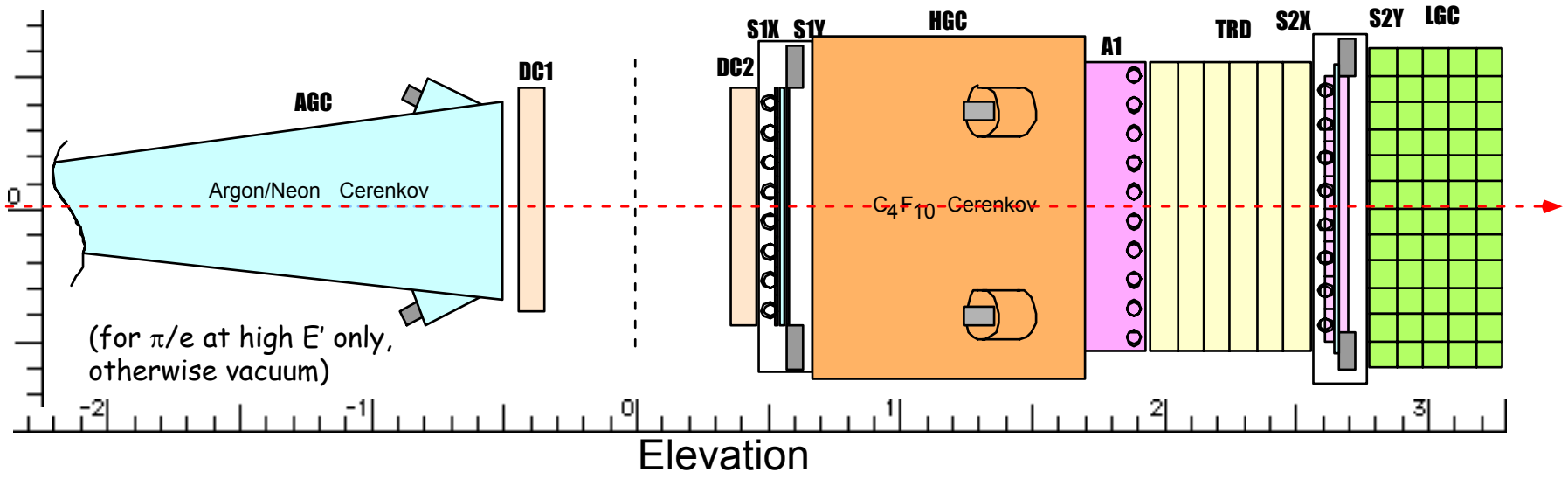
SHMS Atmospheric Čerenkov

Donal Day
University of Virginia
August 4-5 , 2008
Hall C Summer Meeting



Outline

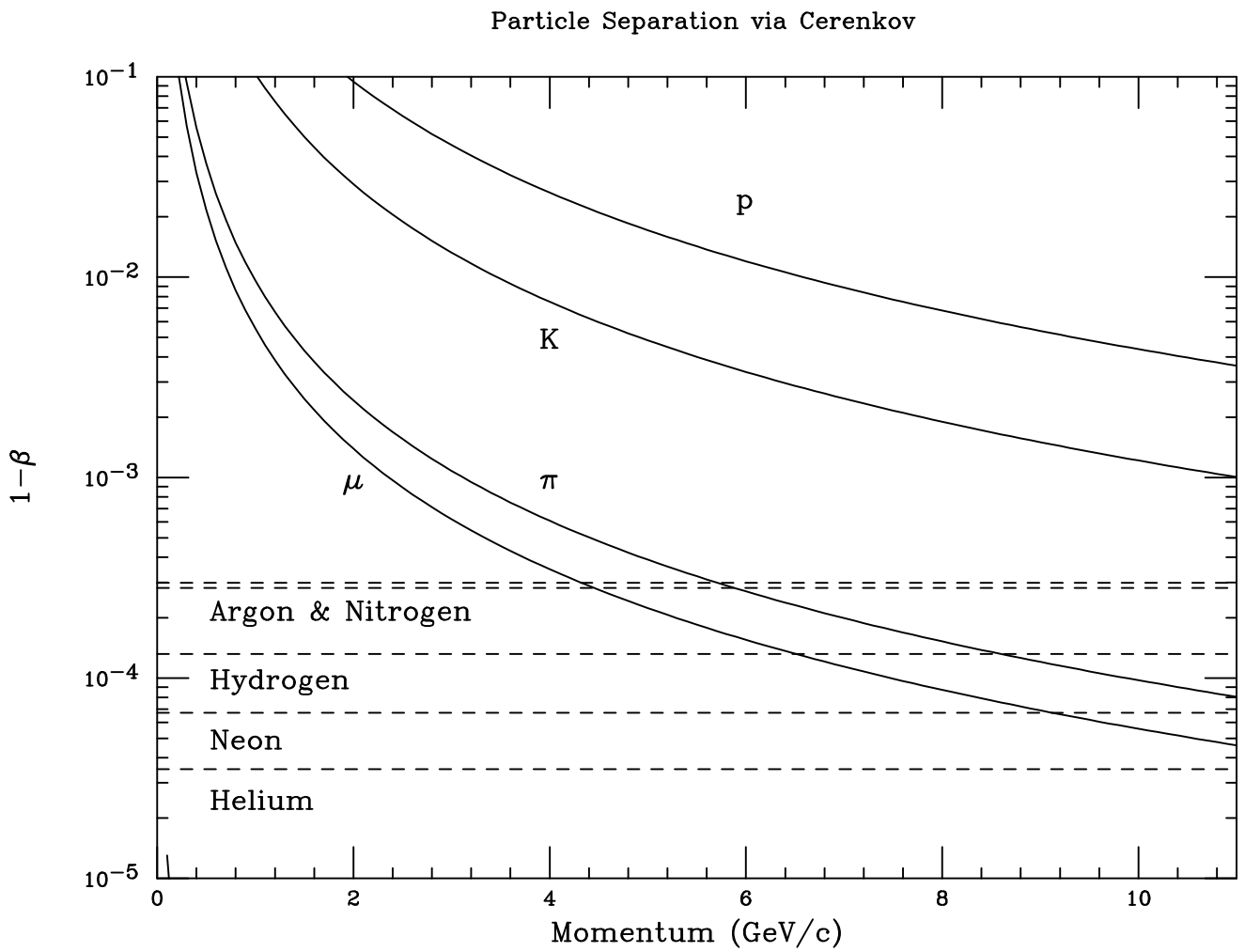
- Introduction
- "Research and Development"
  - Choice of Gas
  - Expected Performance
  - Light Collection
  - GEANT4 simulation of optics
  - Tank Design
- Timeline

Introduction

Threshold Gas Cerenkov Detector shoulders a large portion of the particle identification burden.

