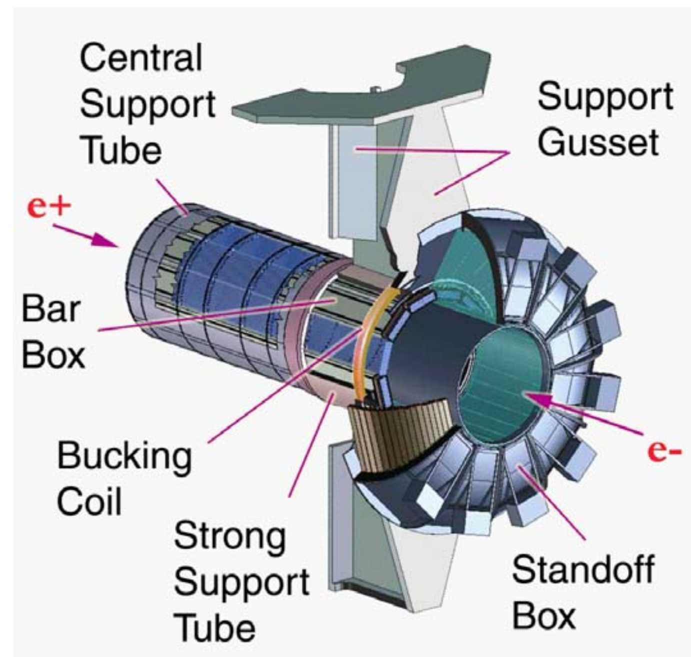
Top View



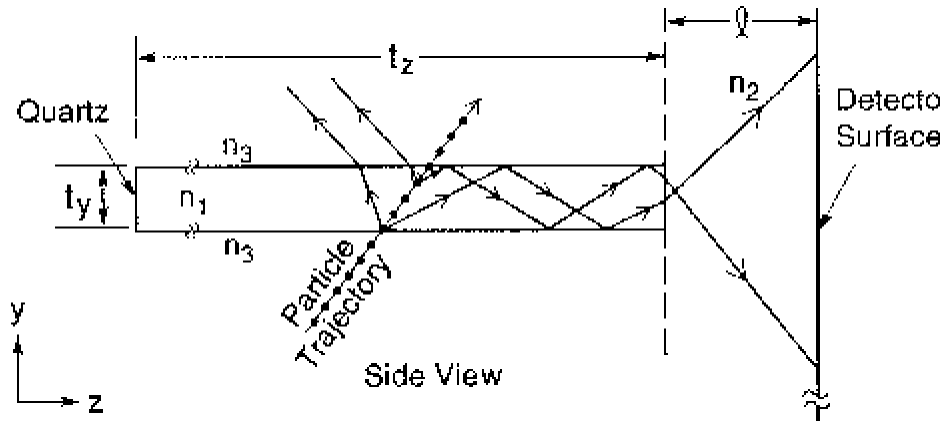
2-dimensional imaging type



following the BaBar design



Barrel a la Babar

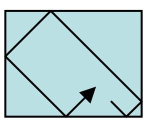


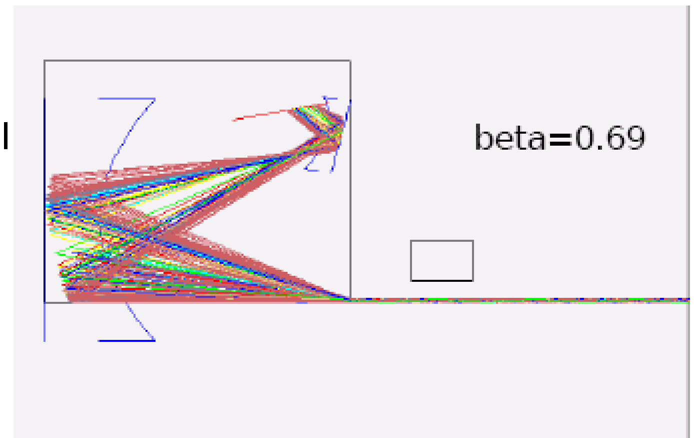
imaging by expansion volume, pinhole “focussing”

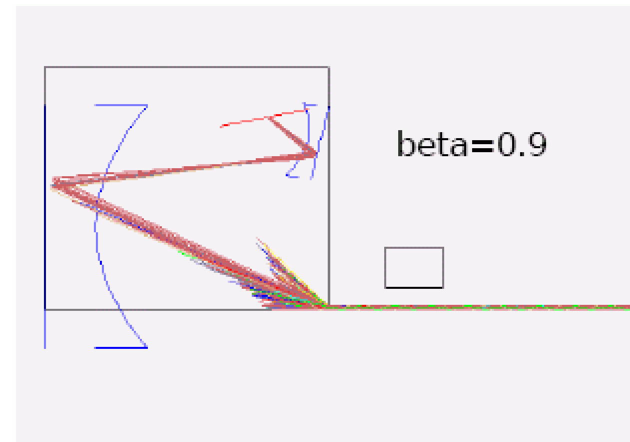
Barrel DIRC

C. Schwarz et al.

2-dimensional imaging type







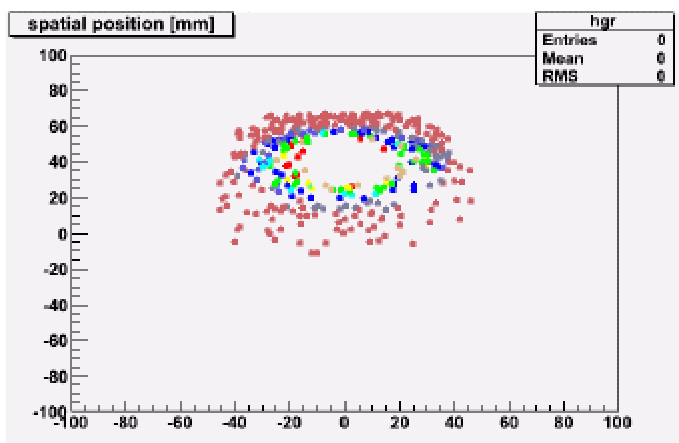
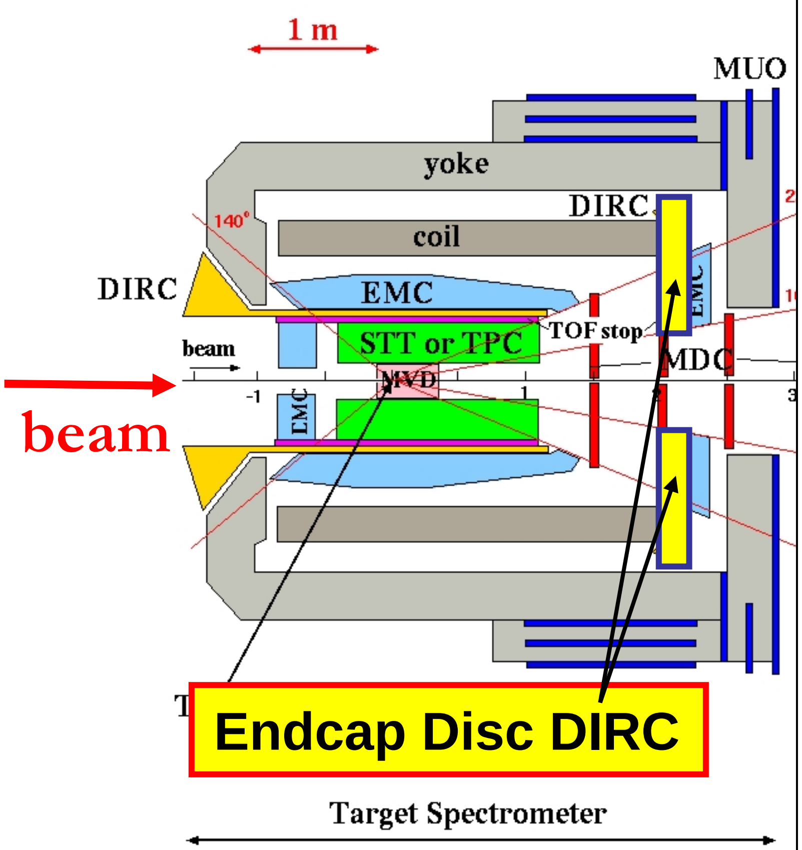


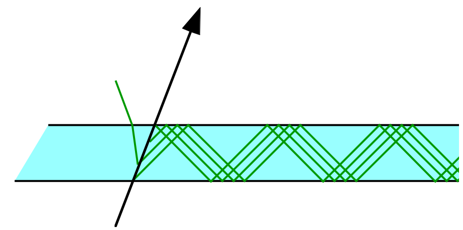
plate instead of bar?

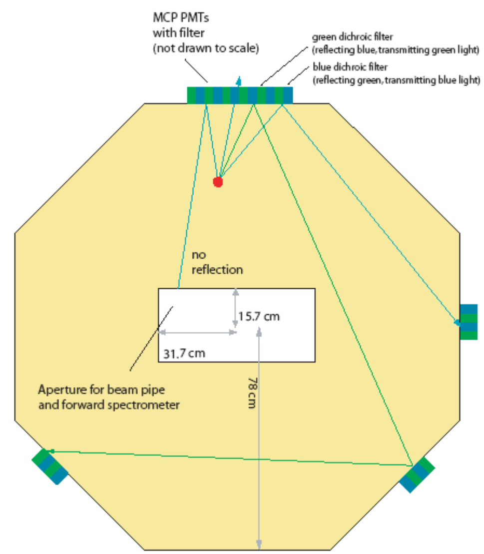
ongoing work for a more compact readout

PANDA Detector

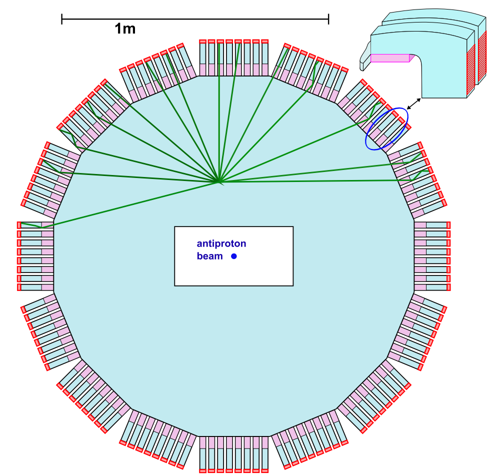
Top View







Time-of-Propagation

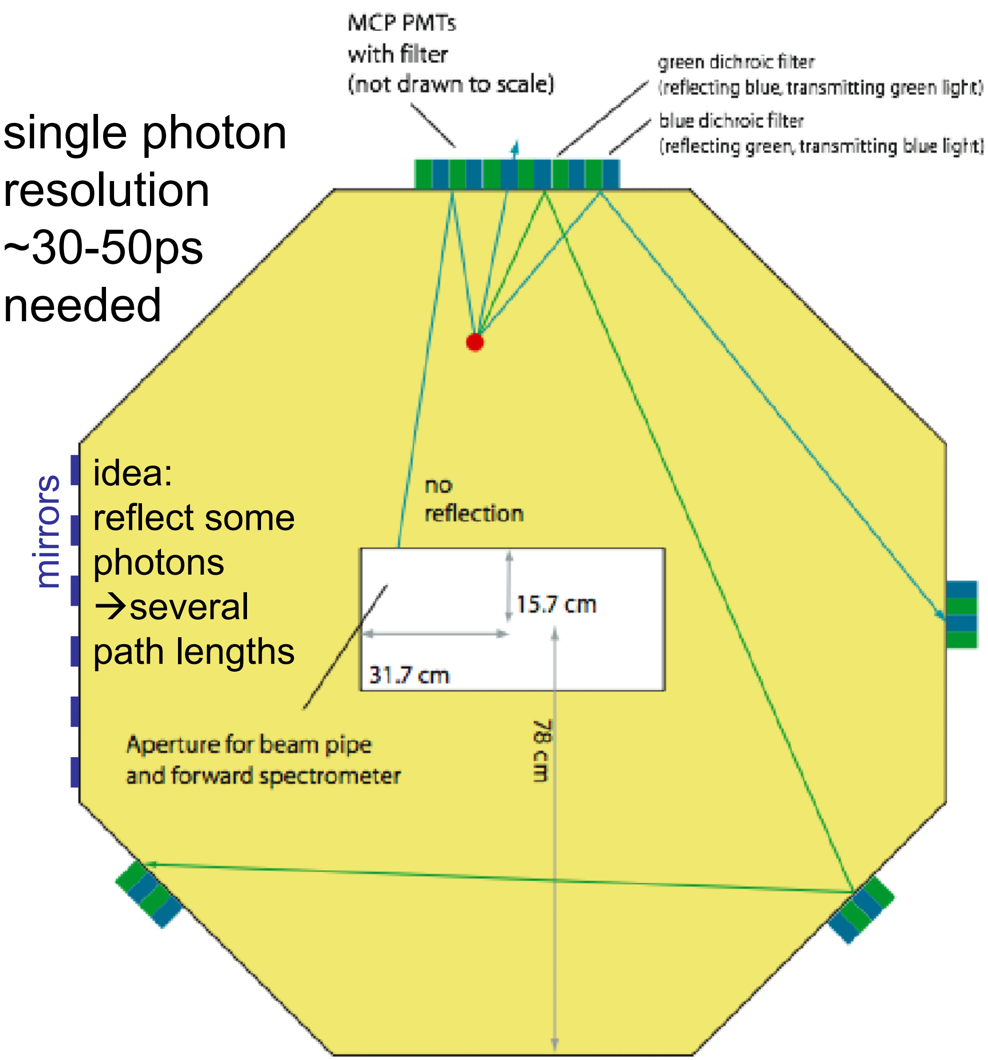


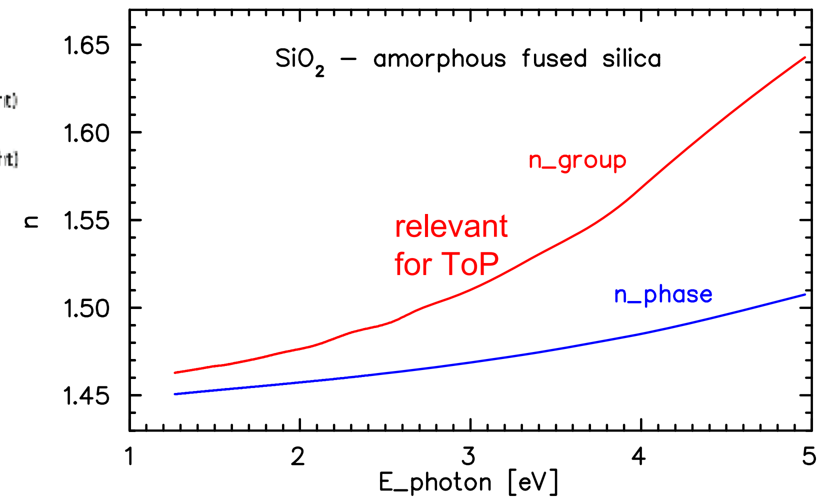
Focussing Lightguide

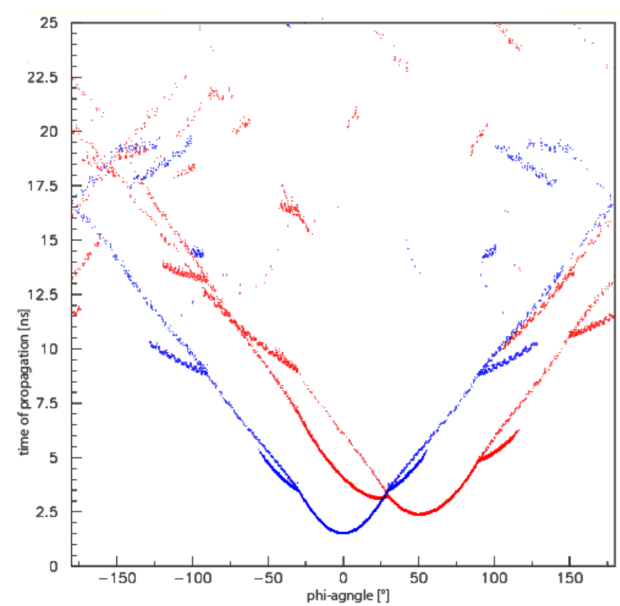
Time-of-Propagation design

M. Düren, M. Ehrenfried, S. Lu, R. Schmidt, P. Schönmeier

single photon resolution ~30-50ps needed







Time-of-Propagation design

M. Düren, M. Ehrenfried, S. Lu, R. Schmidt, P. Schönmeier

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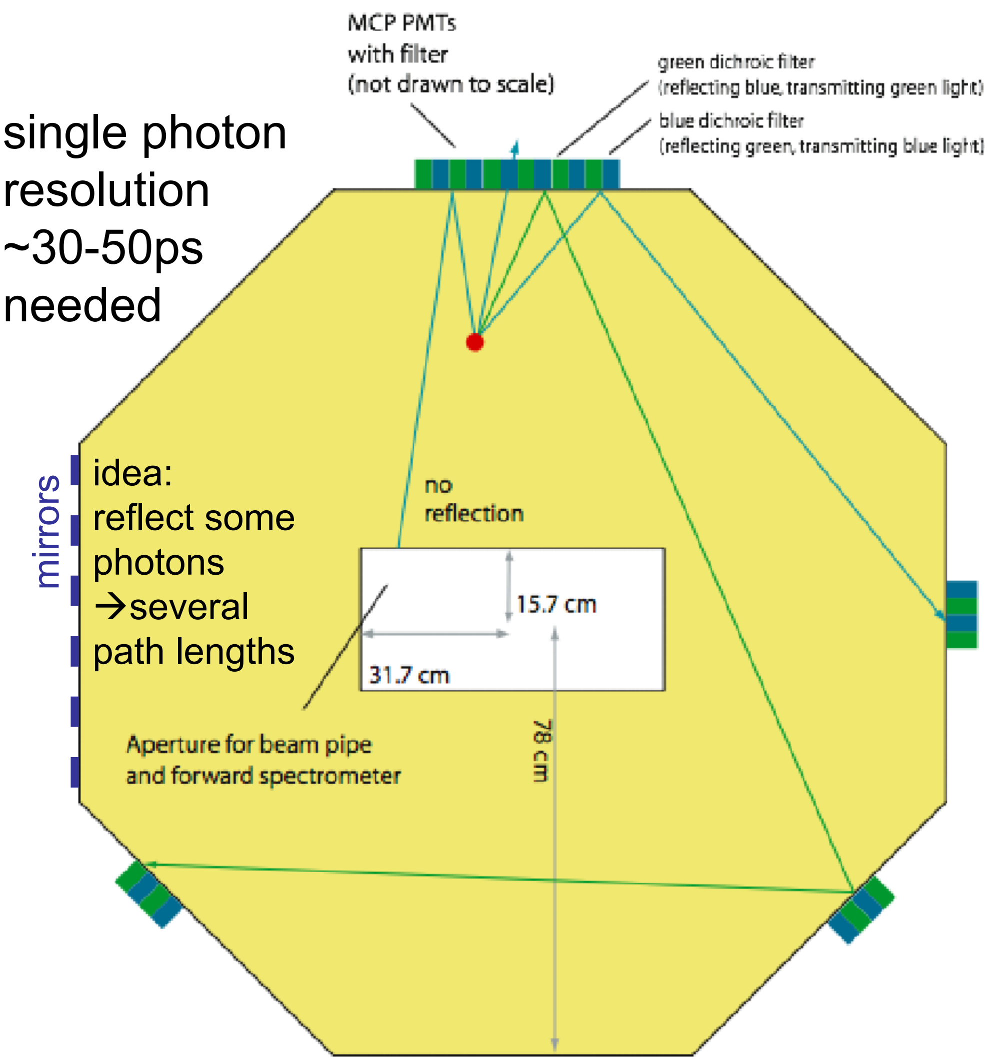
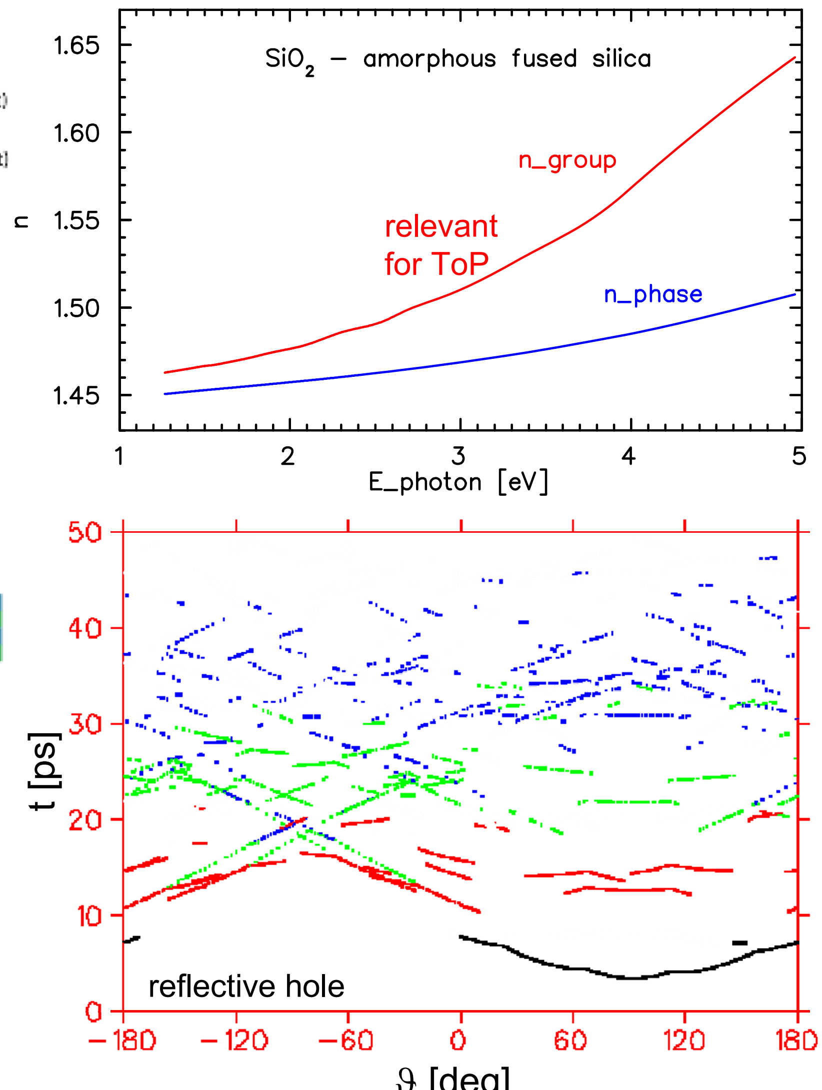
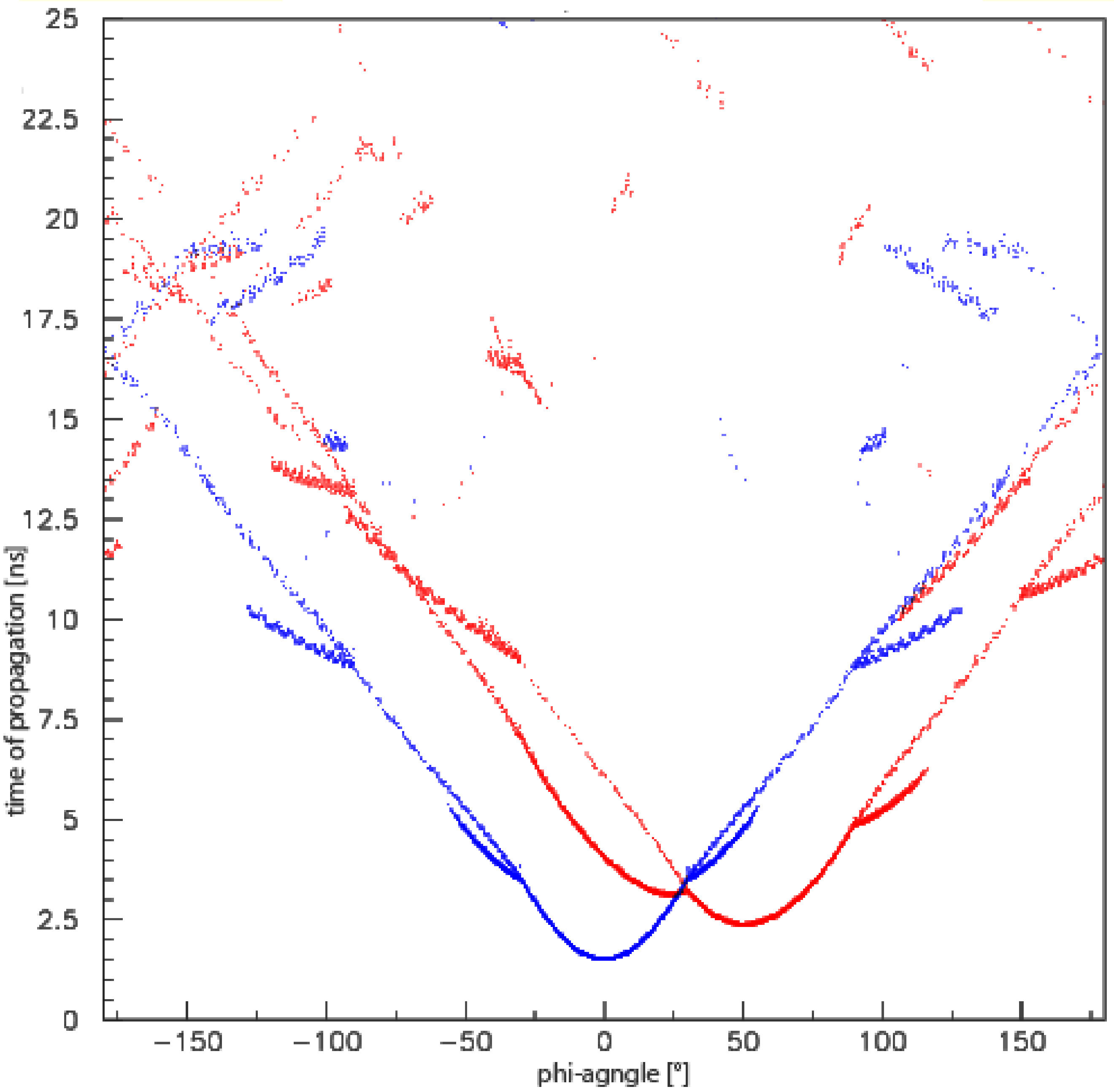
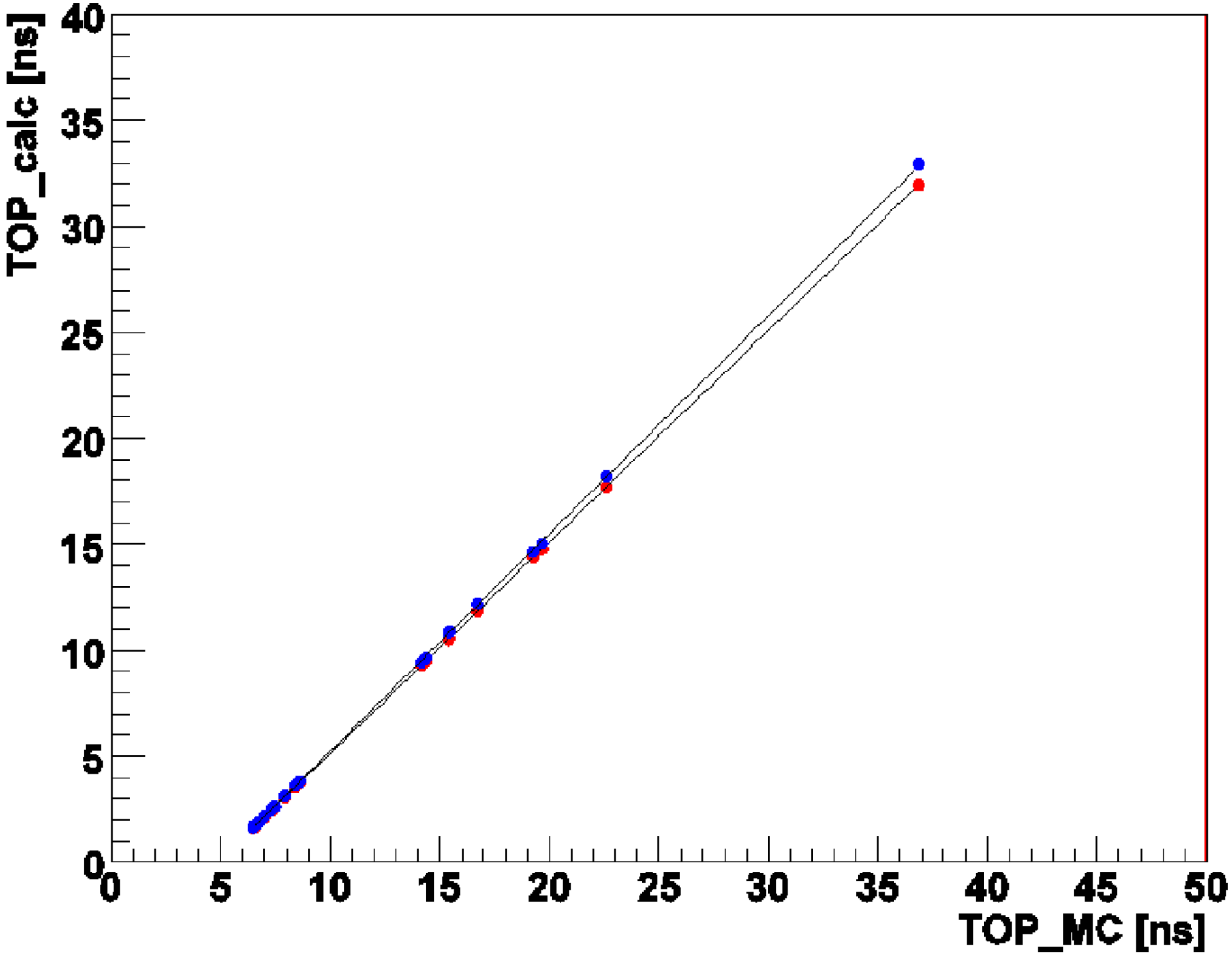


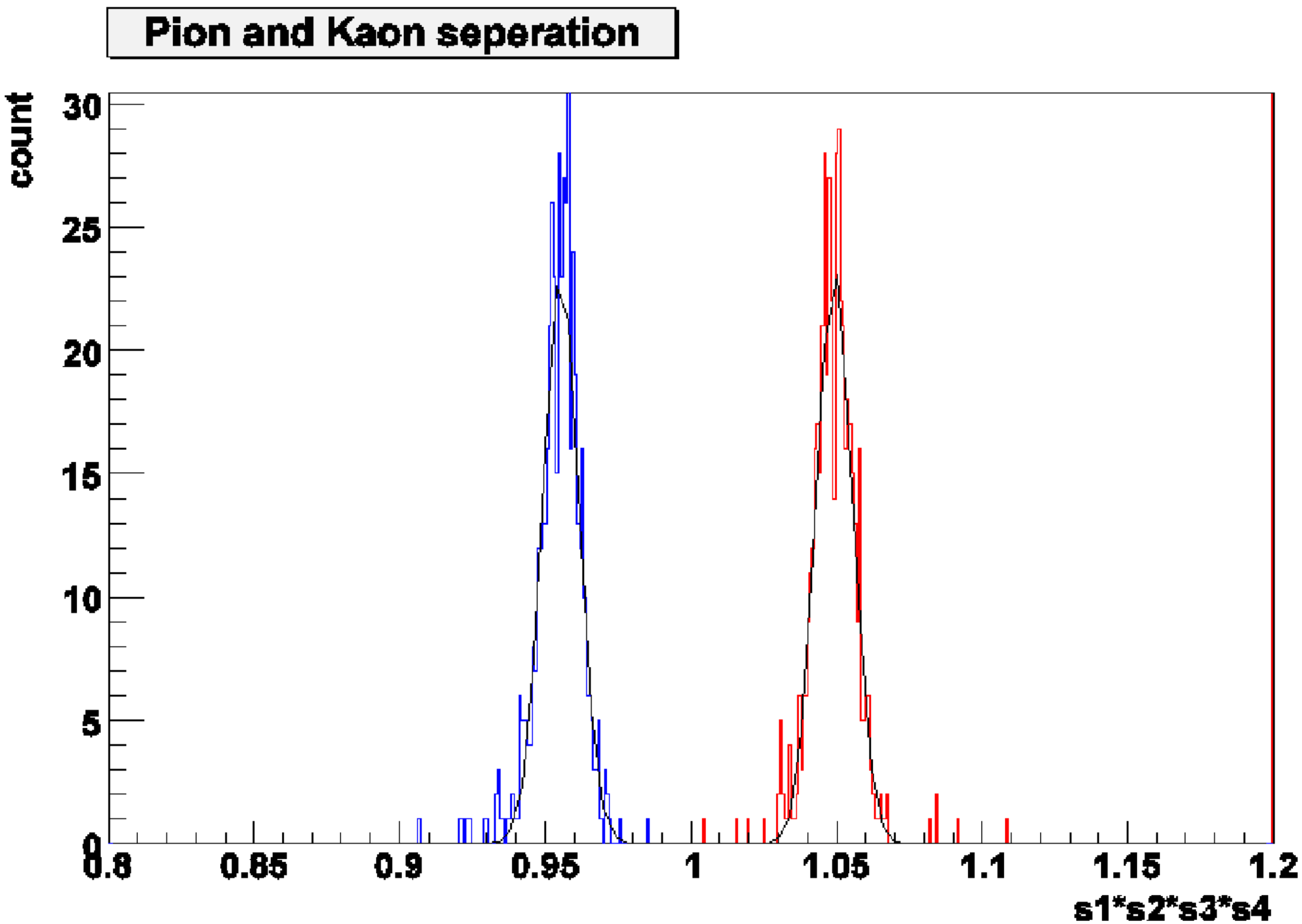


backup slide



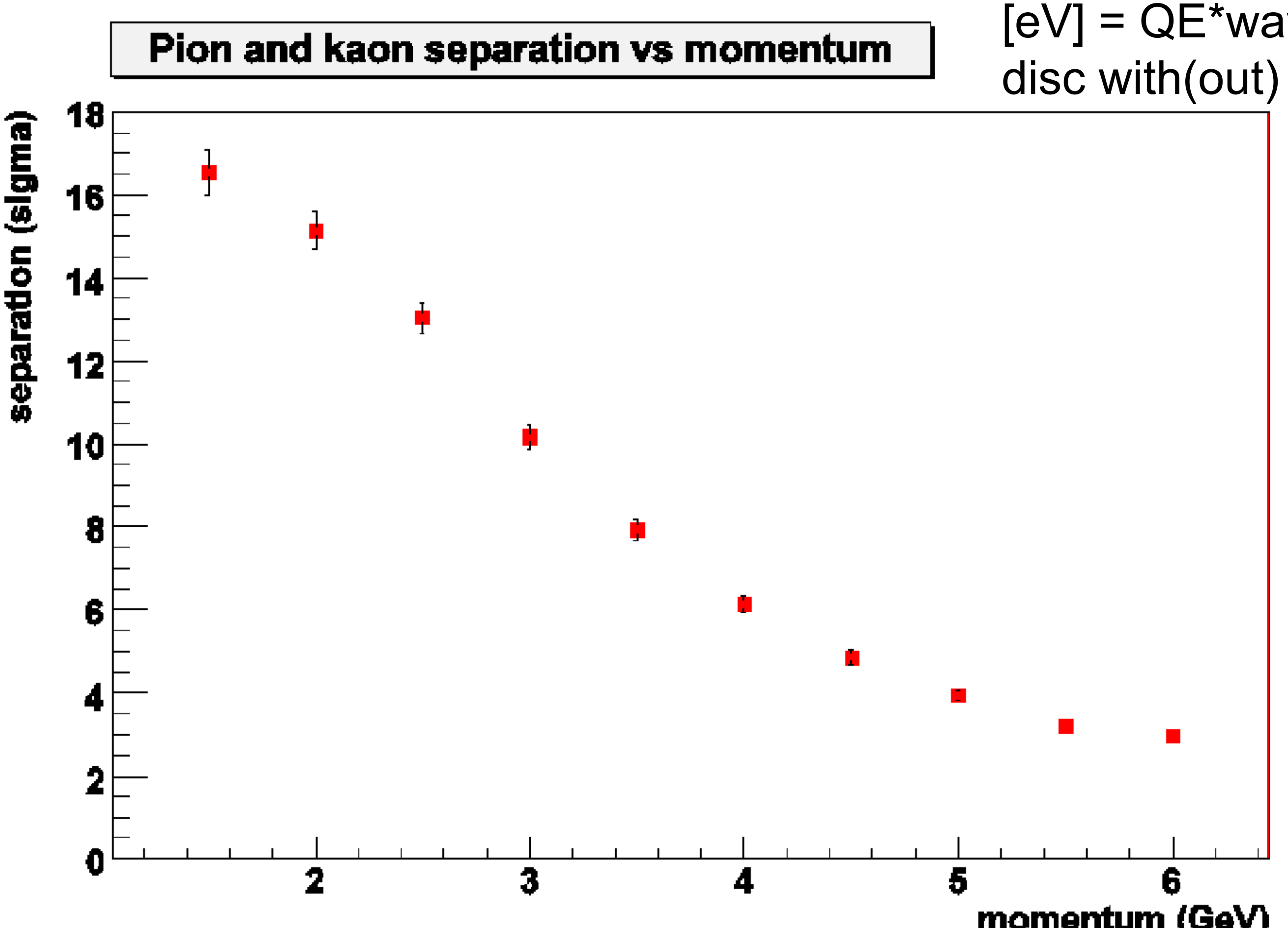
Analysis without external timing

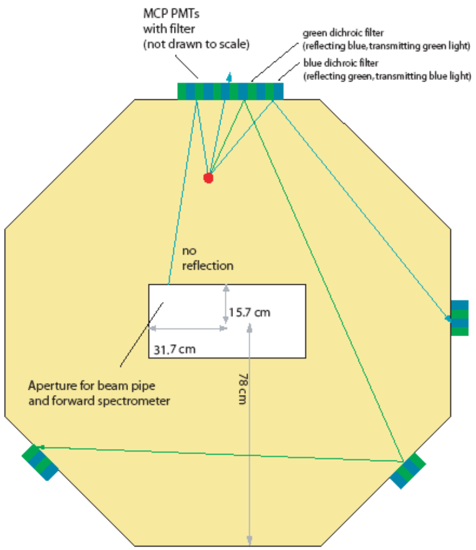



Pion and Kaon seperation
count
30
25
20
15
10
5
0
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
s1*s2*s3*s4

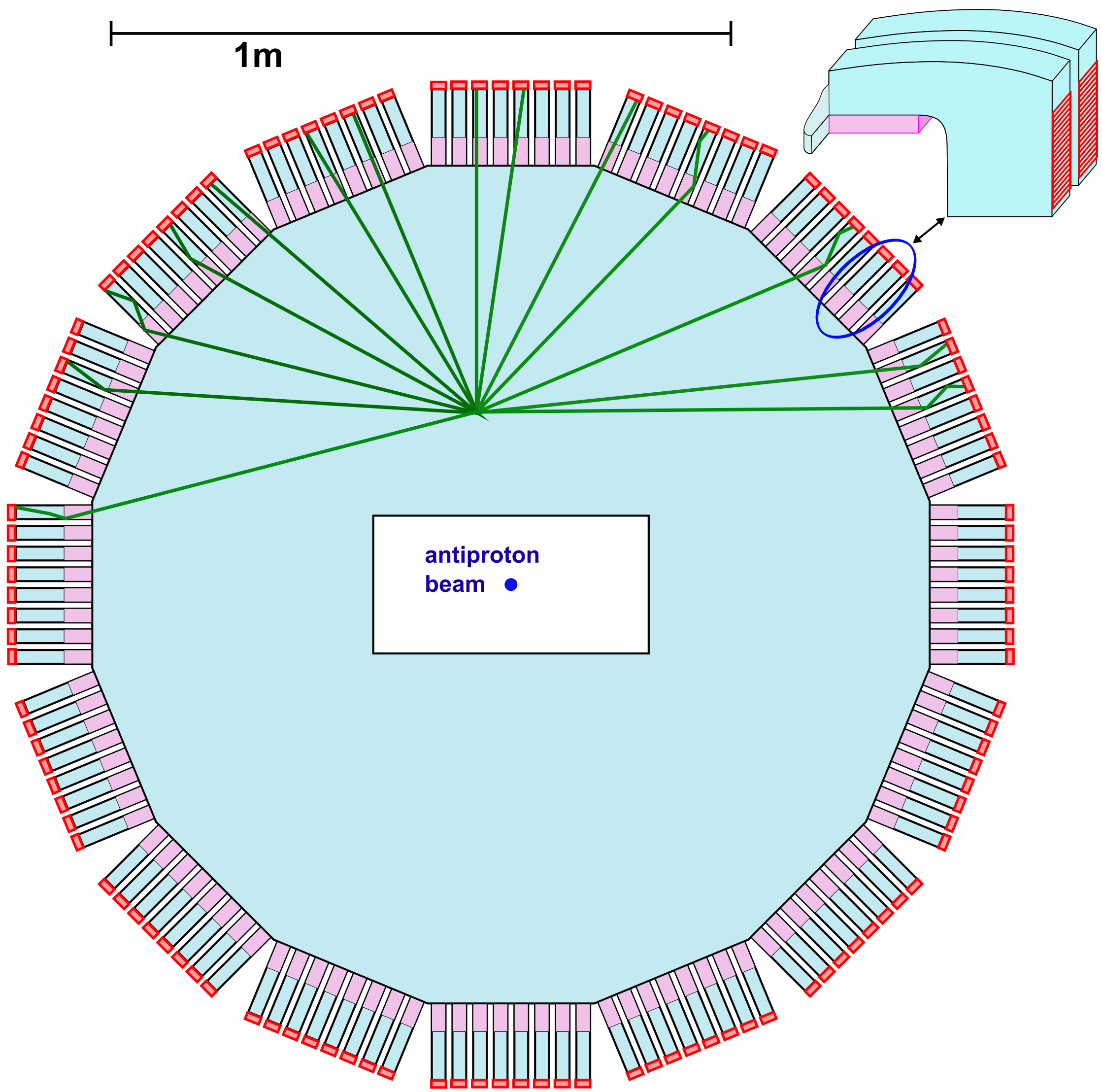
Time-of-Propagation

particle angle ???
time resolution
[eV] = QE*wavelengthband
disc with(out) (black) hole