Basic formula governing Cerenkov radiation $\cos\theta = \frac{1}{\beta n}$

$n < 1/\beta_{\pi,max}$ and $n > 1/\beta_{e^-,min}$



Choice of gases

Gas	k	$P_{max}^{6\ \mathrm{GeV/c}}$	$P_{max}^{10\ \mathrm{GeV/c}}$
Helium	.238	7.73	2.30
Neon	.456	4.04	1.20
Hydrogen	.939	1.96	0.58
Oxygen	1.85	0.99	0.30
Dry Air	1.86	0.99	0.29
Argon	2.21	0.95	0.28

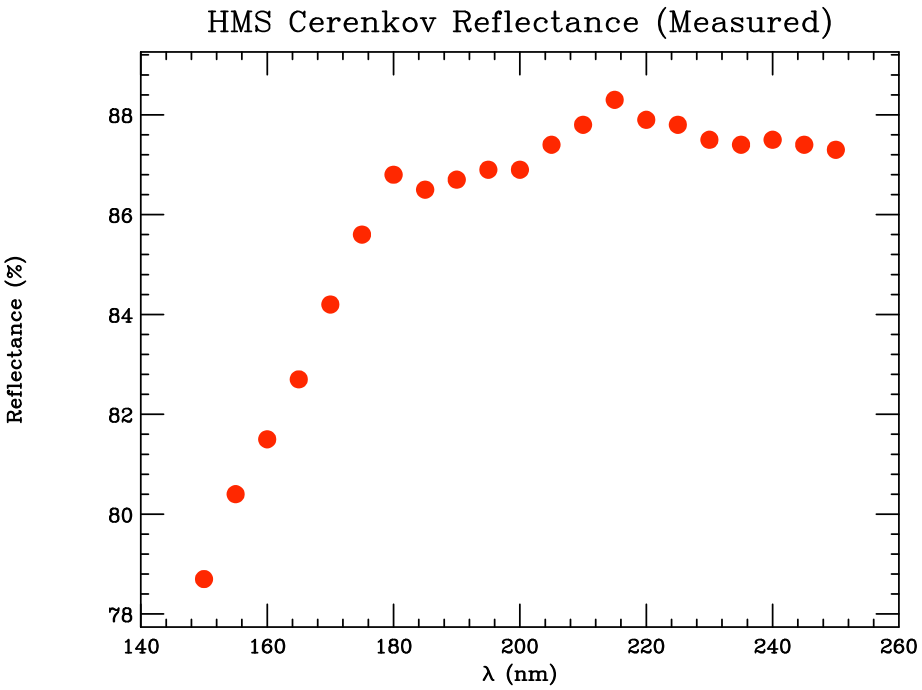
$$P_{max} = \frac{1 - \beta_{\pi,max}}{\beta_{\pi,max} k} \qquad k = \frac{n-1}{14.7}$$

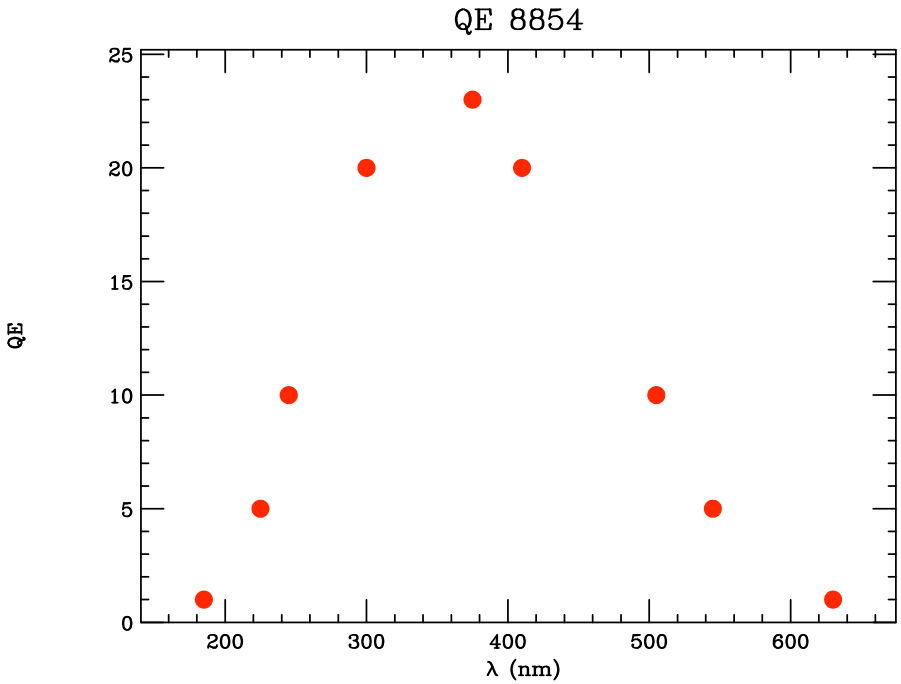
Photoelectron Yield

$$N_e = 2\pi a\left(1 - \frac{1}{\beta^2 n^2}\right) \int_{\lambda_1}^{\lambda_2} \epsilon_c(\lambda) QE(\lambda) G(\lambda) \frac{d\lambda}{\lambda^2} \int_0^L dx$$

$$= AL\left(1 - \frac{1}{\beta^2 n^2}\right)$$

Mixture of Neon and Argon





Company	Tube	Size (in)	λ_1 (nm)	λ_2 (nm)	A cm^{-1}	N_e
Burle	8854	5	185	630	127	5.1
Thorn EMI	9623B 9530B	6.9 4.5	320	650	76	3.1
Thorn EMI	9623BQ 9530BQ	6.9 4.5	160	650	249	10.0
Thorn EMI	9791BQ	4.5	180	620	123	5.0
Hamamatsu	R1836	5	160	650	256	10.3
Hamamatsu	R1584	5	185	650	209	8.4