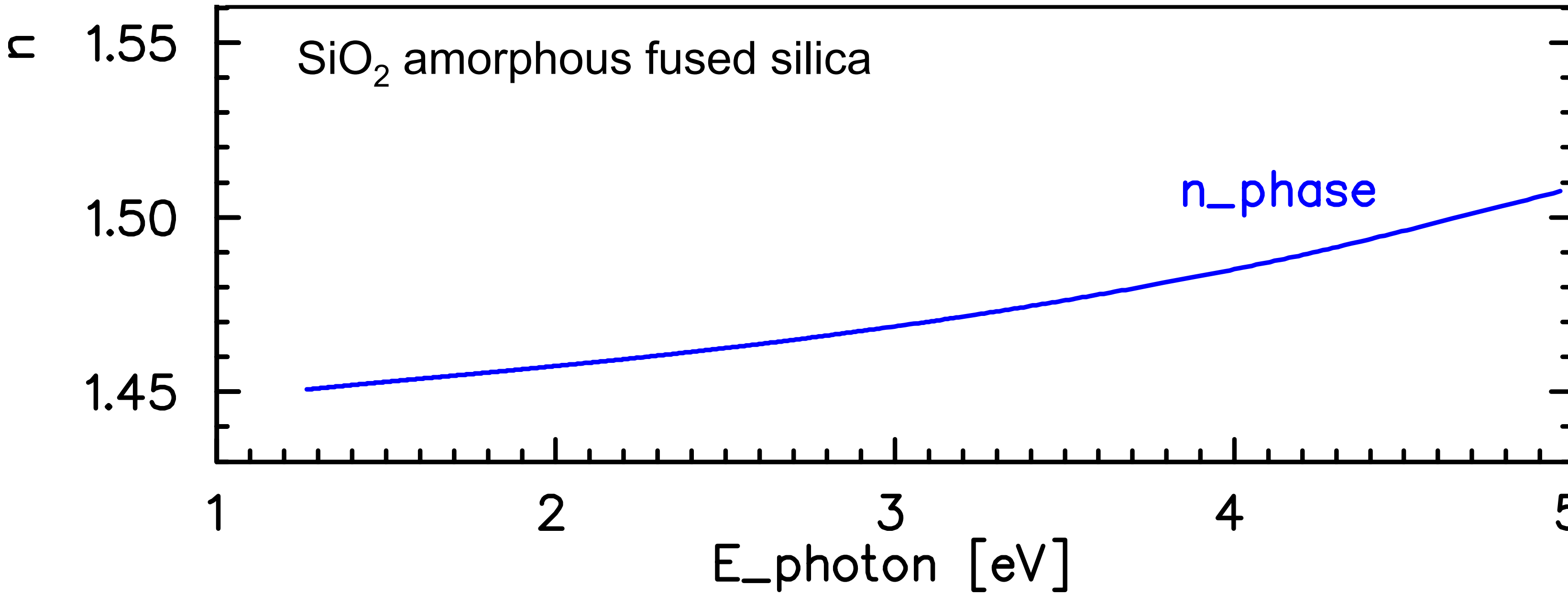




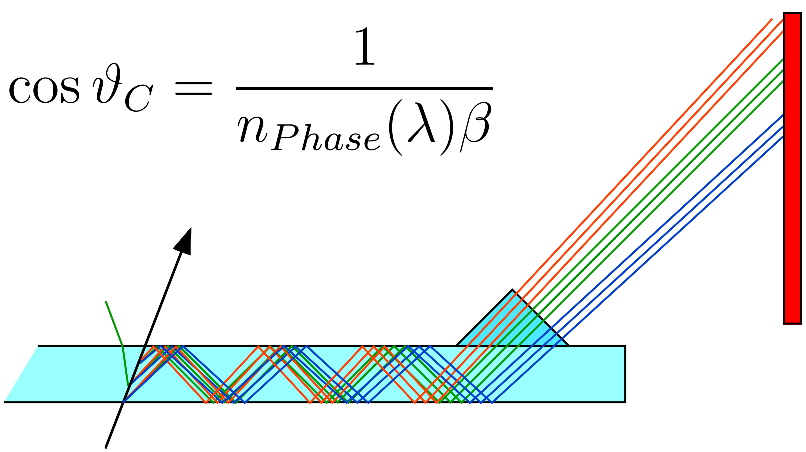
Focussing Lightguide

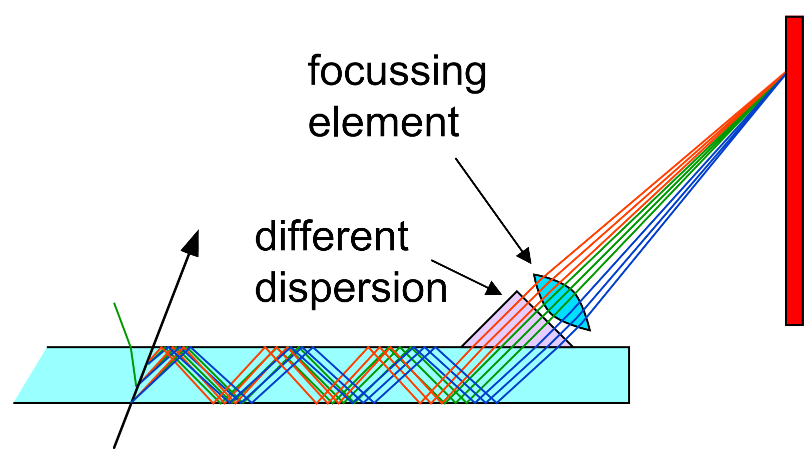


Focussing & Chromatic Correction

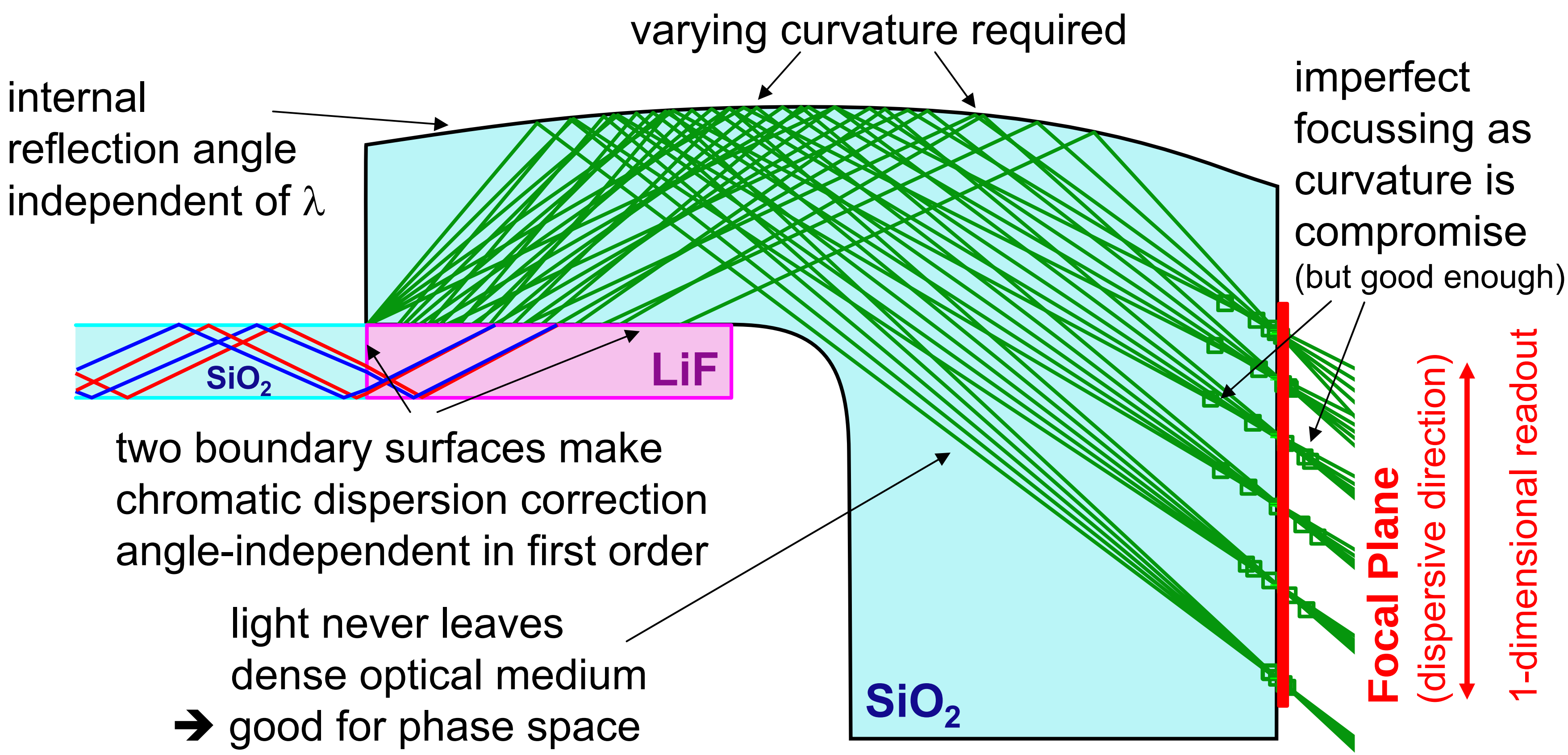


$$\cos \vartheta_C = \frac{1}{n_{Phase}(\lambda)\beta}$$





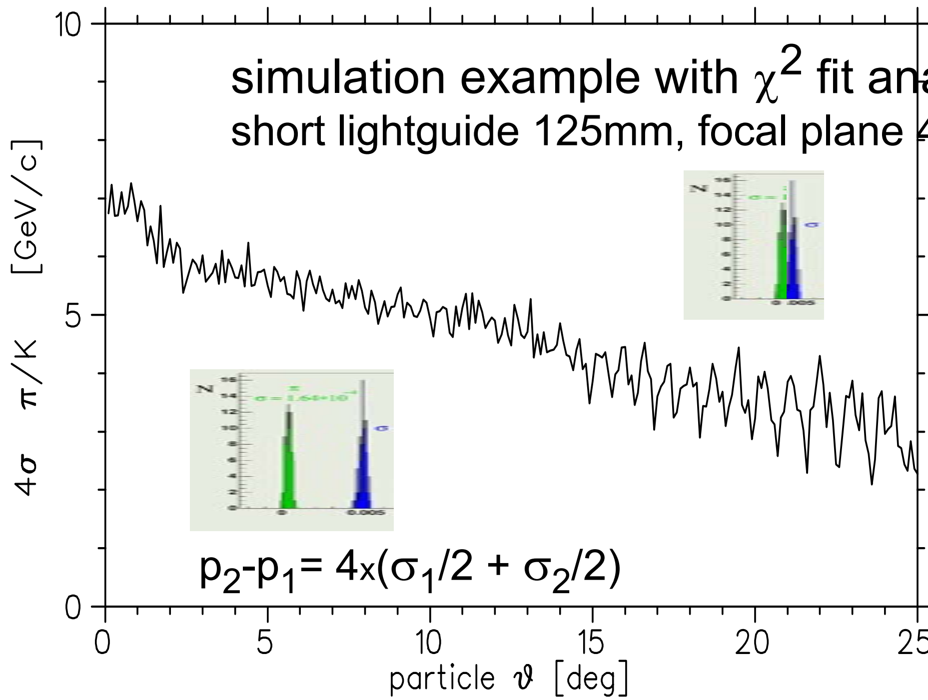
Focussing & Chromatic Correction



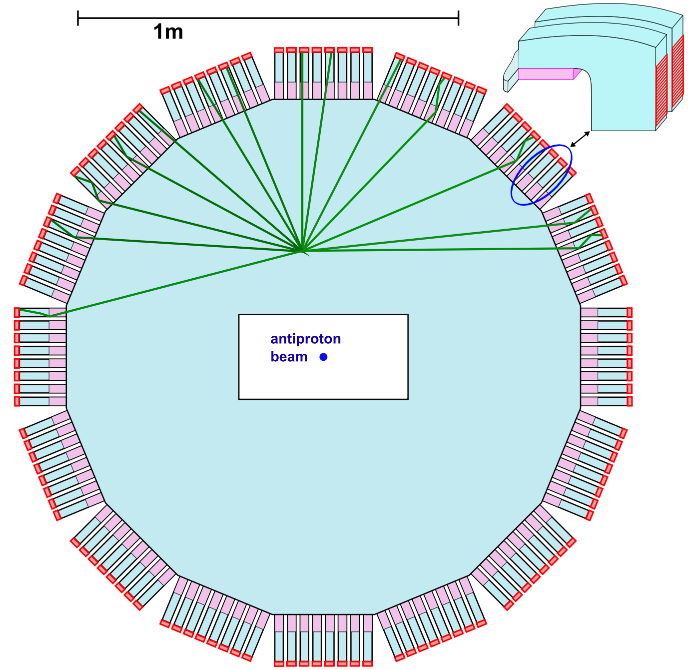
Focussing Lightguide

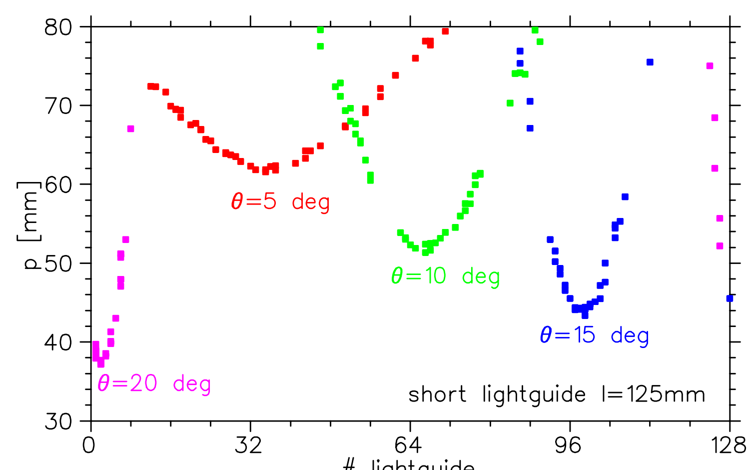
simulation example with χ^2 fit analysis

short lightguide 125mm, focal plane 48mm

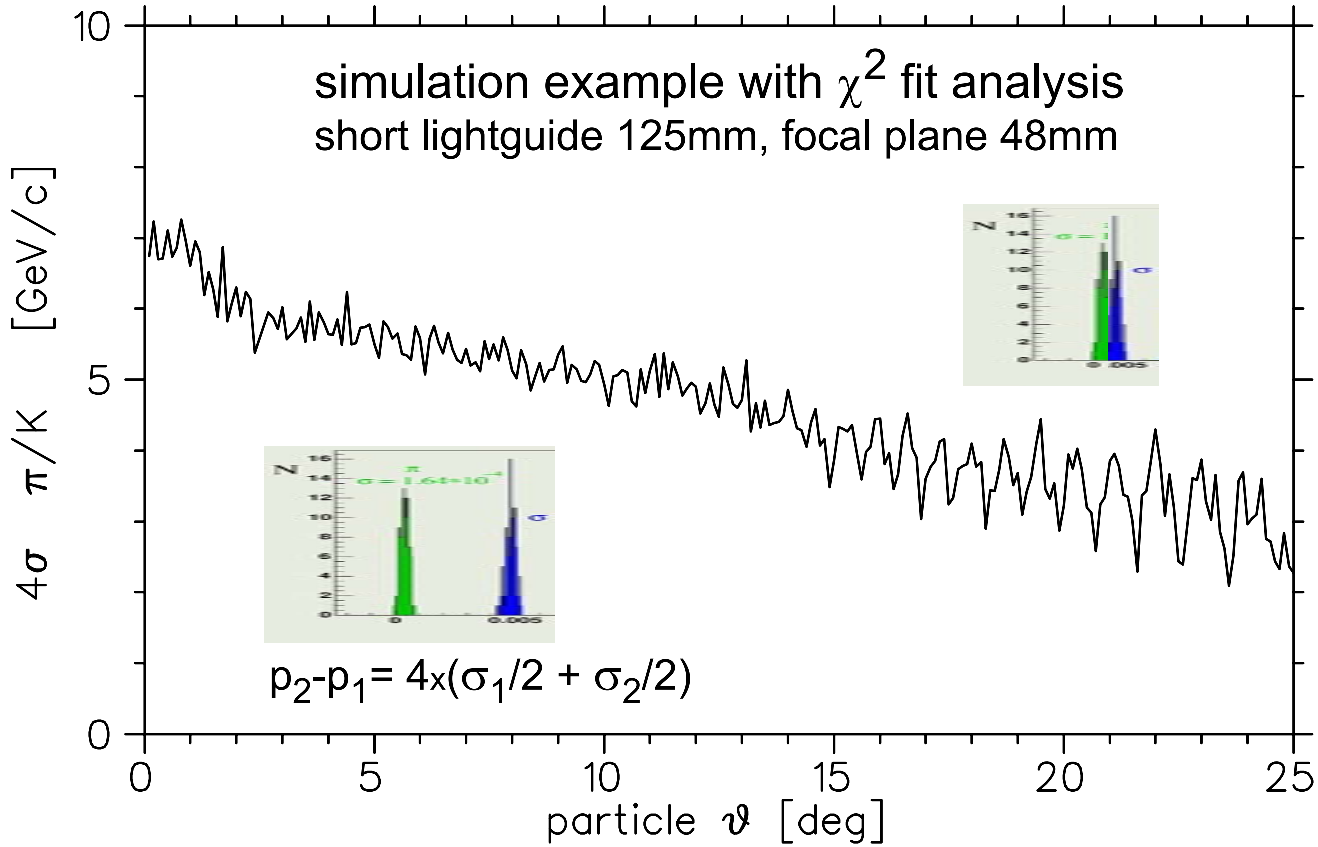


p_2-p_1= 4x(σ_1/2 + σ_2/2)





backup slide



z_from_target[mm]= 2000
disc_radius[mm]= 1100
disc_thickness[mm]= 10
nzero[1/mm]= 14 (0.4eV)
LiF corrector plate

radiation_length[mm]= 126
B [Tesla] = 2
momentum[GeV/c]= 5
beta= 0.98

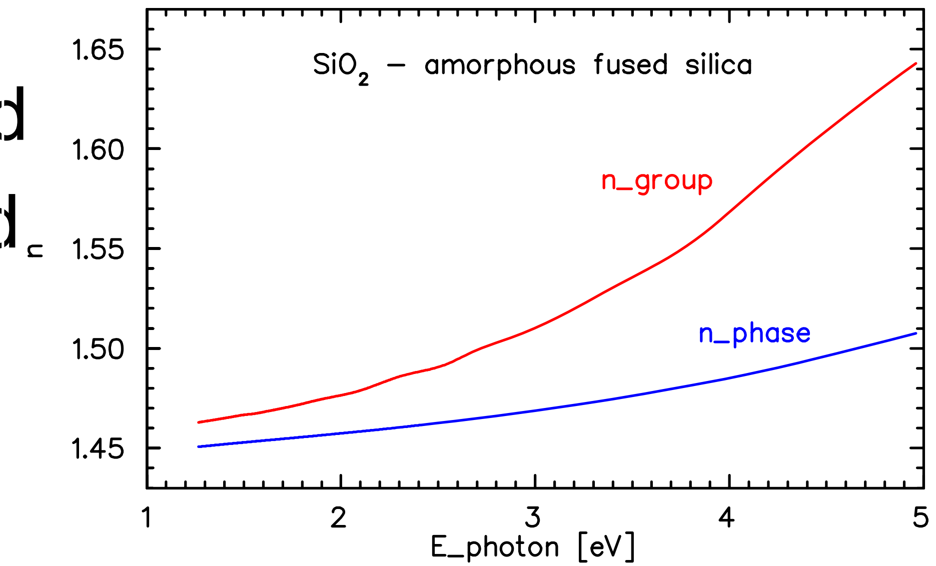
n_lightguides= 192
lightguidewidth= 25
lightguidelength= 65 (from apex)
lightguide focal plane = [32,80]
lightguide pixel size[mm]= 1

Challenges and Compromises

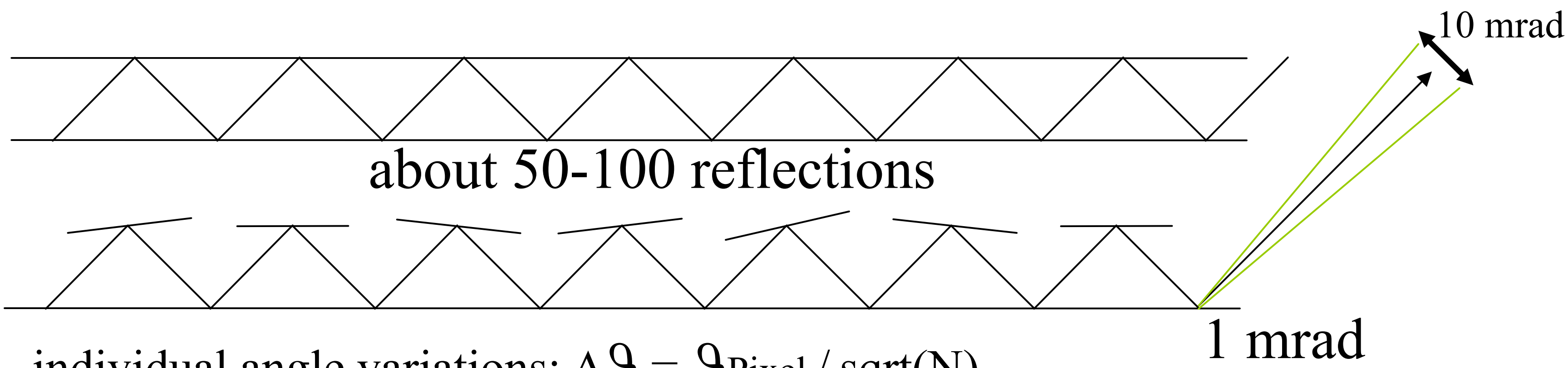
- Radiator bulk and surface properties
- Radiator thickness
- Straggling
- Radiation hardness

Light Generation

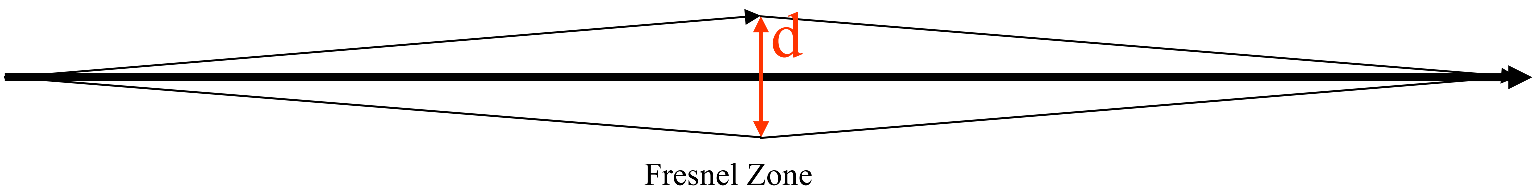
- radiator thickness
  - number of photons
- transparency
  - wide wavelength range (eV) – high statistics
- material dispersion
  - either narrow w. band
  - or correction required



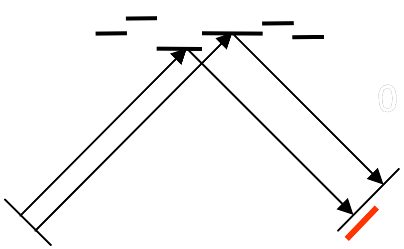
Light Propagation

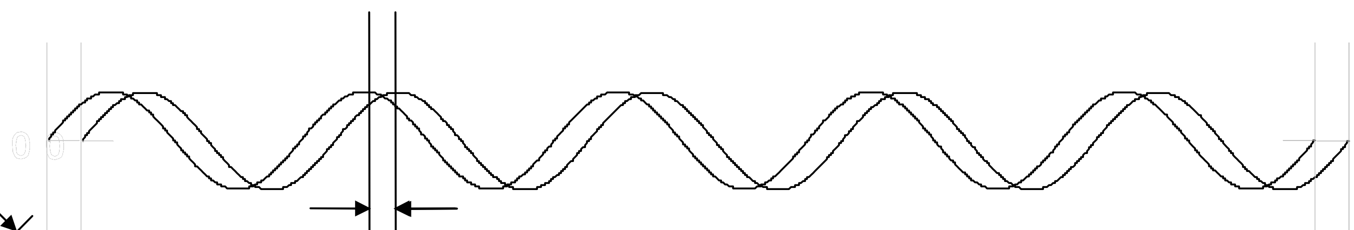


individual angle variations: $\Delta\vartheta = \vartheta_{Pixel} / \mathrm{sqrt}(N)$



length 400mm, λ=400nm → **d=1mm** (approximately)





rough surface causing path length differences and phase shifts

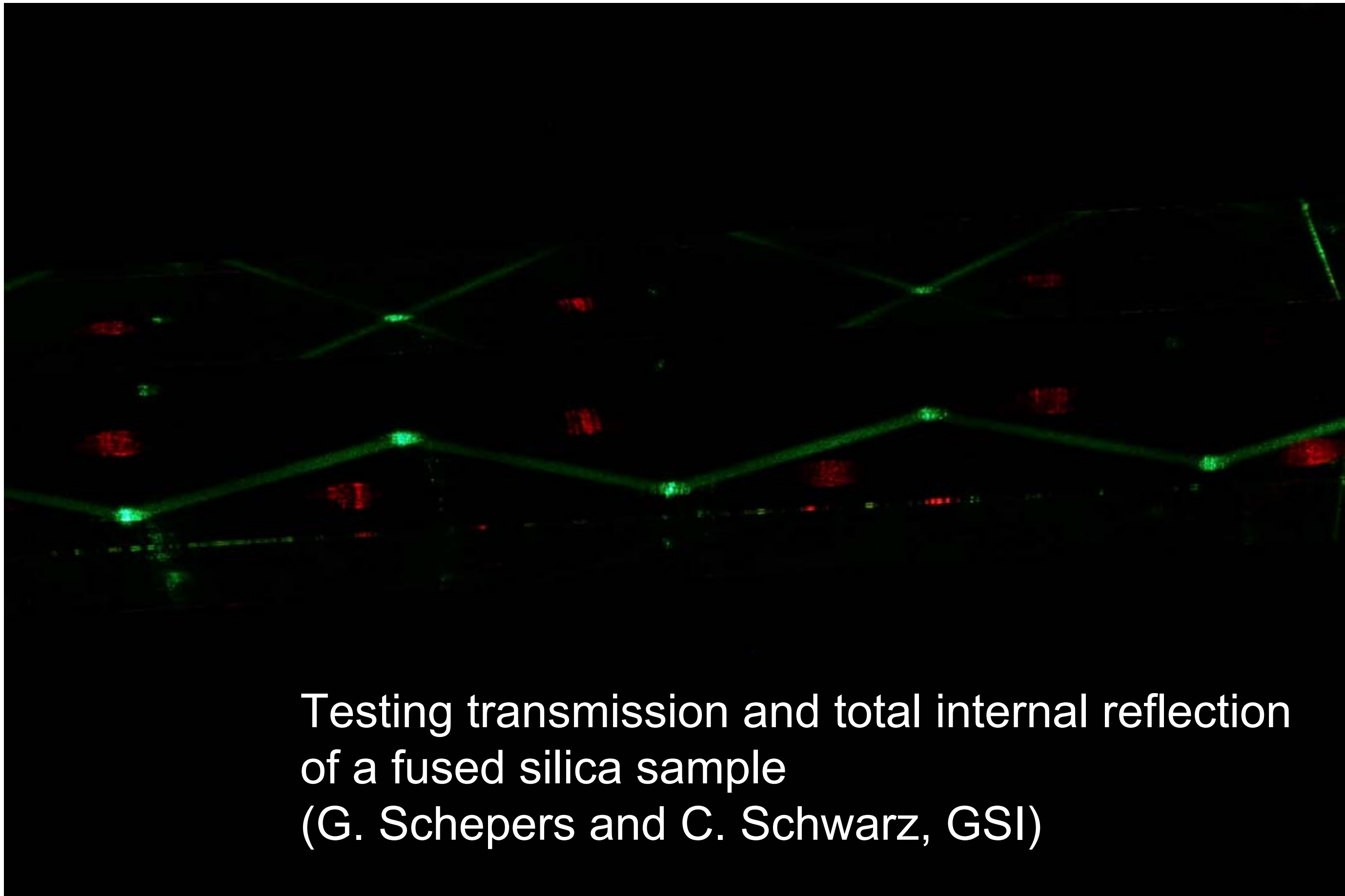
Material Test

AFM image

Ferrara,

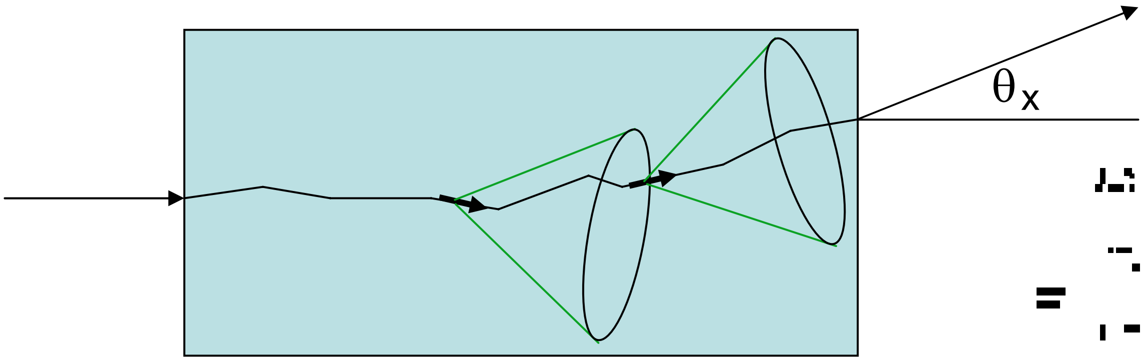
surface from

GW-Glasgow

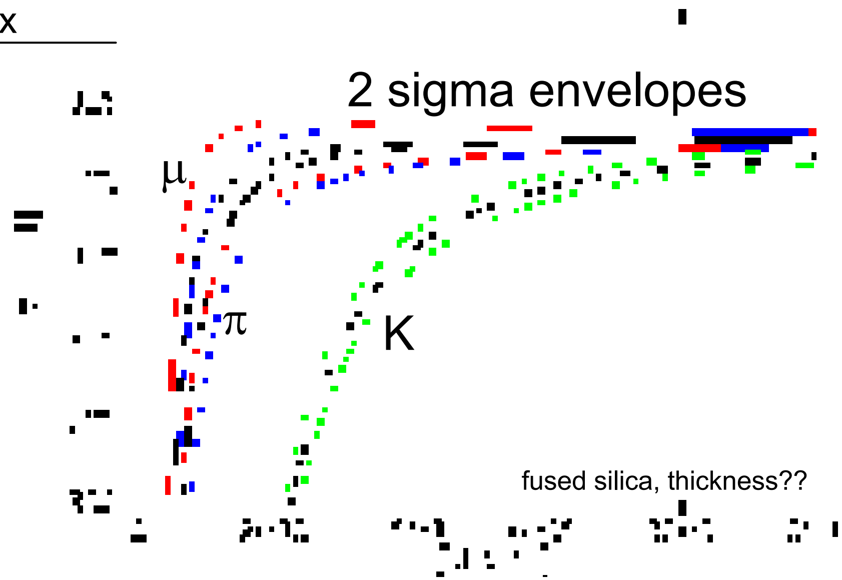


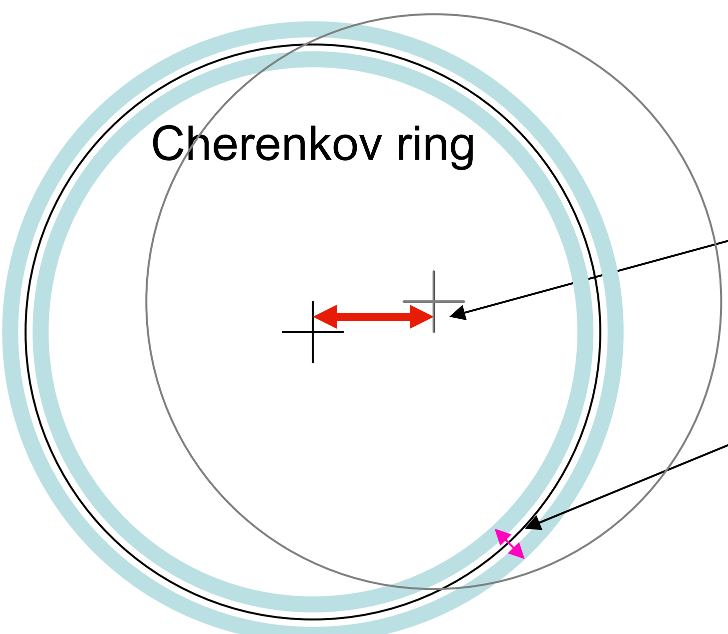
Testing transmission and total internal reflection of a fused silica sample
(G. Schepers and C. Schwarz, GSI)

Particle Path Straggling



$\sigma(\theta_x)$ standard deviation of θ_x



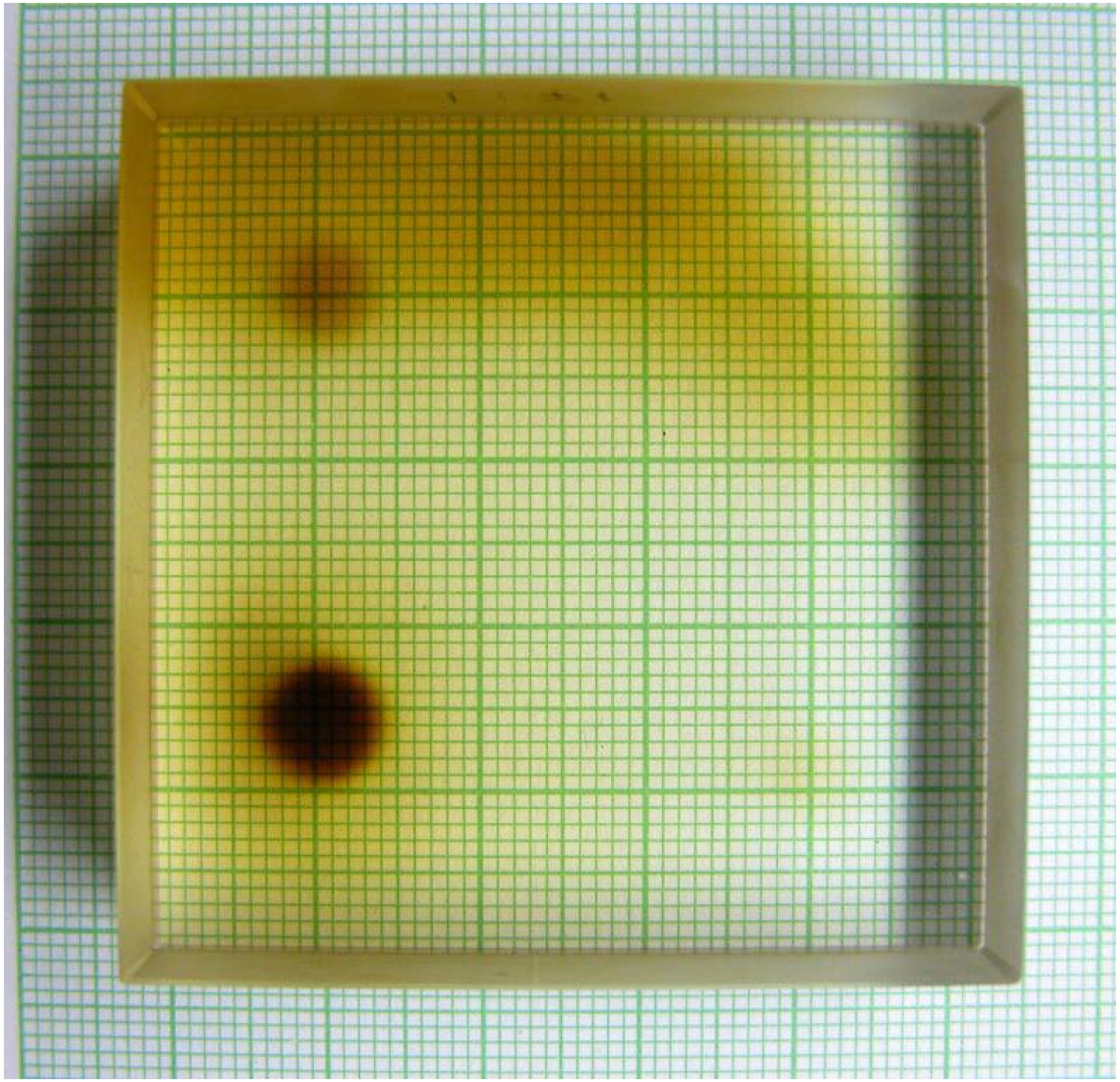


angle information of upstream tracking is 0.57 $\sigma(\theta_x)$ off

Cherenkov ring image is blurred by 0.38 $\sigma(\theta_x)$

➔ reduce radiator thickness, reduce X_0

Material choice for dispersion corr.

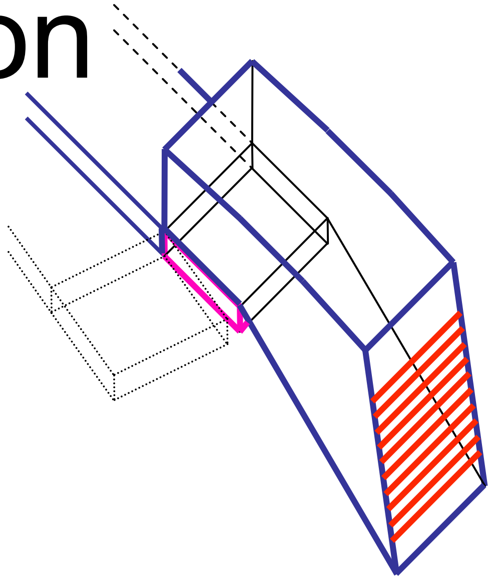


LiF sample photo

Irradiation test at KVI
Schott LLF1 HT
glass sample

(B. Seitz, M. Hoek, Glasgow)

Light Detection



- detector geometry
- magnetic field (~1T)
- photon rate (MHz/pixel)
- light cumulative dose
- radiation dose

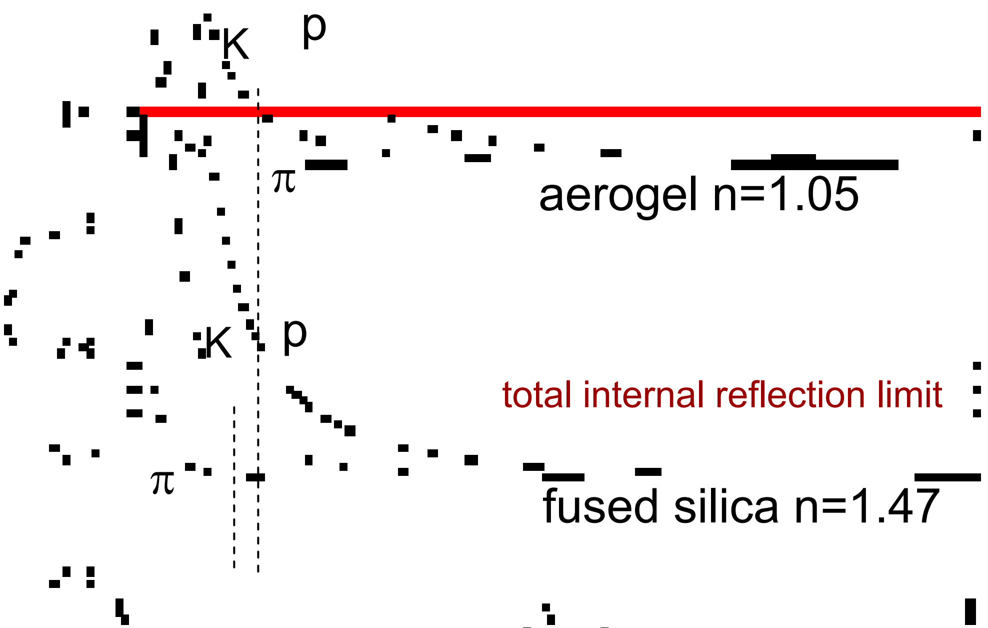
photon detection is a problem still to be solved

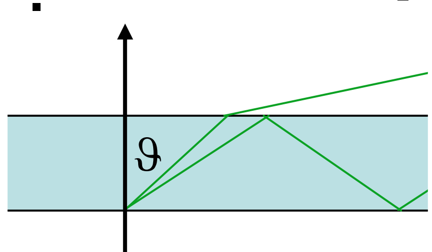
looking into MCP, silicon PMTs, HPDs → Erlangen

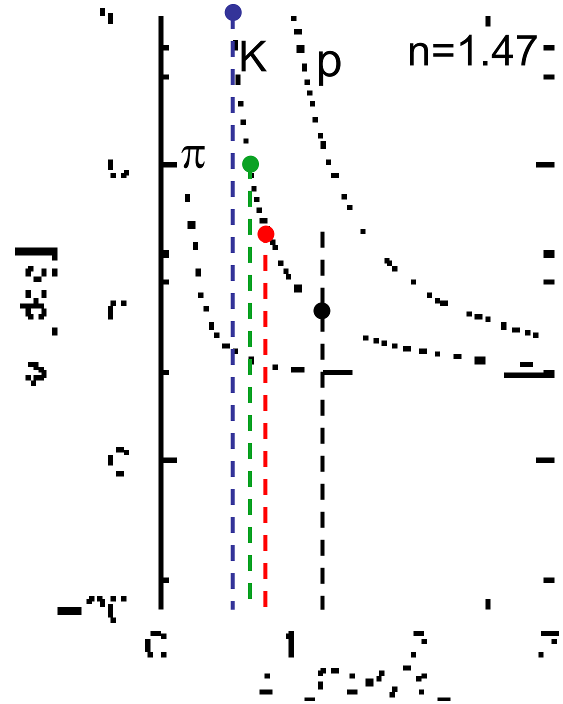
Advantages

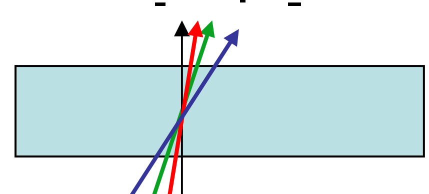
- wide dynamic range (0.6GeV/c-~6GeV/c)