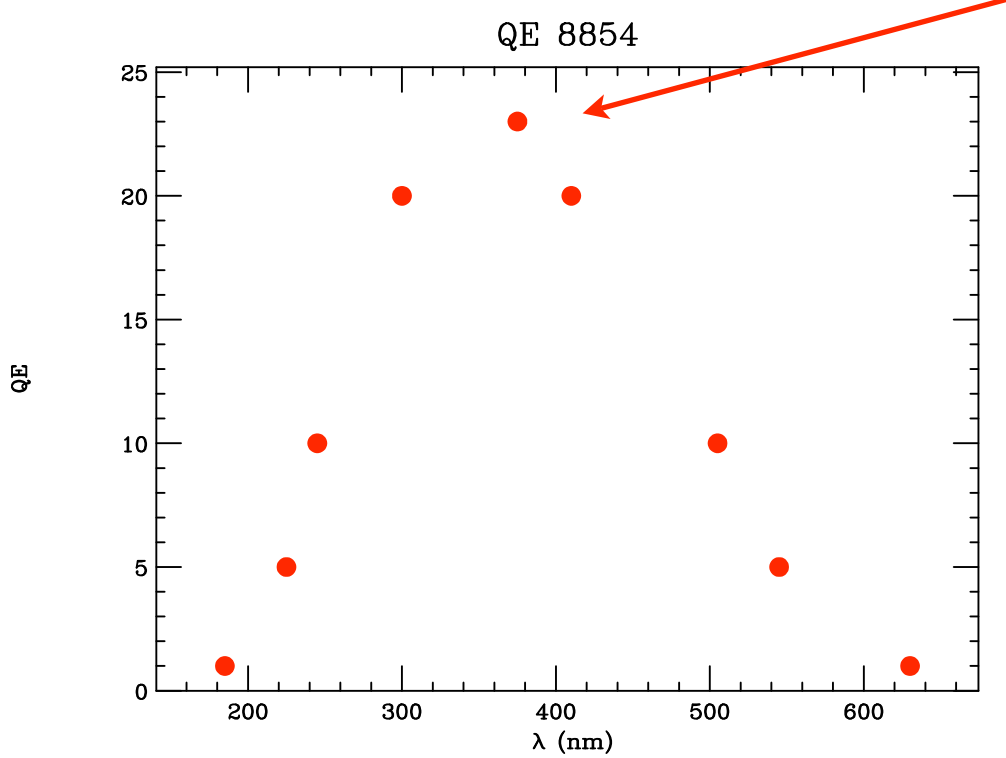
Neon at 1 atm
2.5m active volume
$G(\lambda) = 1$, $\varepsilon(\lambda) = 1$.

Quartz ($$!)

Wavelength Shifter

Circumvent the insensitivity of the PMT at small wavelengths and avoid the expense of quartz tubes by coating the PMT window with a thin layer of WLS material

A thickness of 24.3 kÅ of para-Terphenyl absorbs all light in the wavelength range from 110 nm to 360 nm; within 1 to 2 ns, on average, the pTP subsequently de-excites with 74% efficiency by fluorescence in a narrow band centered on λ = 385 nm, precisely where the 8854 is most sensitive.