Momentum Thresholds









Summary

- Several designs
- There are challenges ahead

Thank you for listening

Backup Slides

Panda Participating Institutes

more than 300 physicists (48 institutes) from 15 countries

U Basel
IHEP Beijing
U Bochum
U Bonn
U & INFN Brescia
U & INFN Catania
U Cracow
GSI Darmstadt
TU Dresden
JINR Dubna (LIT,LPP,VBLHE)
U Edinburgh
U Erlangen
NWU Evanston
U & INFN Ferrara
U Frankfurt
LNF-INFN Frascati

U & INFN Genova
U Glasgow
U Gießen
KVI Groningen
U Helsinki
IKP Jülich I + II
U Katowice
IMP Lanzhou
U Mainz
U & Politecnico & INFN Milano
U Minsk
TU München
U Münster
BINP Novosibirsk
LAL Orsay

U Pavia
IHEP Protvino
PNPI Gatchina
U of Silesia
U Stockholm
KTH Stockholm
U & INFN Torino
Politechnico di Torino
U Oriente, Torino
U & INFN Trieste
U Tübingen
U & TSL Uppsala
U Valencia
IMEP Vienna
SINS Warsaw
U Warsaw

Particle ID & Kinematics

$p\bar{p}$ i.e. charmonium production

$D^+ \rightarrow K^- \pi^+ \pi^+$
$\pi^- \pi^+ \pi^+$
$K^- K^+ \pi^+$

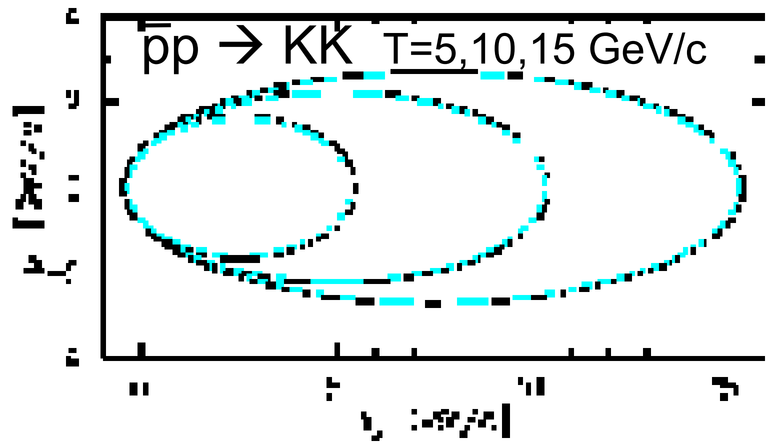
$\pi^- \pi^+ K^+$ even
or $K^- \pi^- \pi^+ \pi^+ \pi^+$

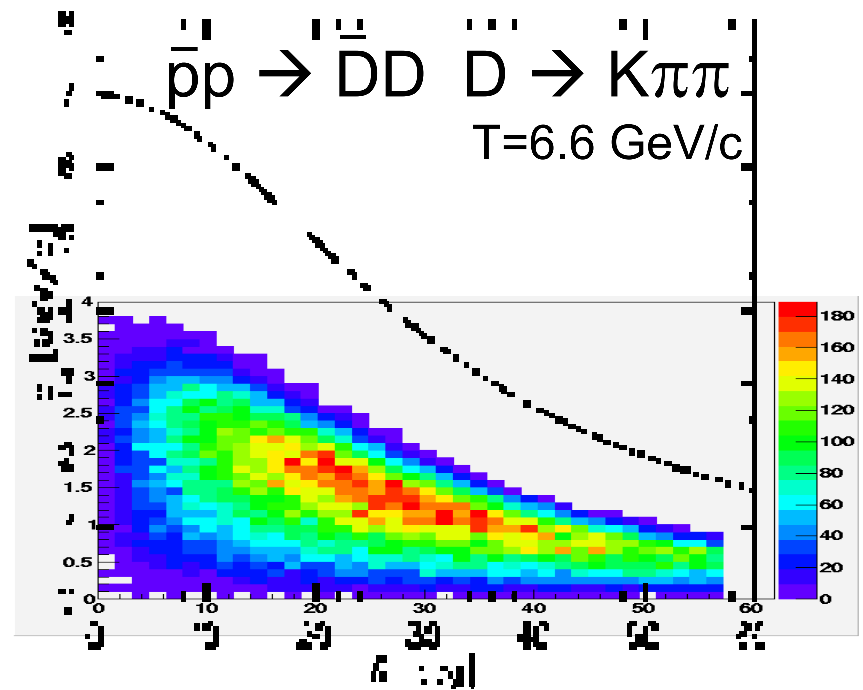
distinguish π and K (K and p) ...

if mass known, particle identified

need to measure two quantities:

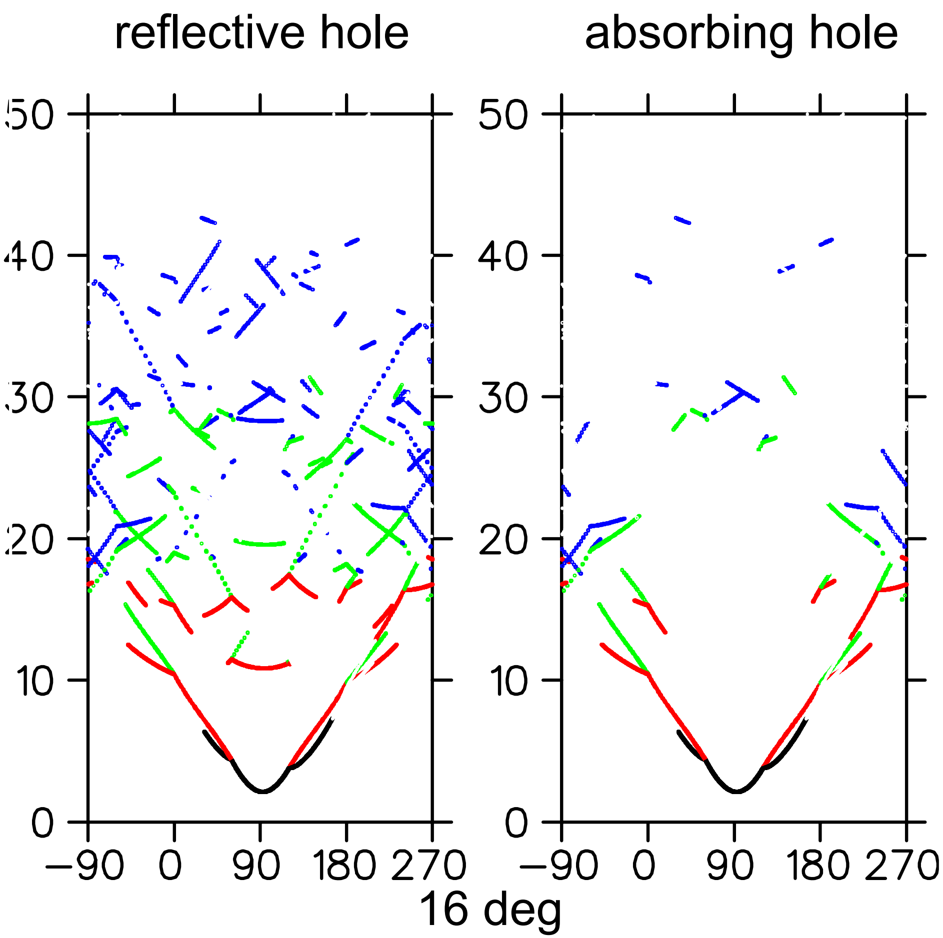
dE/dx
energy
momentum (tracking in magnetic field)
velocity (Cherenkov Radiation)





Time-of-Propagation

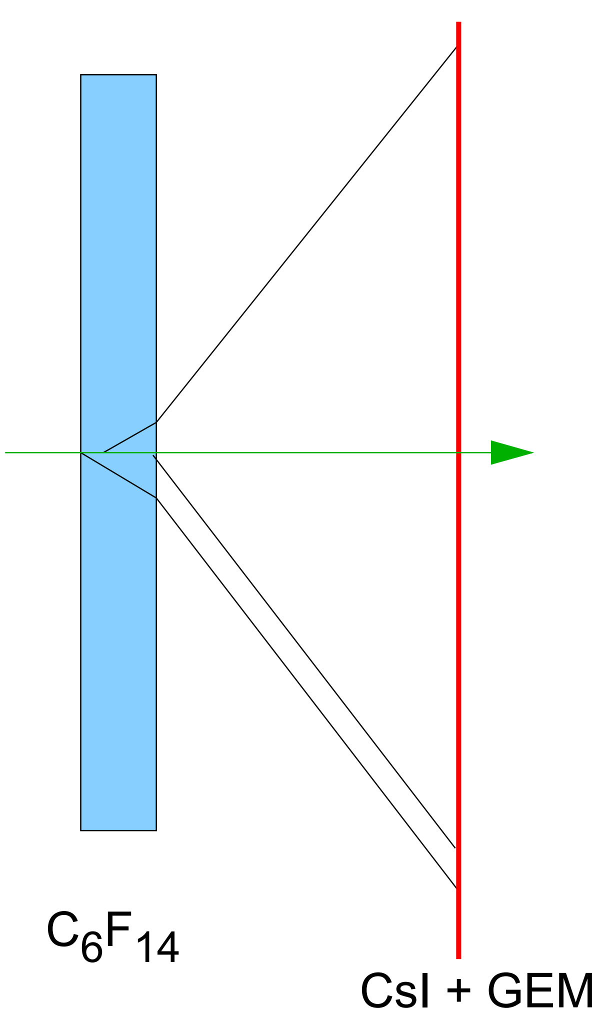
<u>these calculations</u>: λ=400nm-800nm Quantum Efficiency 30% n_0=17.19/mm
per band: Δn(group)=0.0213 (inspired by [480nm-600nm] → σn=0.00615

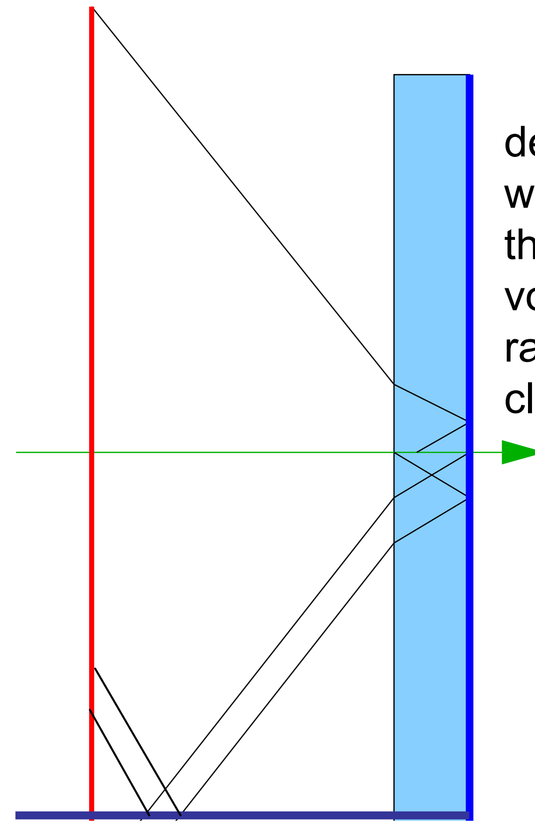


- single photo timing crucial
- performance increase comes with more tracks in the time-angle-plane

Proximity Focussing design

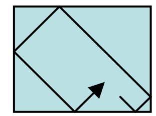
suggestion Lars Schmitt: combine tracking and PID

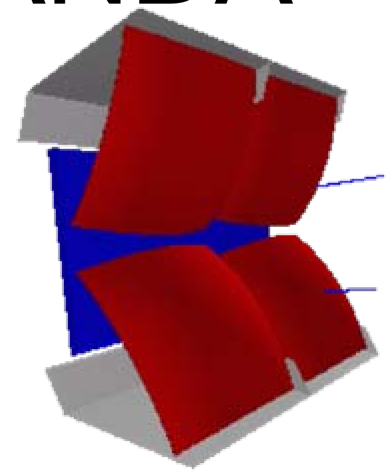




design variation with mirror and the expansion volume upstream radiator placed closer to EMC

Cherenkov Detectors in PANDA

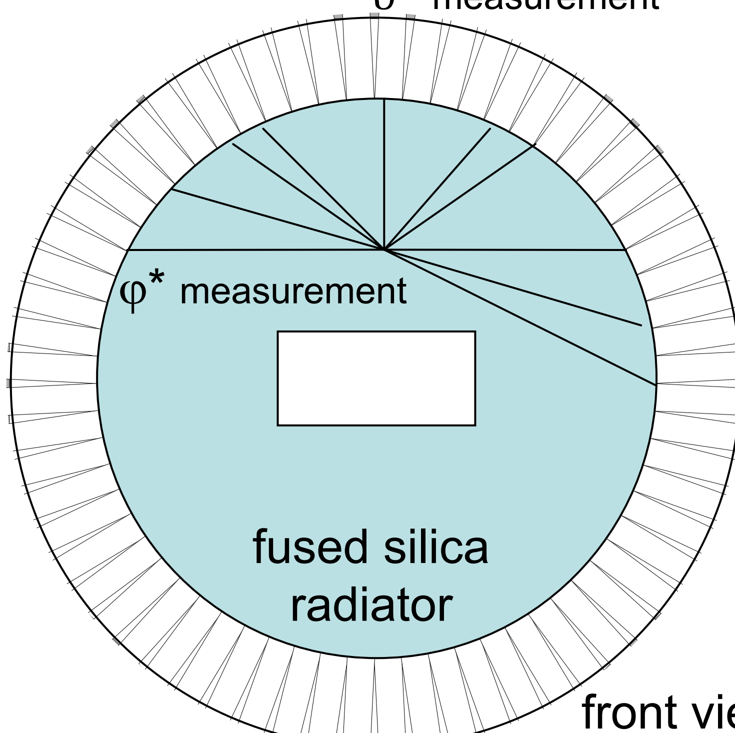
- HERMES-style RICH
- BaBar-style DIRC 2-dimensional imaging type 
- **Disc DIRC**



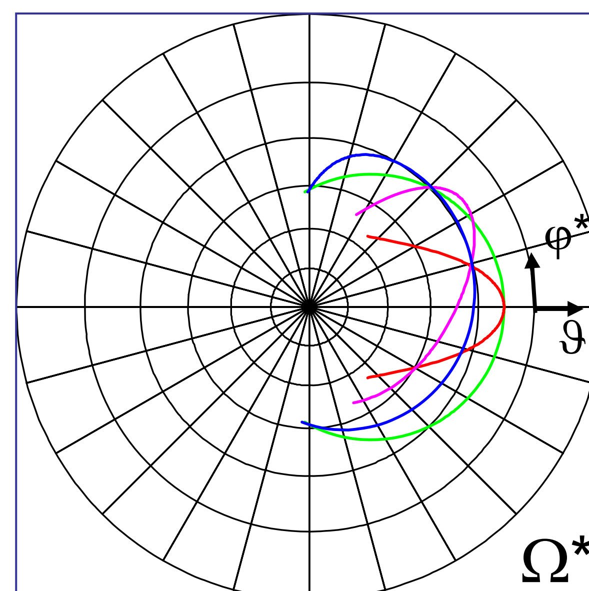
4 instead of 2 mirrors

one-dimensional imaging DIRC type

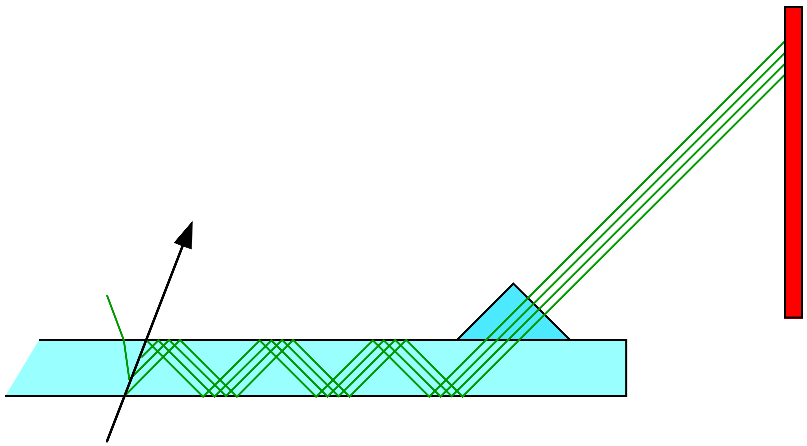
side view

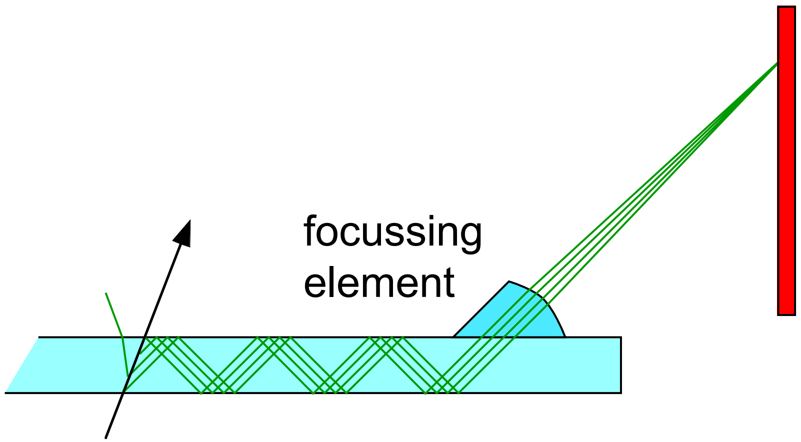


front view



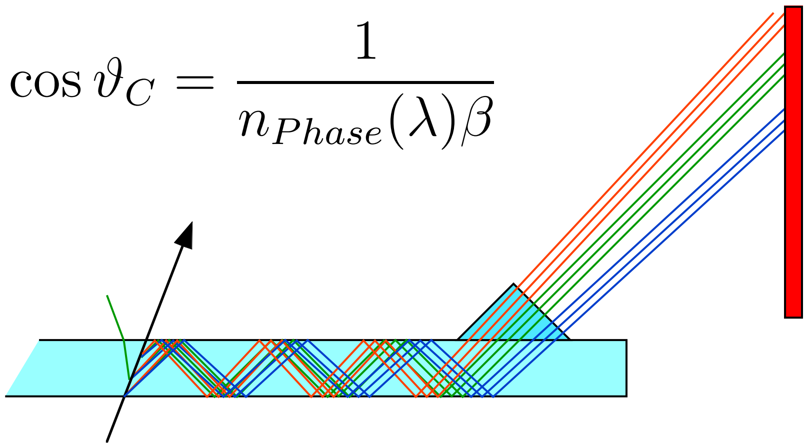
Focussing

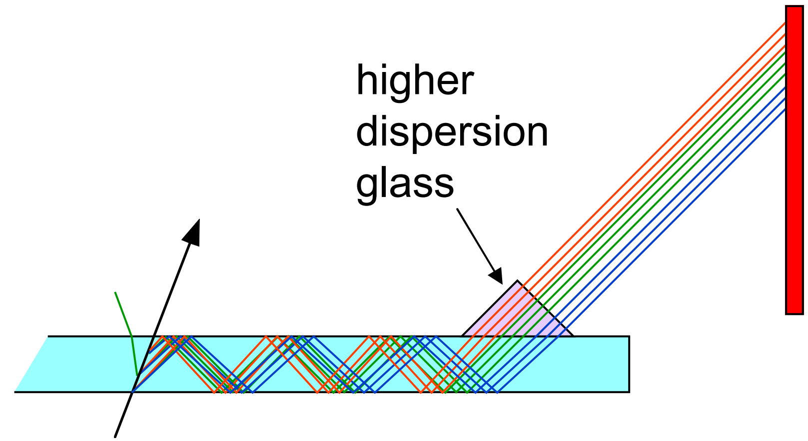


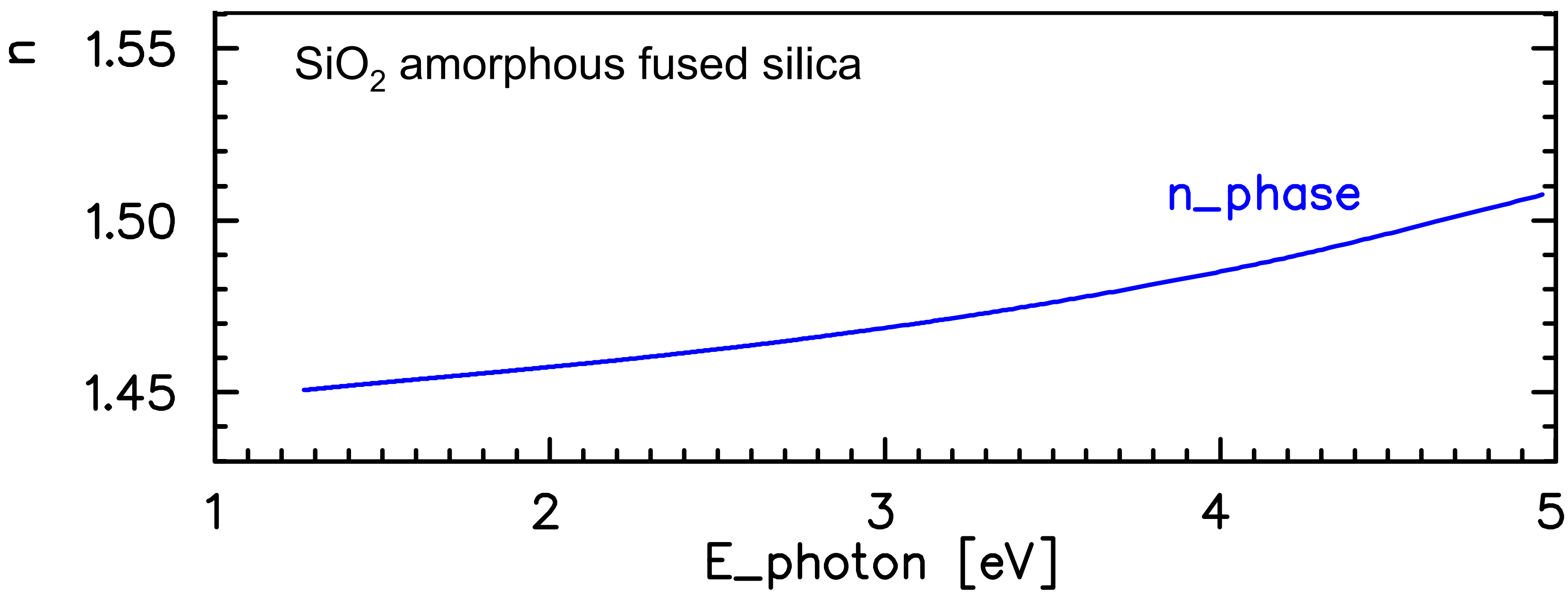


Chromatic Correction

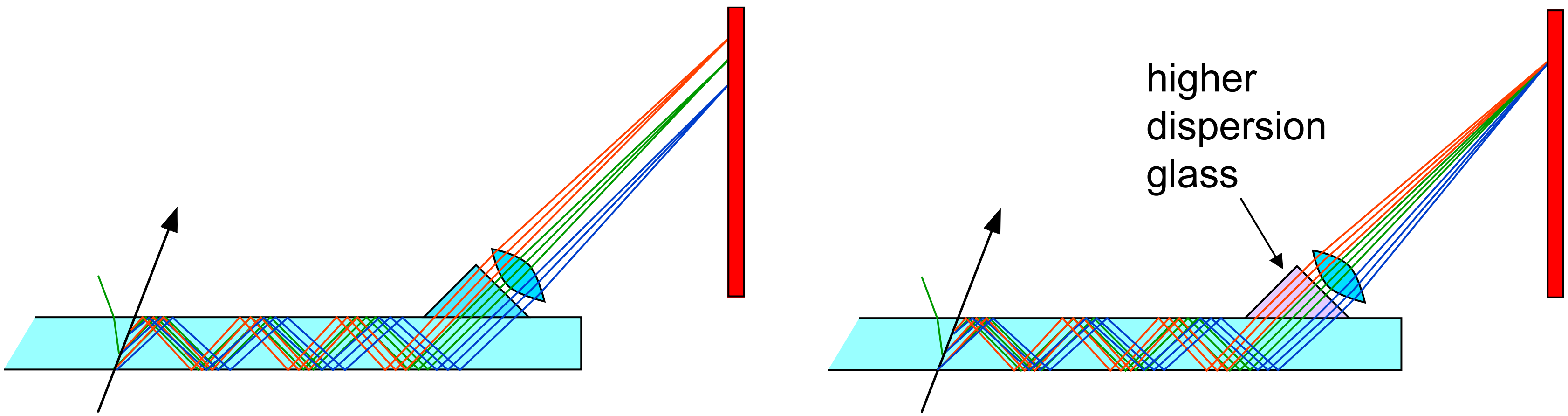
$$\cos\vartheta_C = \frac{1}{n_{Phase}(\lambda)\beta}$$

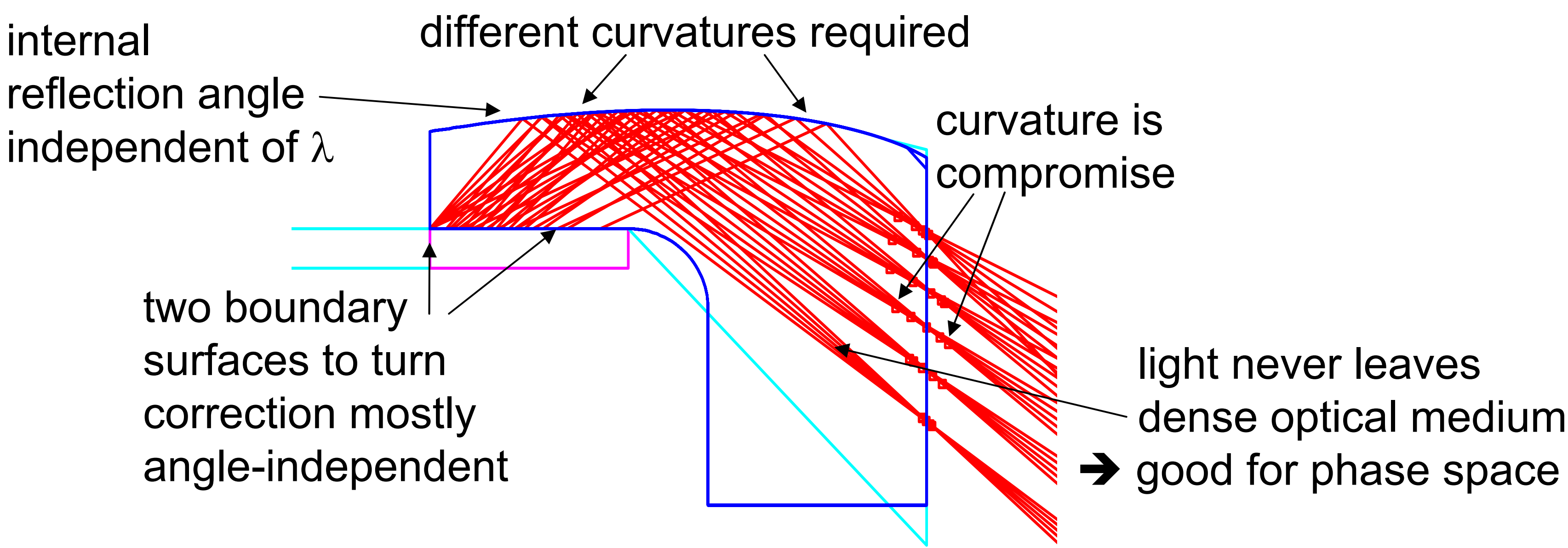






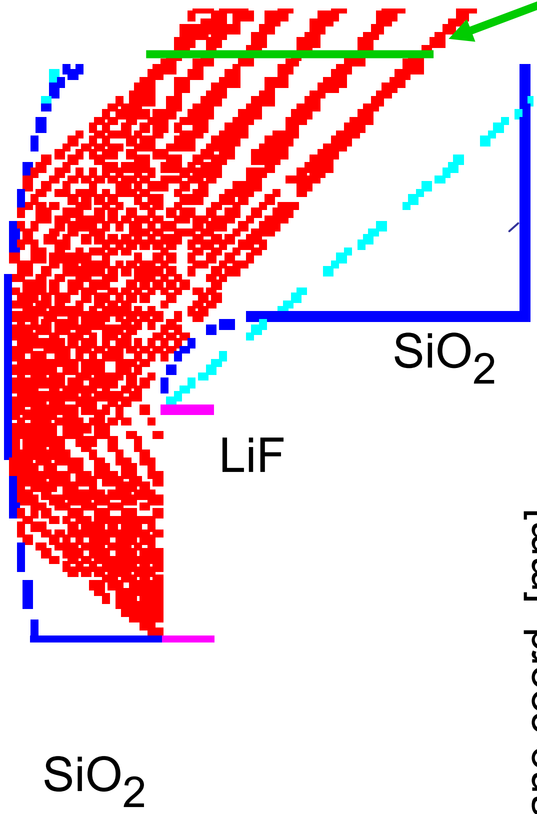
Focussing & Chromatic Correction

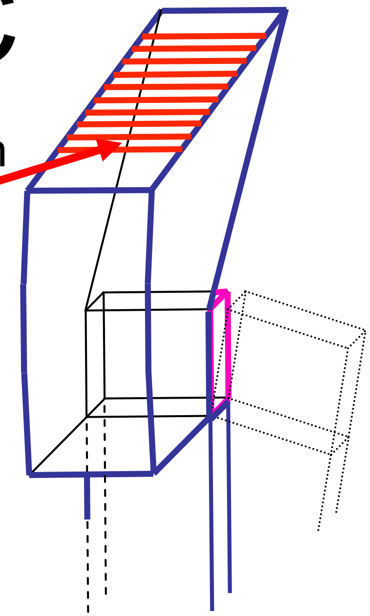


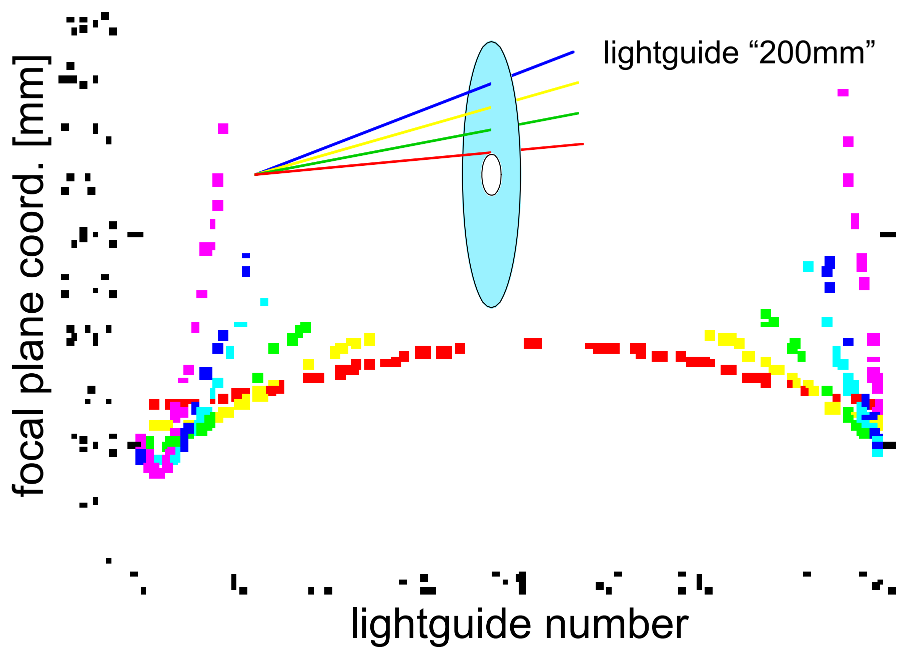


Focussing disc DIRC

focal plane of focussing lightguide with rectangular photon detector pixels

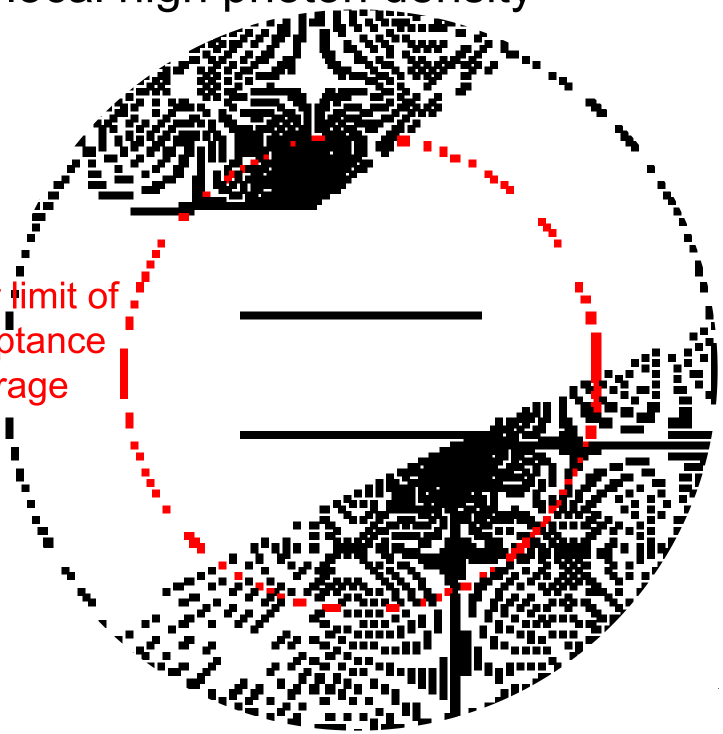






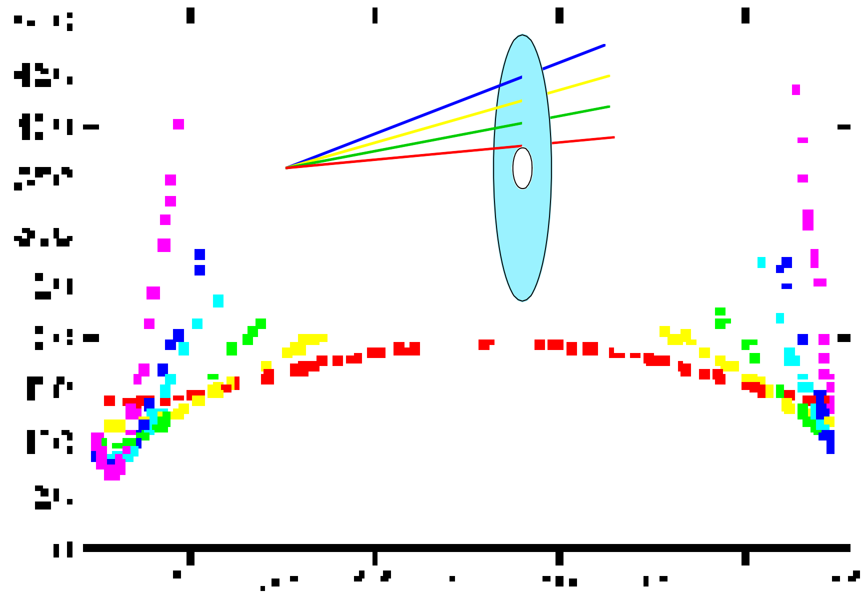
Expansion Volume advantageous

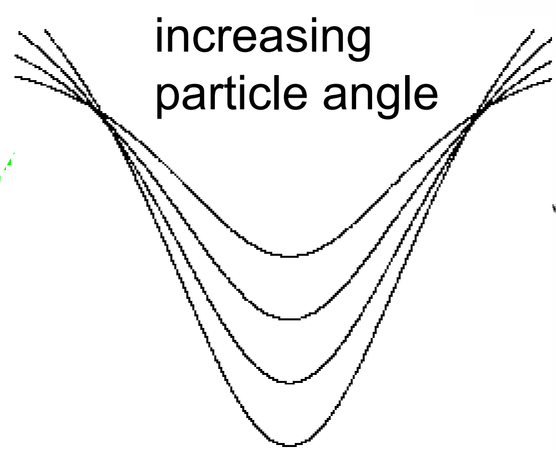
peripheral tracks create
local high photon density

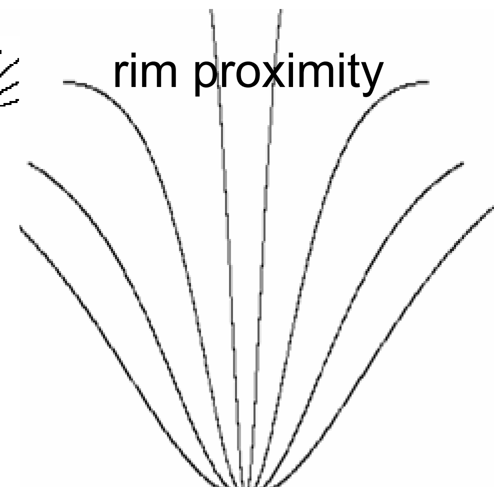


outer limit of
acceptance
coverage

the further outward,
the more radial the light paths

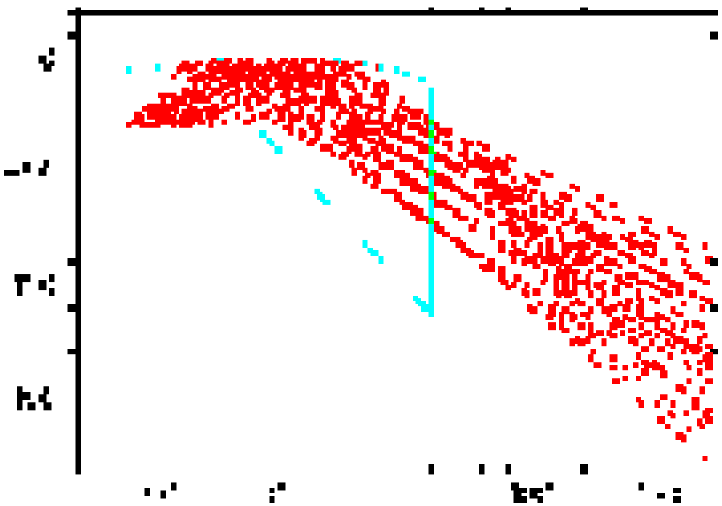


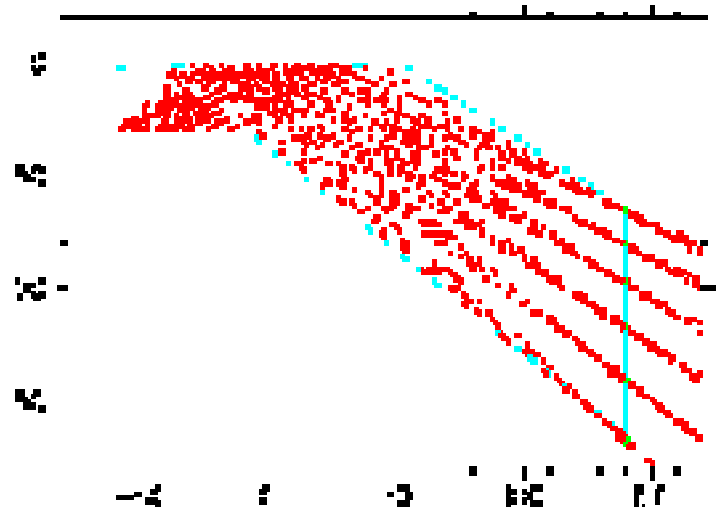




performance does drop towards disc perimeter

Focussing Lightguides

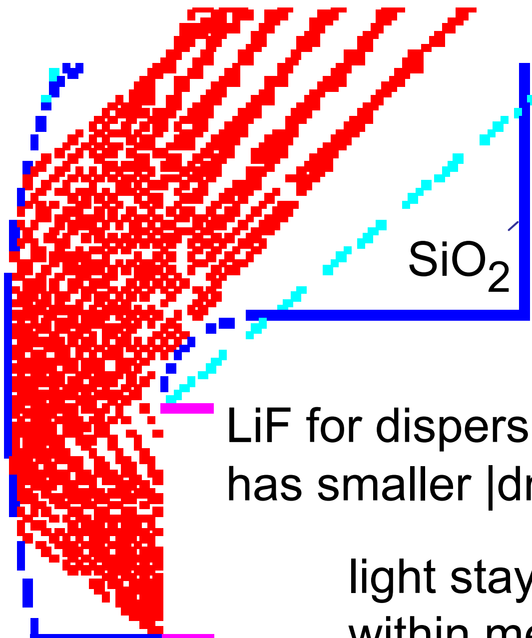




- short focal plane 50mm
- ~1mm pixels needed
- optical errors exist
- thicker plate a problem

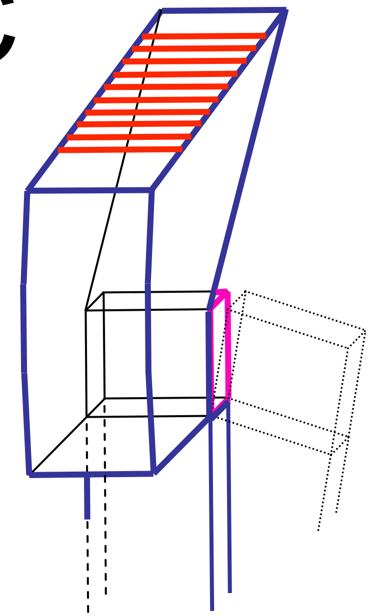
- focal plane 100mm
- pixel width 2-3mm
- benign optics
- thicker plate ok