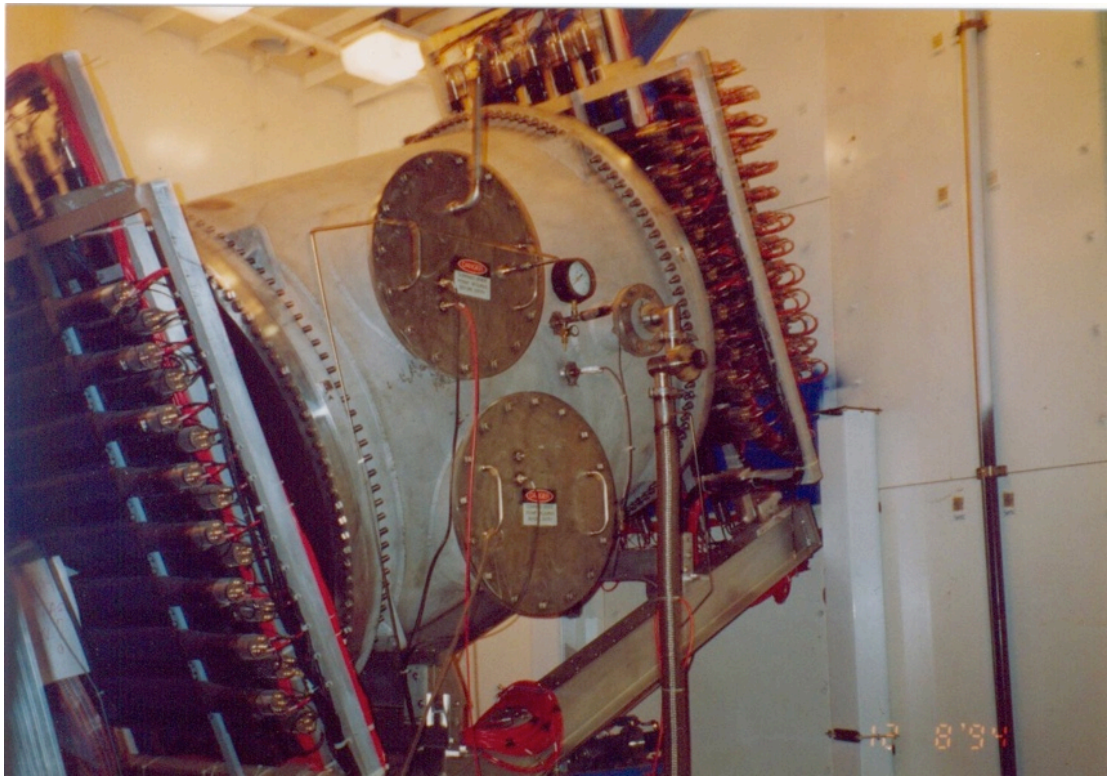


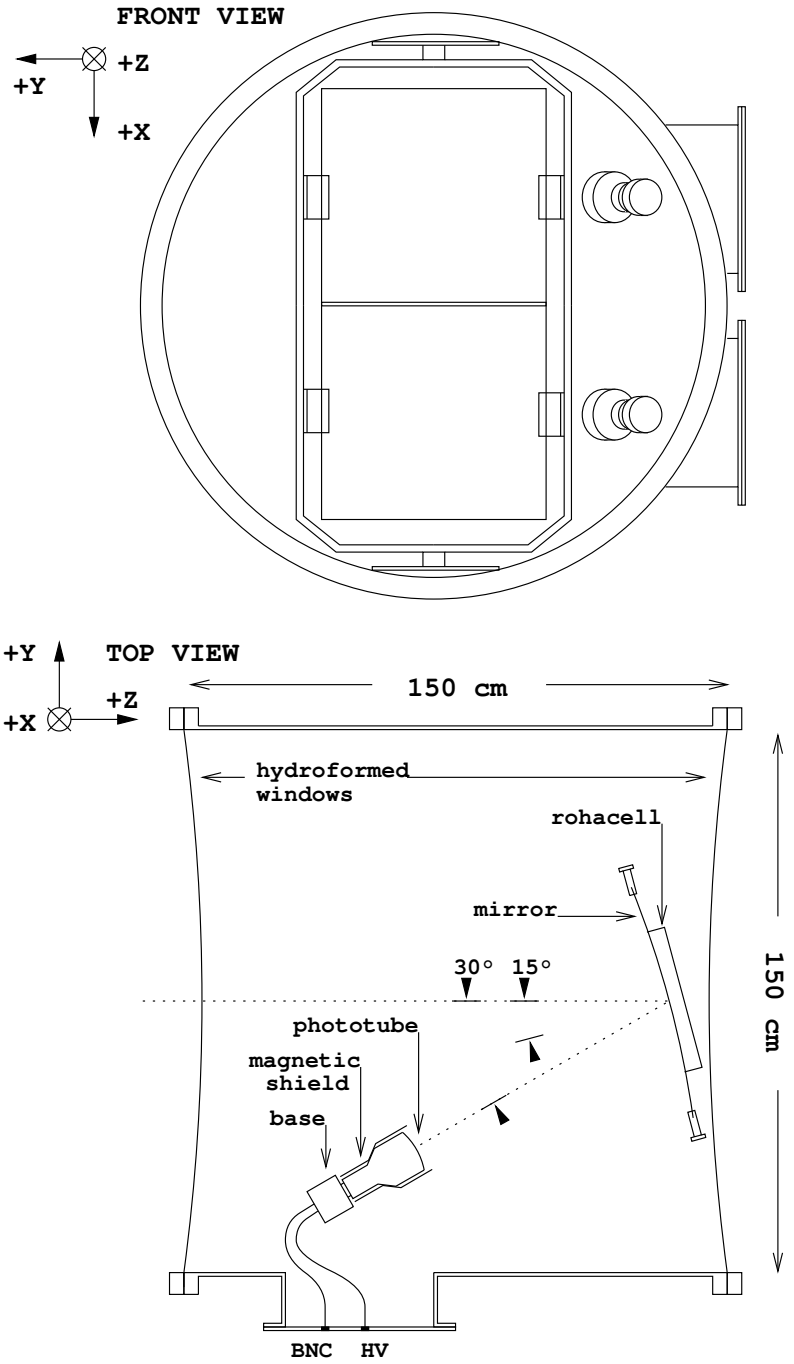
Expected performance

10 p.e.