Focussing disc DIRC



focussing is
better than 1mm
over the entire line
chosen as focal plane

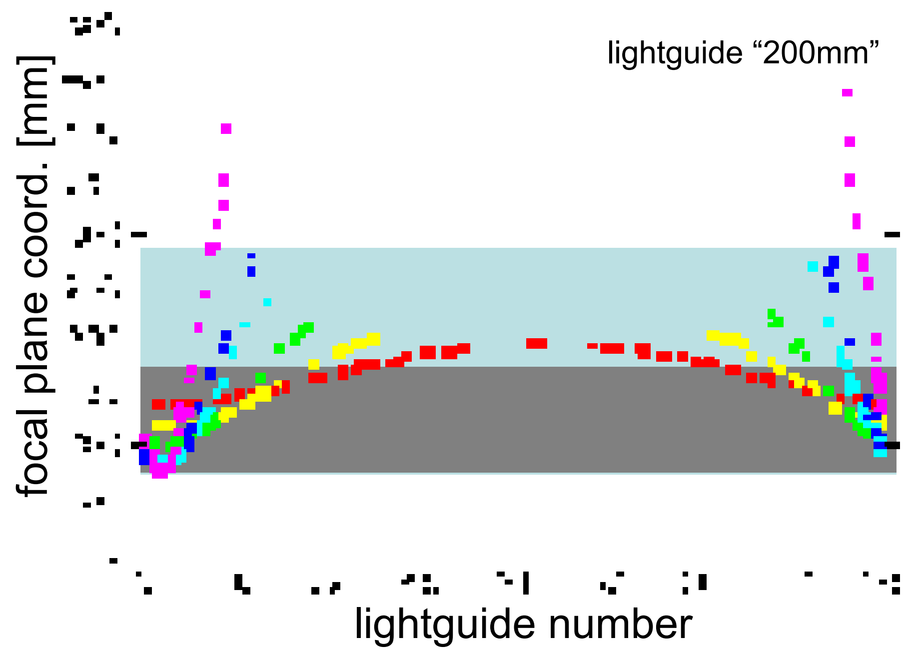
rectangular
pixel shape



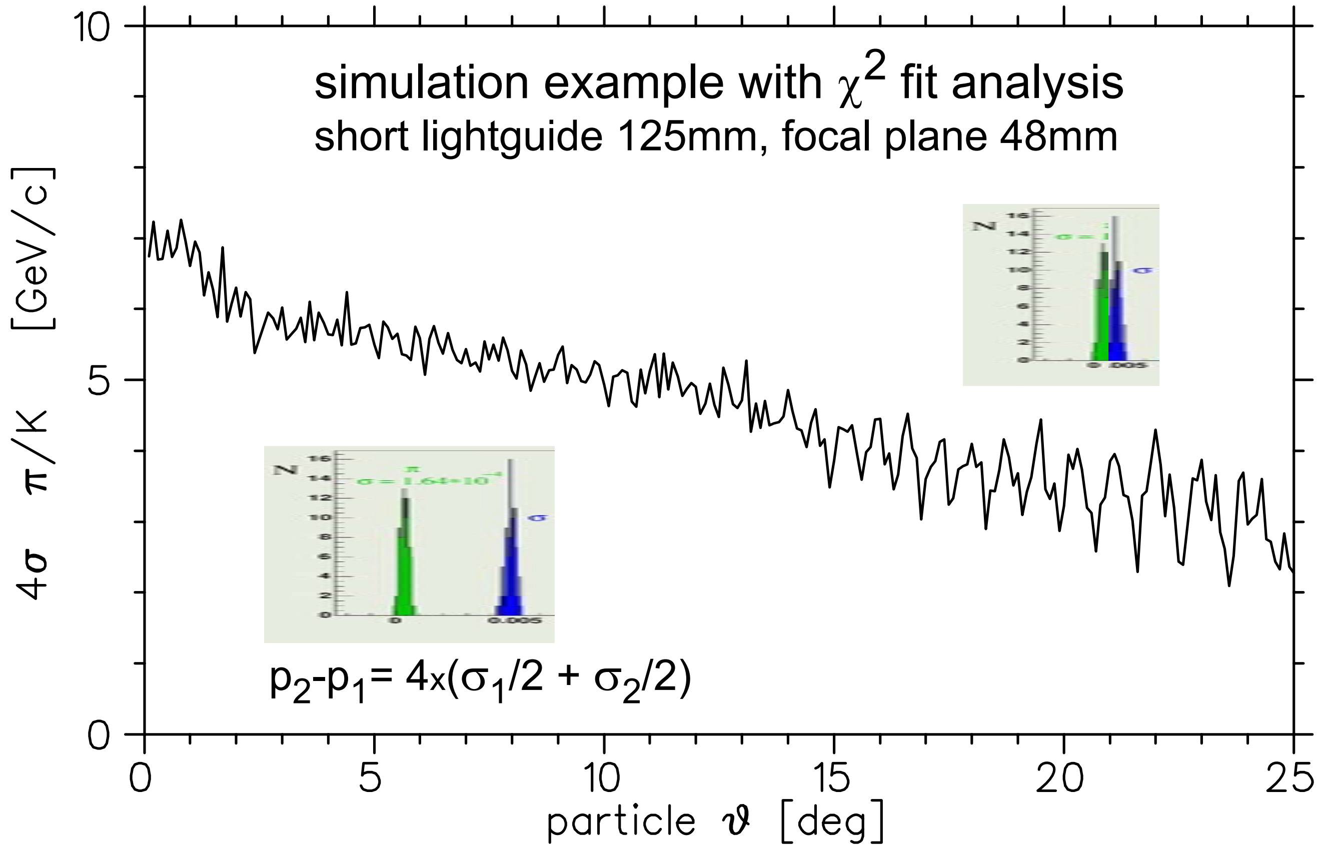
LiF for dispersion correction
has smaller |dn/dλ| than SiO_2

light stays completely
within medium
all total reflection
compact design
all solid material
flat focal plane

radiation-hard "glass"
RMS surface roughness
at most several Ångström



Detector Performance



z_from_target[mm]= 2000
disc_radius[mm]= 1100
disc_thickness[mm]= 10
nzero[1/mm]= 14 (0.4eV)
LiF corrector plate

radiation_length[mm]= 126
B [Tesla] = 2
momentum[GeV/c]= 5
beta= 0.98

n_lightguides= 192
lightguidewidth= 25
lightguidelength= 65 (from apex)
lightguide focal plane = [32,80]
lightguide pixel size= 1

In brief

- fused silica radiator disc, around the rim:
  - LiF plates for dispersion correction
  - internally reflecting focussing lightguides
- one-dimensional imaging DIRC
- radiator with very good RMS roughness required
- perfect edges (as in the BaBar DIRC) not needed
- number-of-pixels ~ p^4
- stringent requirements for photon detectors

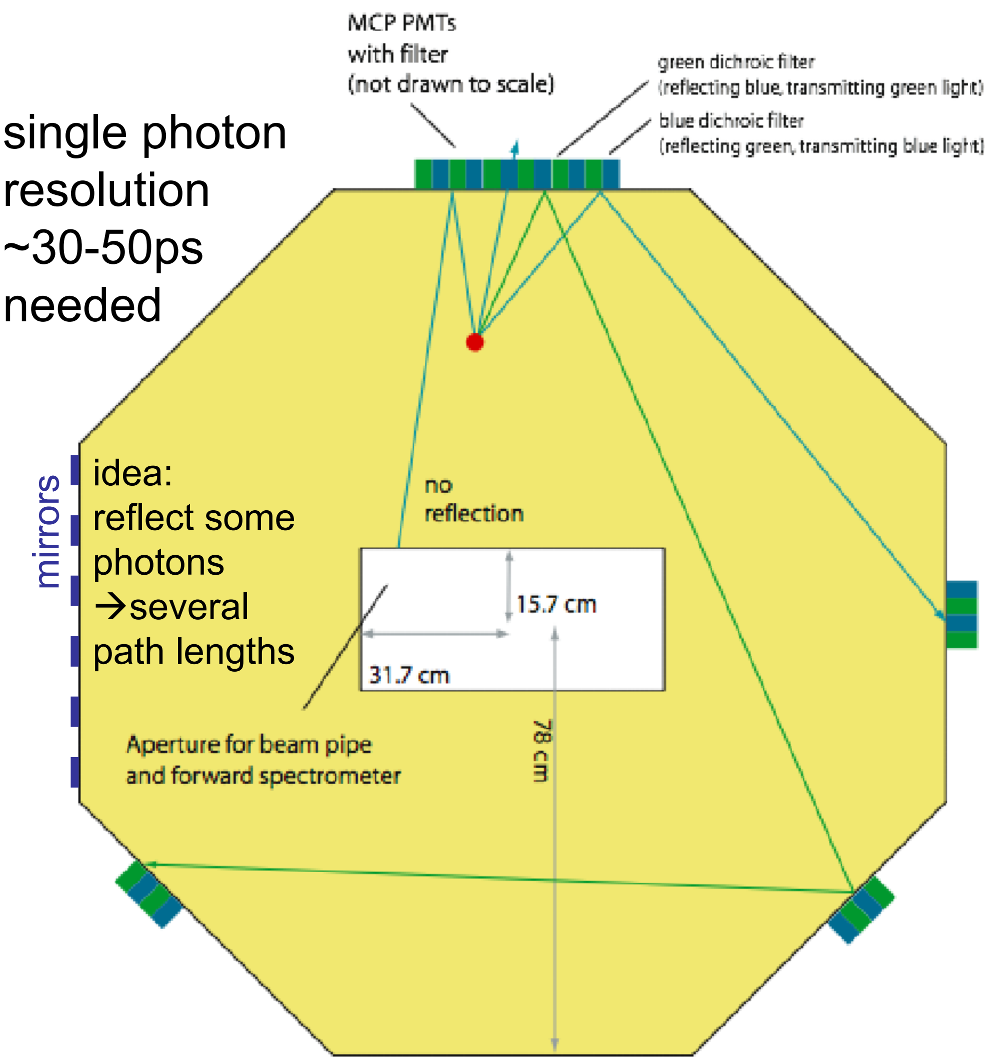
- two alternative designs, one DIRC, one RICH
- two examples of material tests

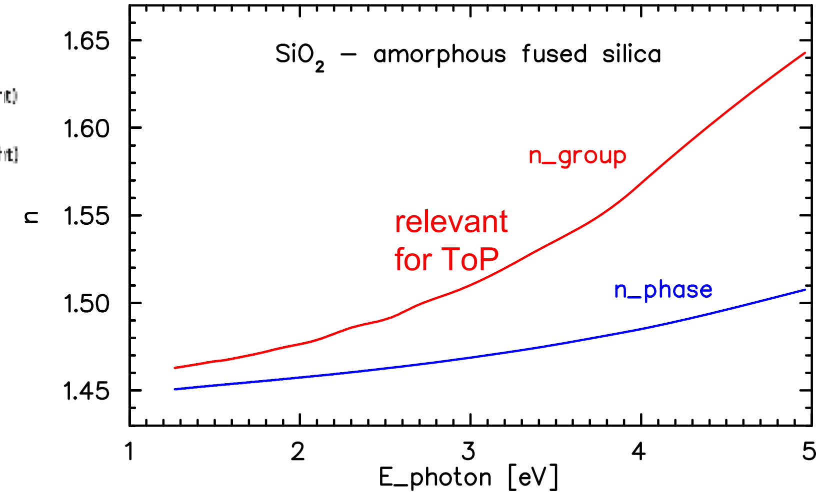
working on Čerenkov detectors for PANDA:
Edinburgh, GSI, Erlangen, Gießen, Dubna, Jülich, Vienna, Cracow, Glasgow

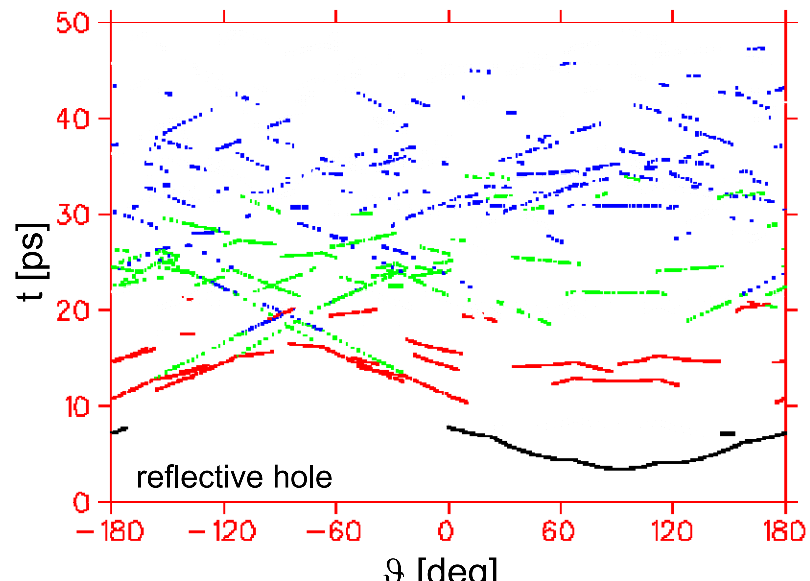
Time-of-Propagation design

M. Düren, M. Ehrenfried, S. Lu, R. Schmidt, P. Schönmeier

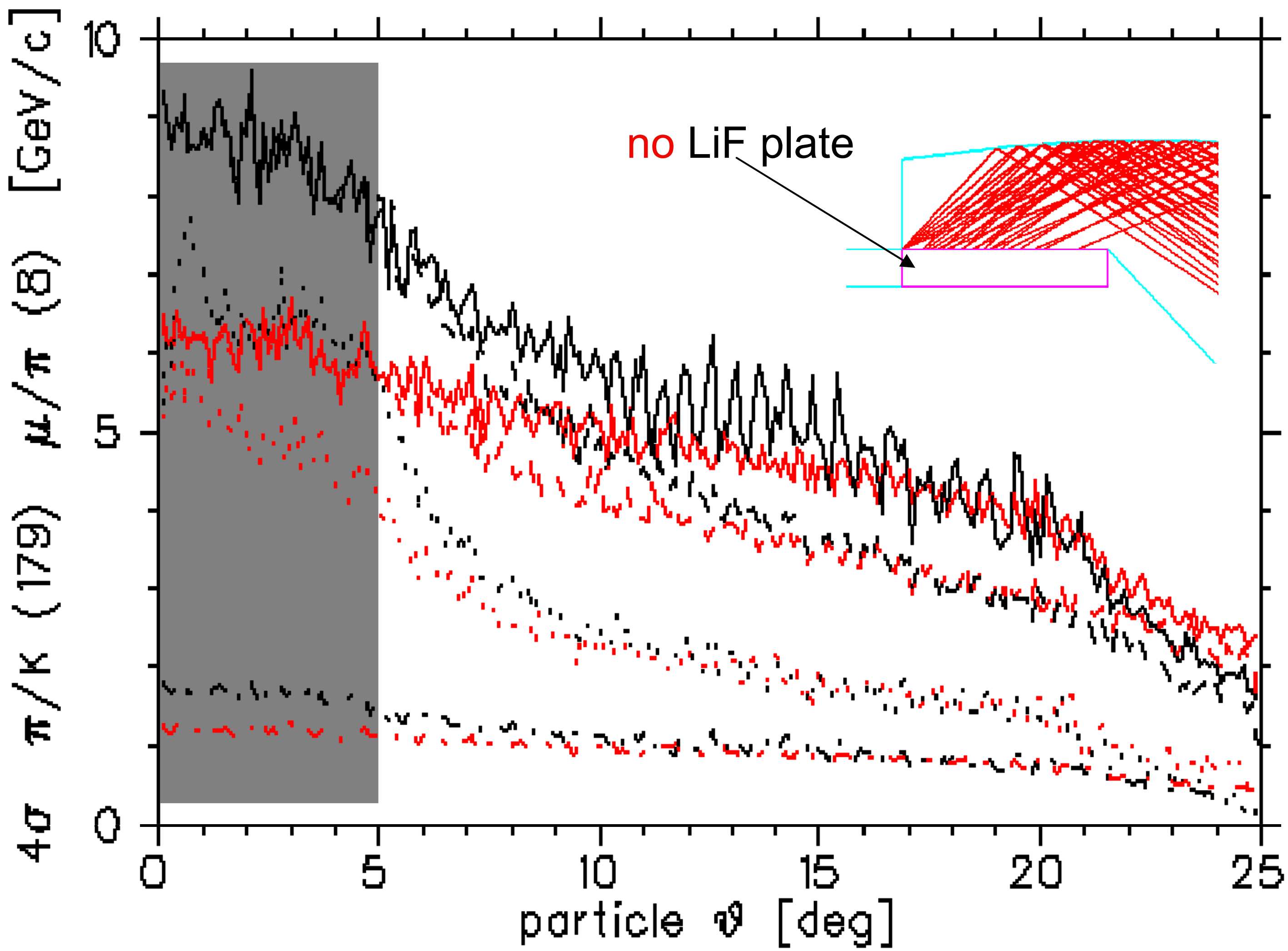
single photon resolution ~30-50ps needed