Proof of Principle

HMS 1.5 m Threshold Cerenkov



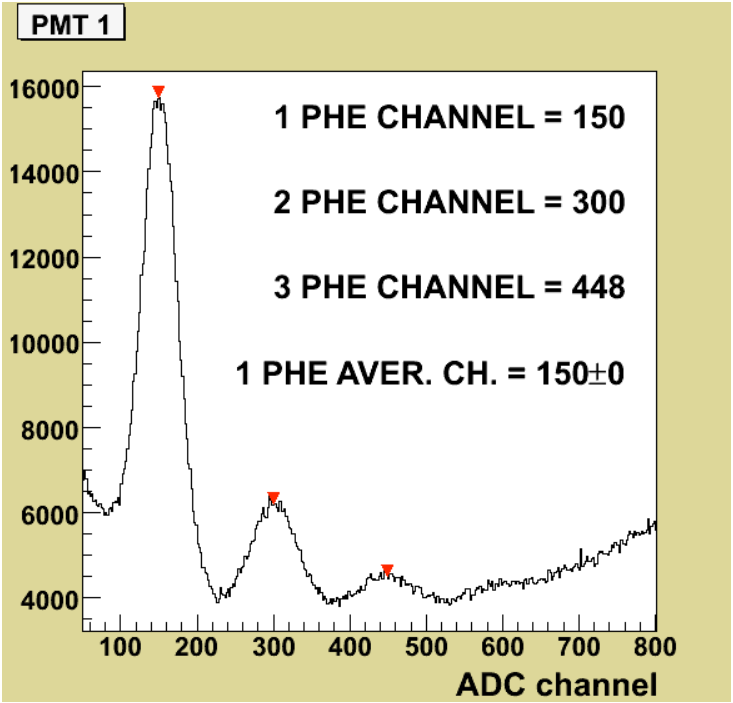


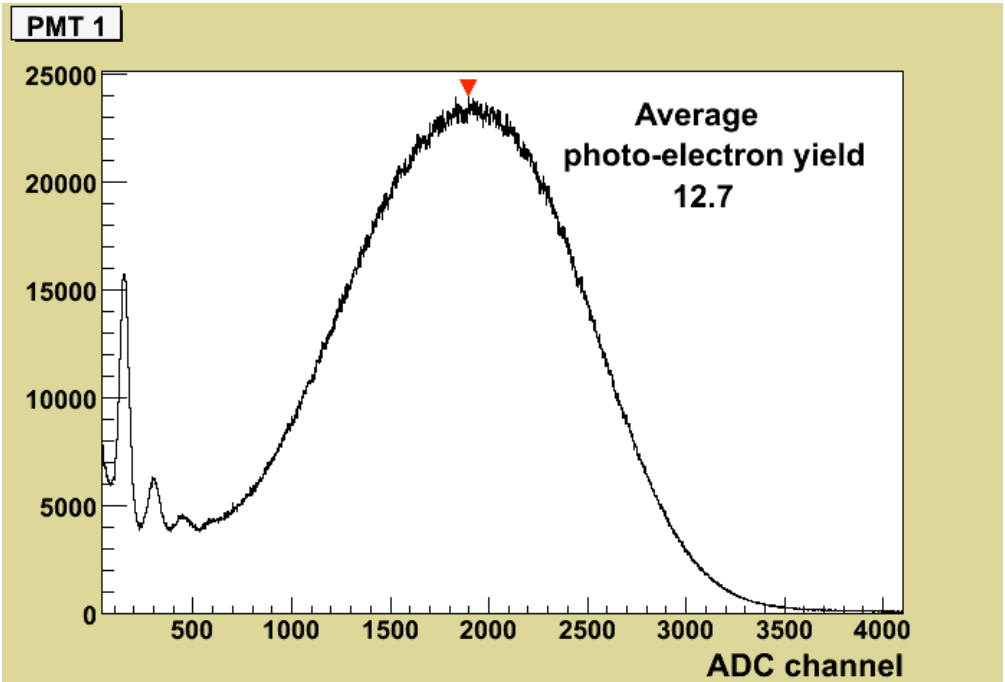
Mirrors etc.

R = 163 cm, 3mm, 65 by 60 cm from CERN, backed by Rohacell for stiffness

Performance during Rosen07

4 GeV pion threshold: C_4F_{10} at 0.6 atm

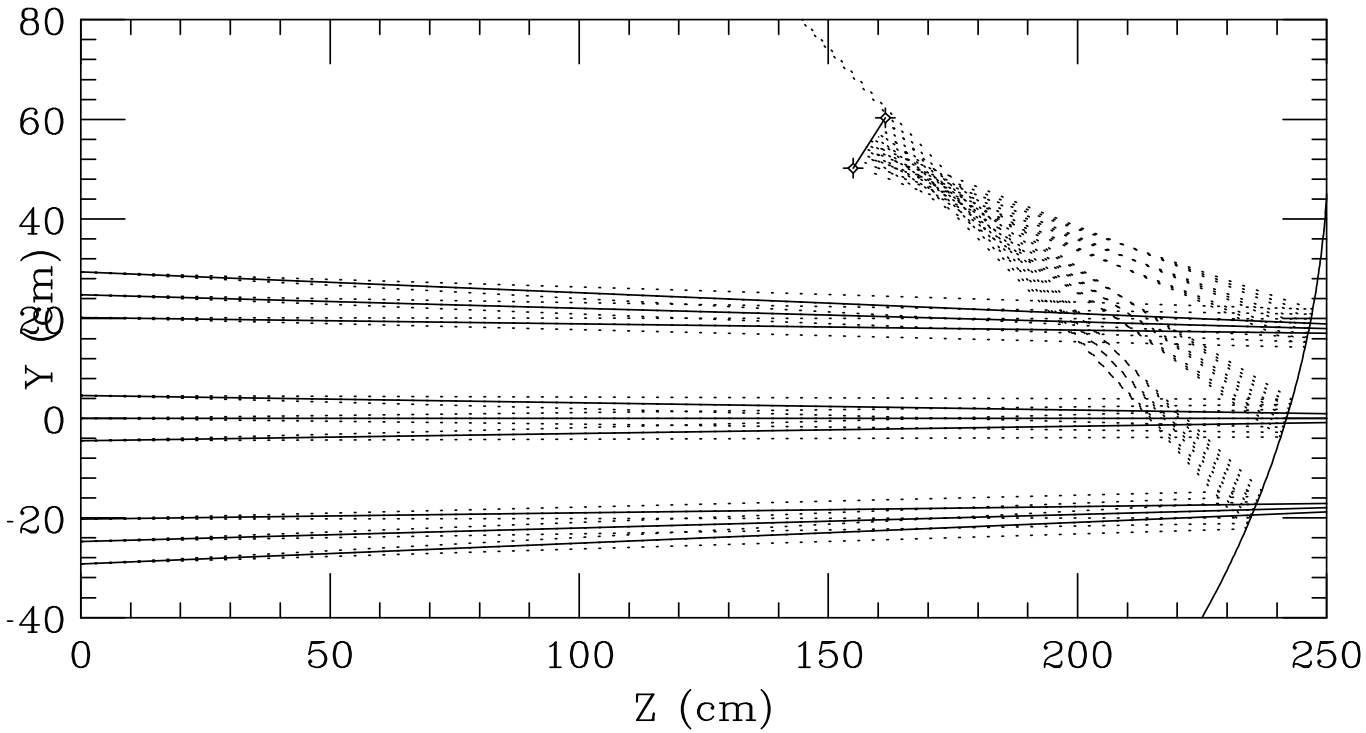




E′ (GeV/c)	π/e ratio	Rejection				
		Calorimeter	Cer	Total	Spect	Status
> 5-6	< 50:1	100:1	50:1	5000:1	SHMS	To be Built
< 5	≤ 1000:1	50:1	200:1	10000:1	HMS	Demonstrated

Light Collection Efficiency, # Mirrors

- Parallel rays focus light to a location f = R/2. With a Cerenkov angle of θ_c light focuses onto a ring of radius r = f θ_c . Ring is blurred due to aberrations and variation of the angles in the beam.
- r = f(θ_c + $\Delta\theta_m$ + $\Delta\theta_b$) $\Delta\theta_b$ are the electron angles
- Light collection must be studied by tracing rays



Single 200 cm spherical mirror

$\Delta\theta$=±24 mr, Δy= ±10 cm

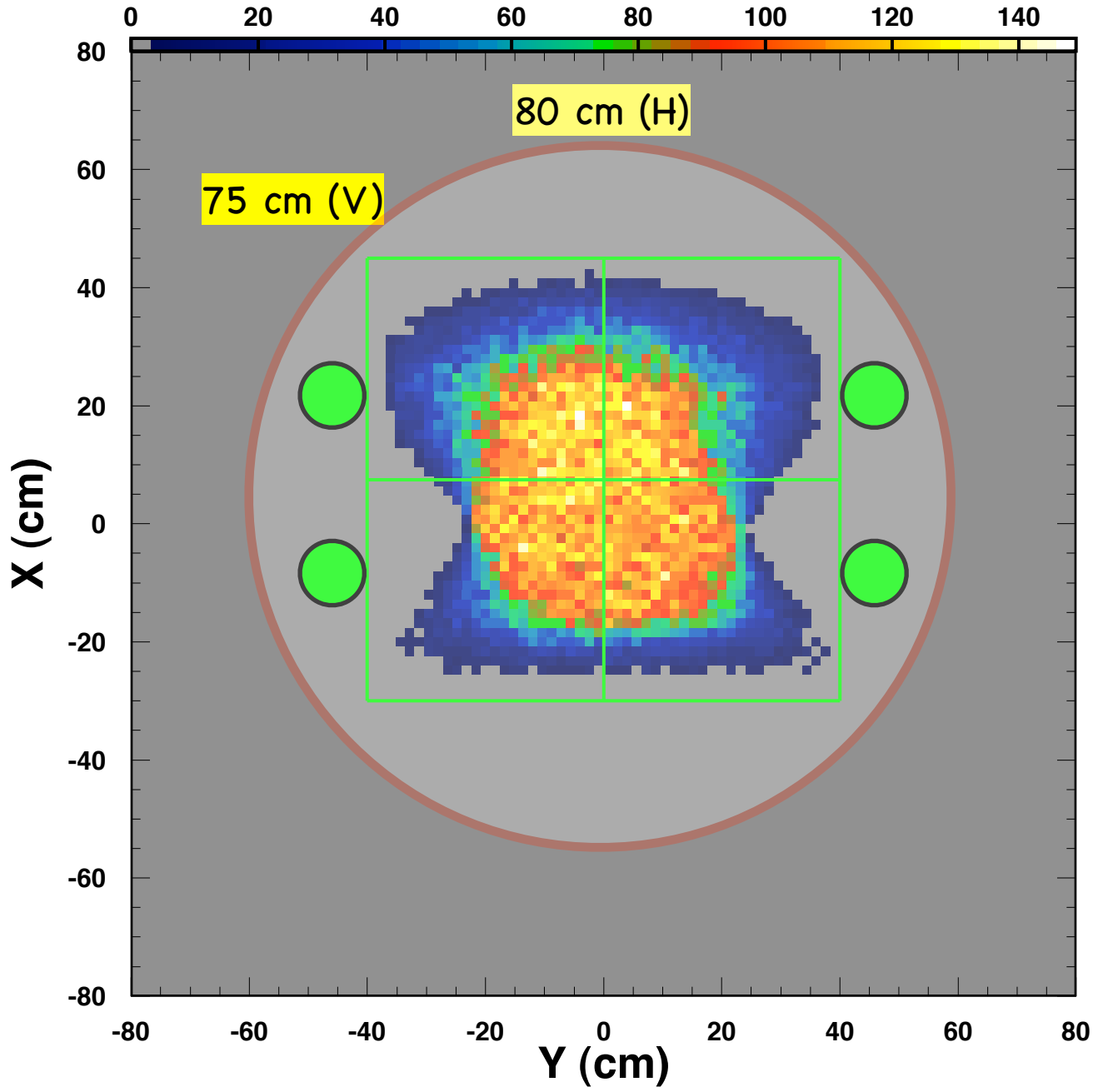
Prefer small tilt angle, smaller mirrors