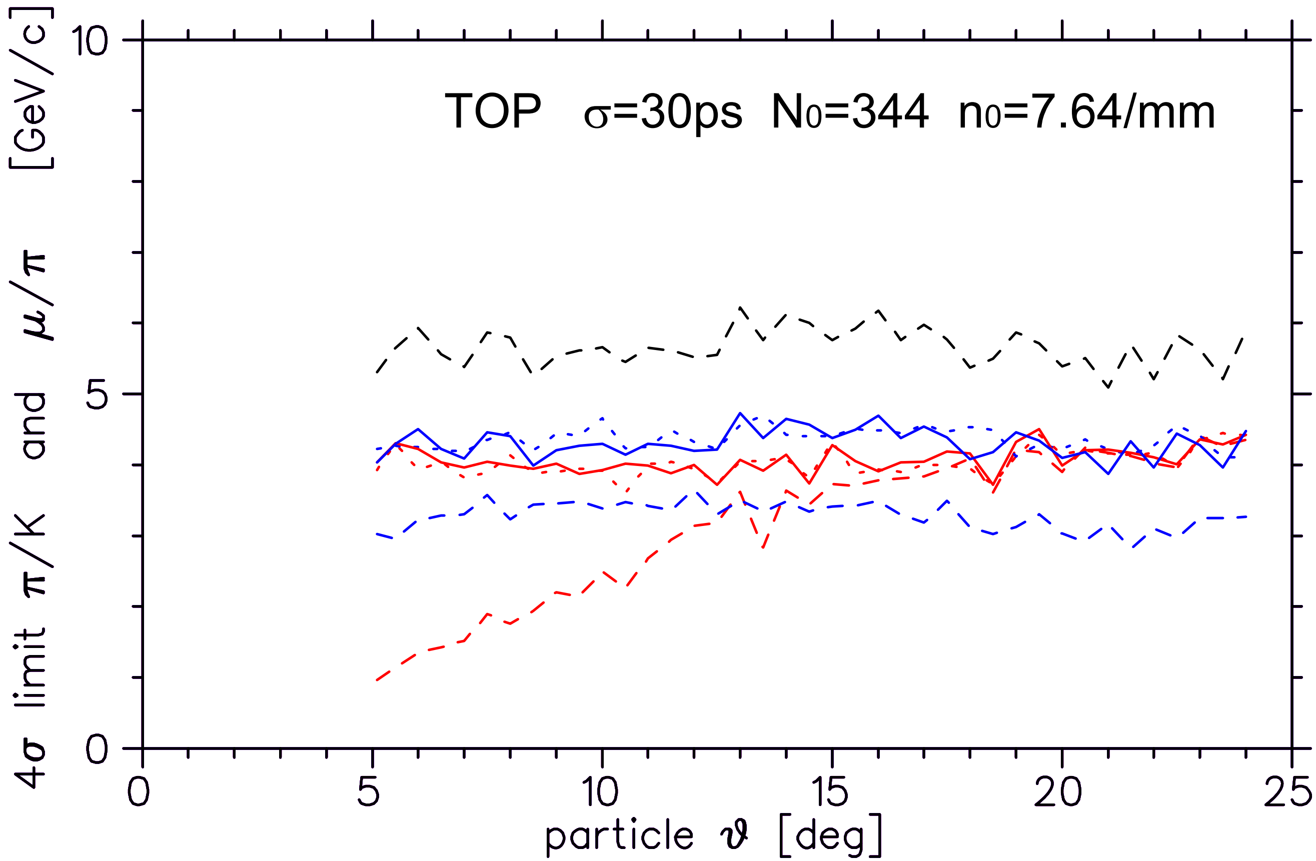




Focussing Lightguides

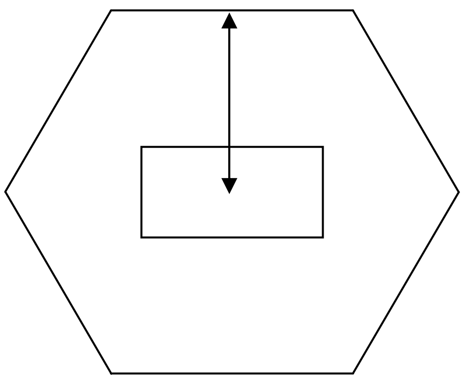


Time-of-Propagation

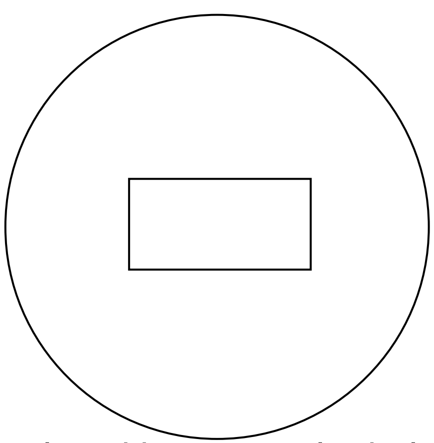


Time-of-Propagation

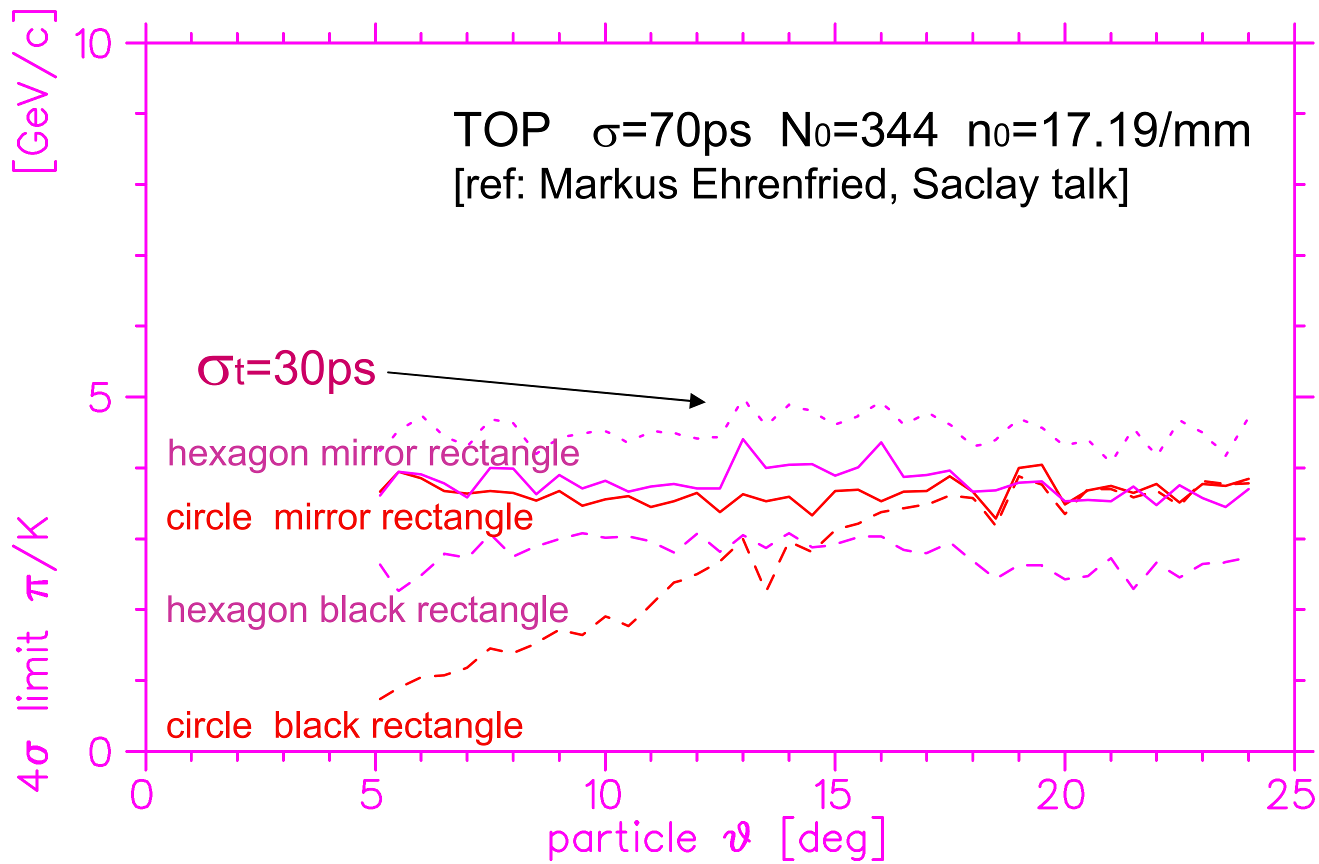
comparison:
hexagon 960mm width or round disc 1100mm radius



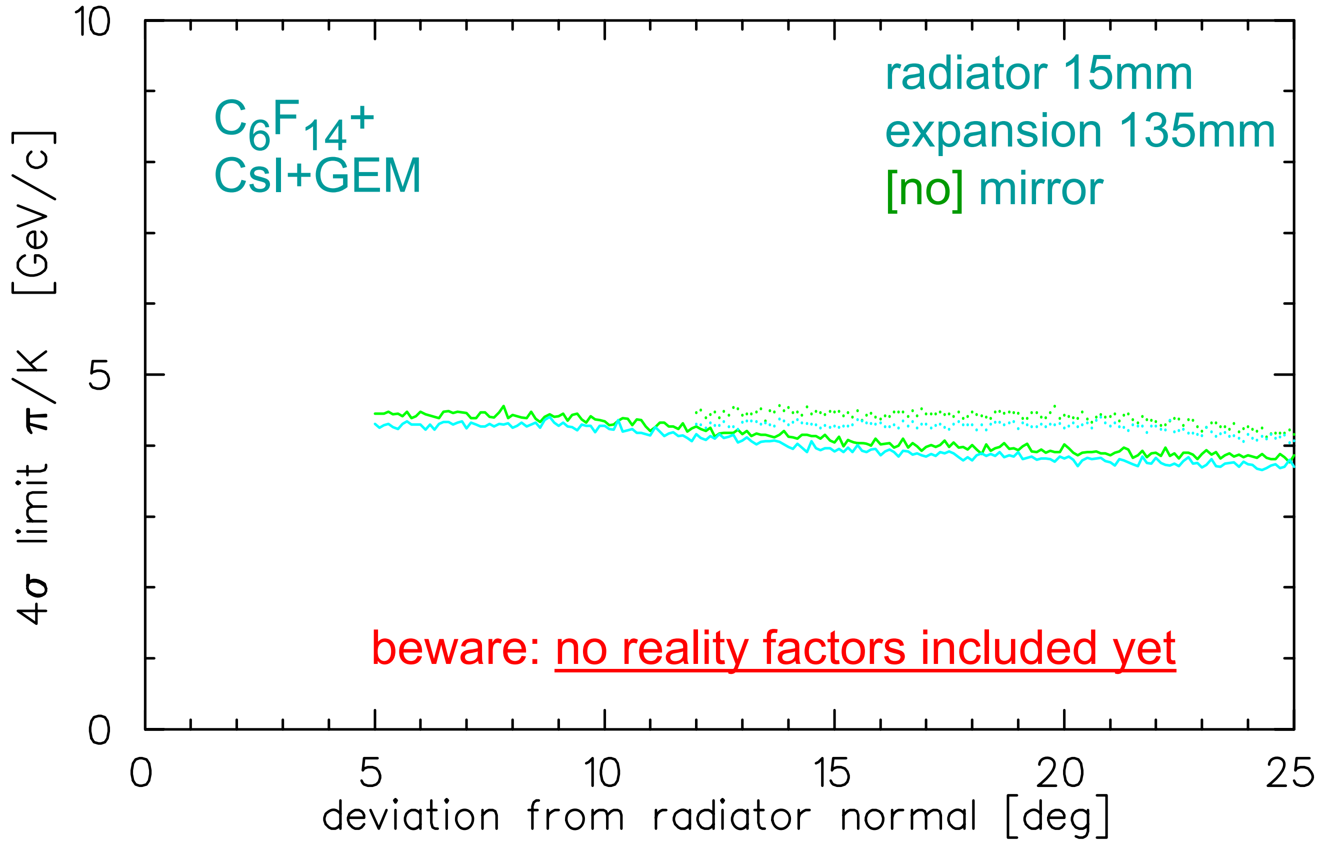
hexagon with rectangular hole



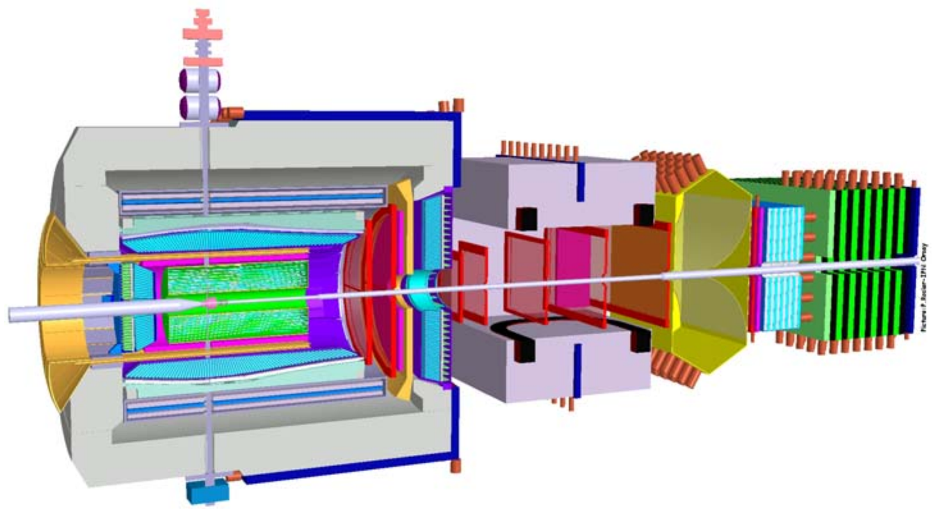
circular with rectangular hole



Proximity Focussing



Focussing disc DIRC design for PANDA

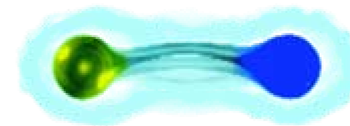


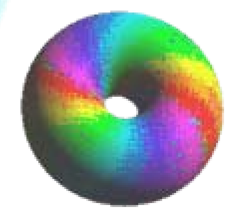
Klaus Föhl

18 July 2007

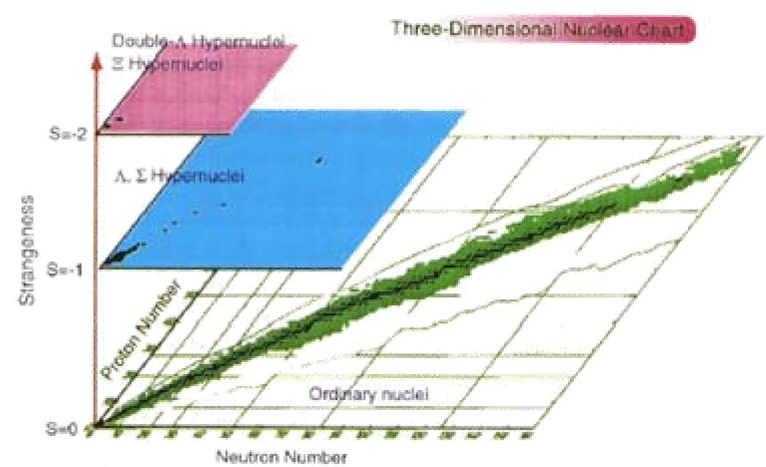
LHCb RICH Group meeting at Edinburgh

Core programme of PANDA (1)

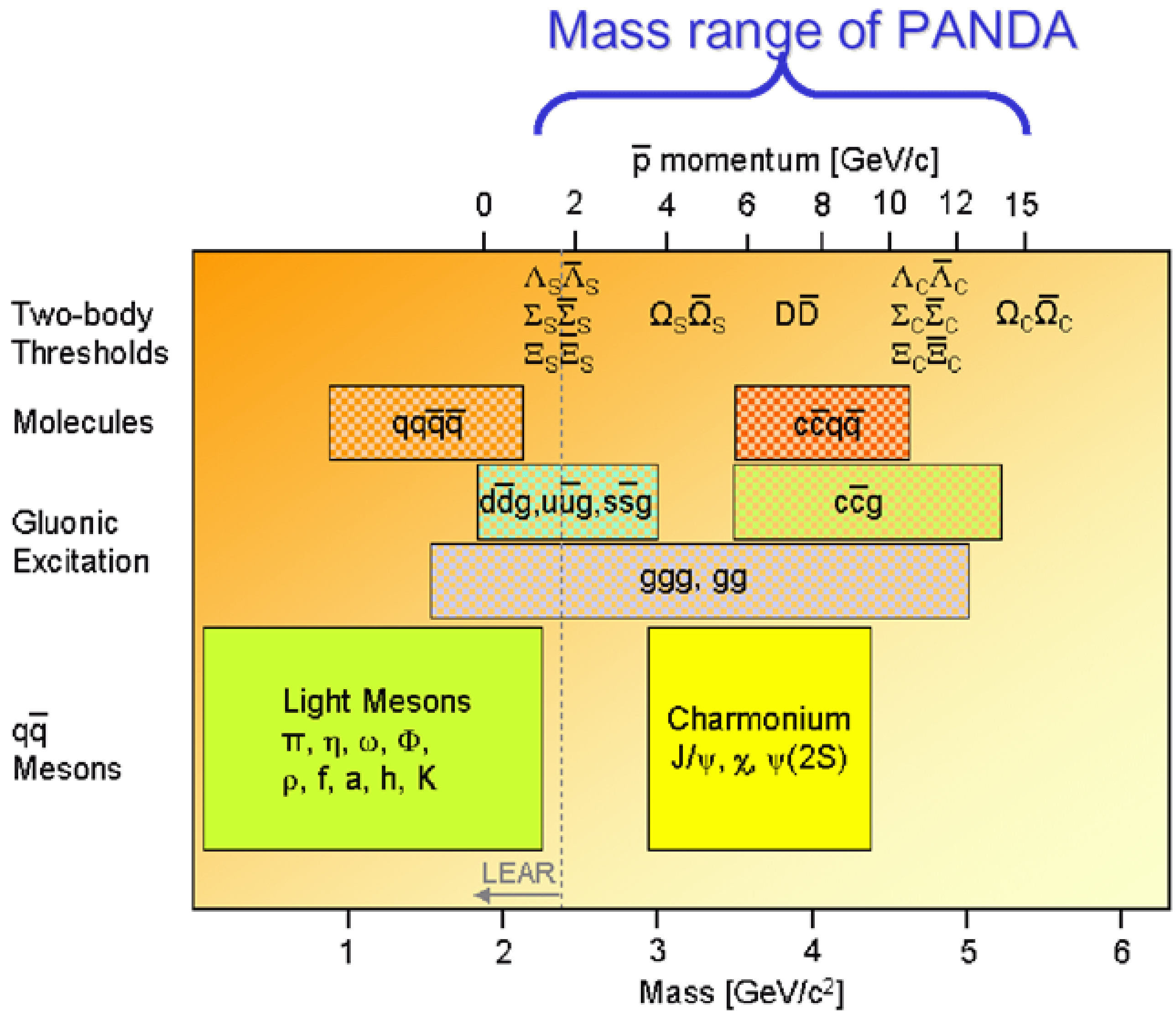




- Hadron spectroscopy
  - Charmonium spectroscopy
  - Gluonic excitations (hybrids, glueballs)
- Charmed hadrons in nuclear matter
- Double Λ-Hypernuclei

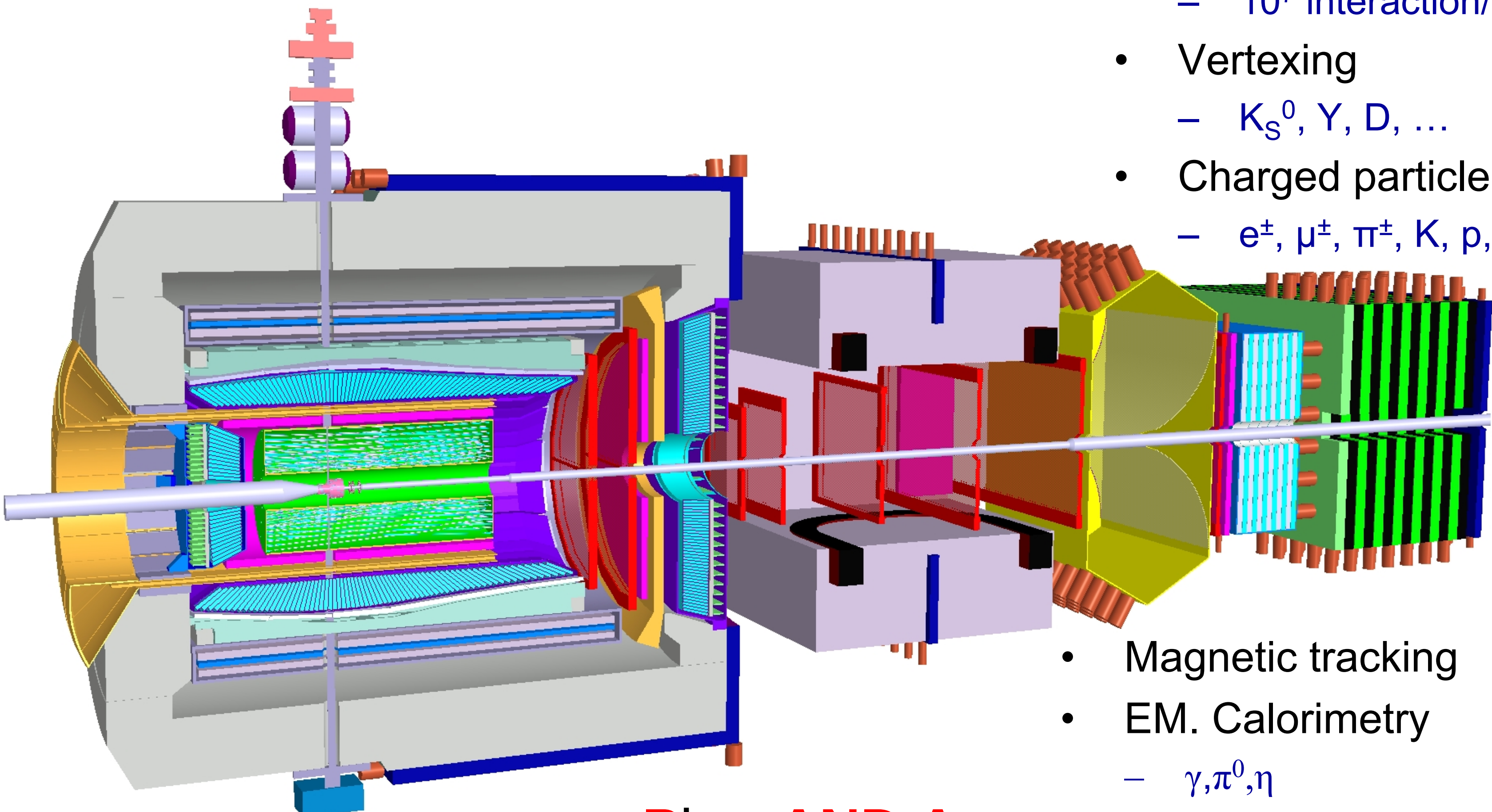


Core programme of PANDA (2)



- Production of open charm
- Charmed hybrids
- Glueballs
- Charmonium

P̄ANDA Side View



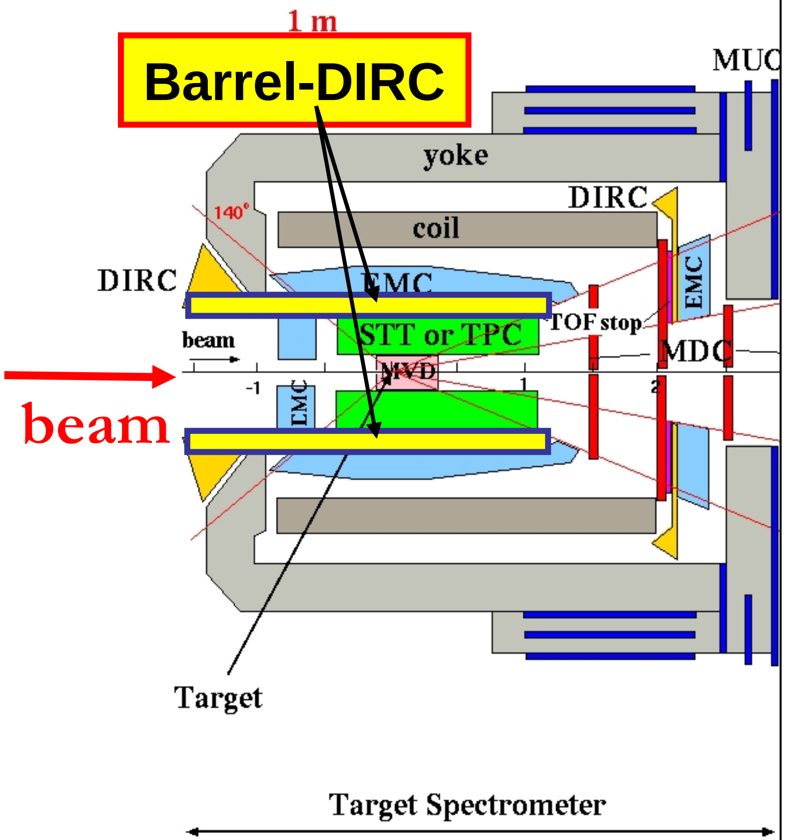
- High Rates
  - 10^7 interaction/s
- Vertexing
  - K_S^0, Y, D, …
- Charged particle ID
  - $e^\pm$, $\mu^\pm$, $\pi^\pm$, K, p,…
- Magnetic tracking
- EM. Calorimetry
  - γ, π^0, η
- Forward capabilities
  - leading particles
- Sophisticated Trigger(s)

Pbar **AND A**

Anti**P**roton **AN**ihilations at **DA**rmstadt

PANDA Detector

Top View



2-dimensional imaging type