Number of mirrors/PMTs to be studied

4 mirrors on 4 PMTs

200 cm radius of curvature

80/2 cm x 75/2 cm

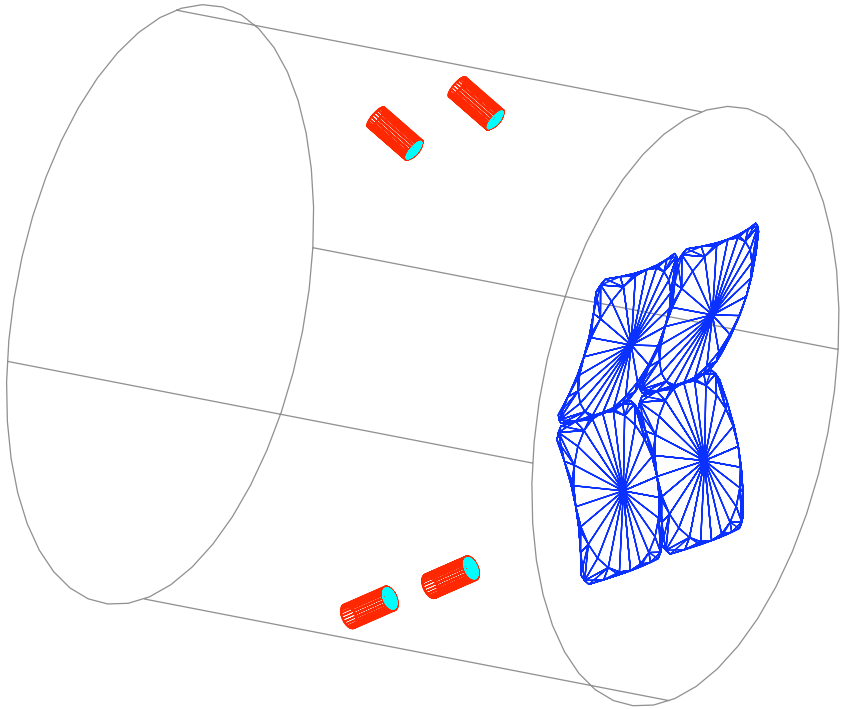


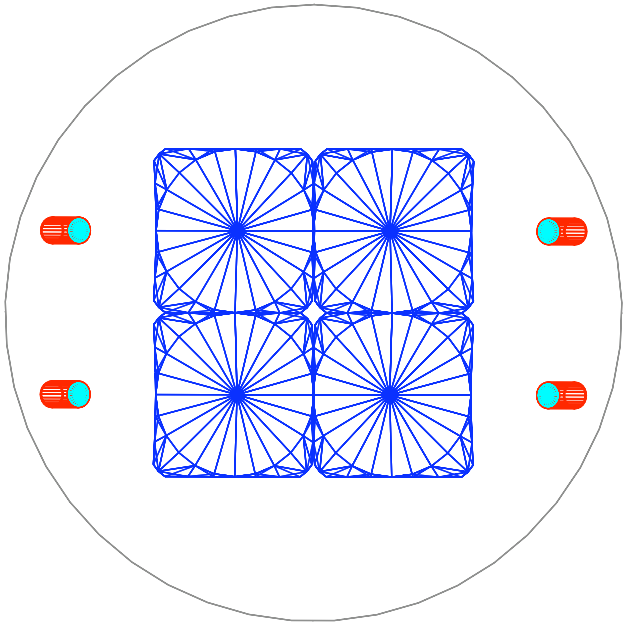
What's New

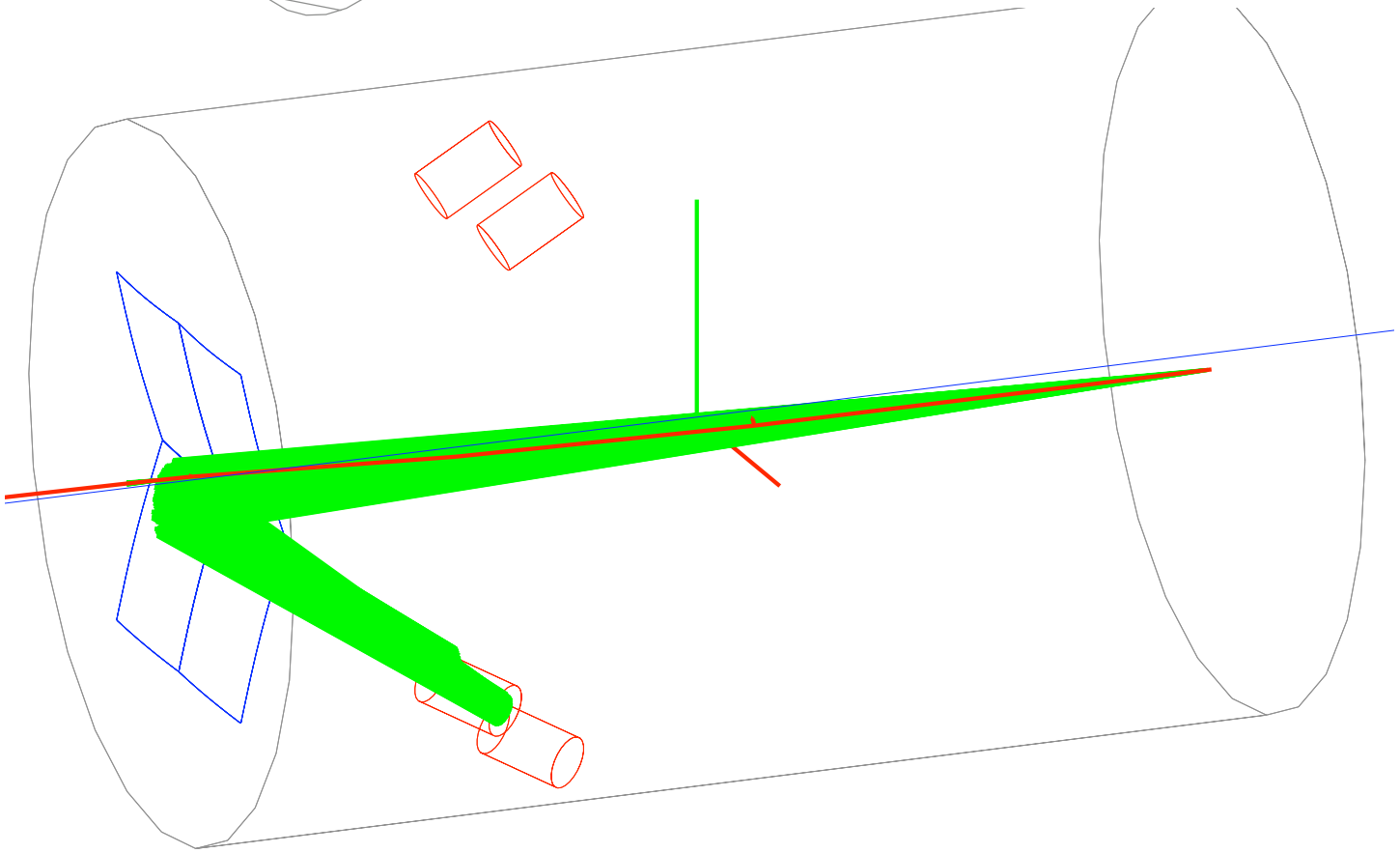
- Raytrace code used for mirror placement until now is inflexible, does not allow (easily) four mirrors. Single purpose code.
  - GEANT 4 simulation of optics
    - Work done by Vahe Mamyan, UVa student on Rosen07.
  - Would be useful in a full blown model of SHMS detector stack, something that does not exist for the HMS

GEANT 4 simulation of optics

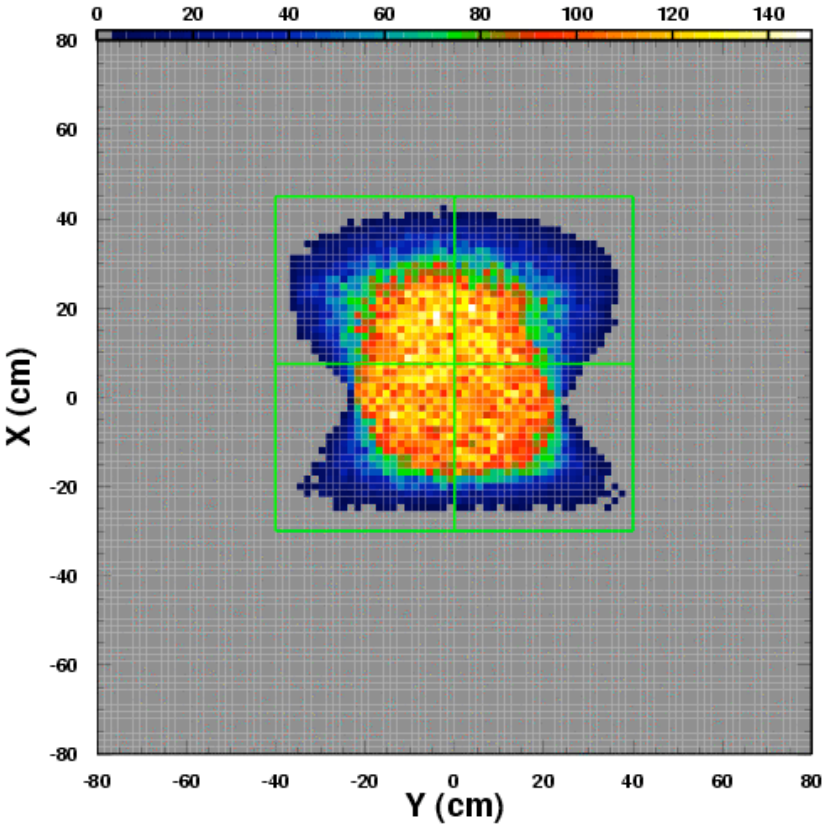
- 250 cm tank, 15 meters from the target
- 1 Atm Neon
- 4 mirrors; each 75/2 cm tall and 80/2 cm wide
- 200 cm radius of curvature, 15^0 degree tilt
- 3 mm glass coated with Al



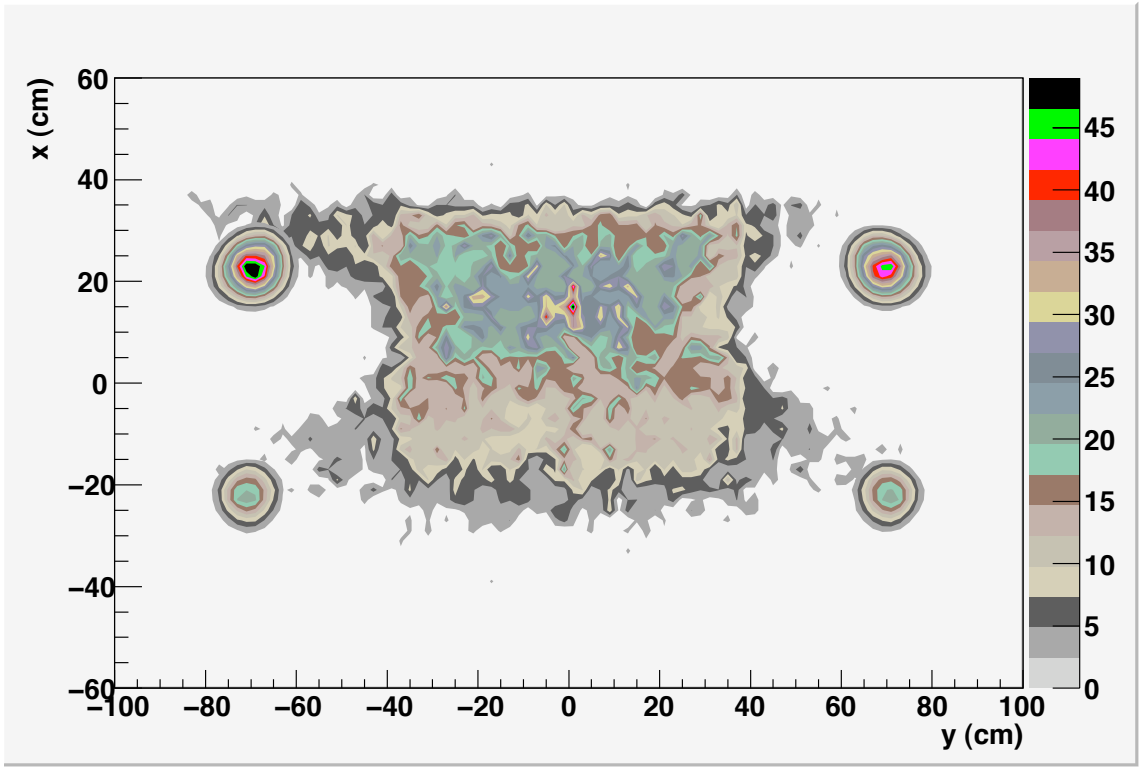




- Flat distribution in δp (+22 to -10), in y_{targ} (-20 to +20 cm), in θ (-24 to + 24 mr) and Φ (-55 to + 55 mr)
- 2nd order transport matrices of electrons from target to Cerenkov



From T. Horn



Electron distribution at the front of Cerenkov after transport. The 4 circles are spots where photons hit a plane perpendicular to z axis inside the Cerenkov after reflection from mirrors

Tank design

- Tank at 1 Atm trivial, fill by repeated dilution
  - Demand that tank serve as extension of vacuum when not in use demands more
    - Removal of mirrors when not used?
    - Cylindrical tank or conical tank?
- Current thinking is to simply pull the tank and replace with vacuum vessel as needed.
- Design and layout unfinished

Timeline

- Conceptual Design: Jan. 2009
  - GEANT4 simulation
  - Mirror Selection, tube placement
  - Tank concepts, gas handling, etc.
- Preliminary Design Report: Jun. 2009
- Engineering Design: Jun. 2009- Jan 2010
- Procurement/Construction: Jan. 2010 - Dec. 2011
- Delivery: Summer 2012
- Installation: Winter, 2013
- Commissioning: Winter, 2014