Issues for a Quadrupole Spectrometer Option for Møller Scattering at JLab

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12 GeV Møller Workshop

Outline

- Some facts on Møller at JLab
- Basic Quadrupole Concept
- E158 Spectrometer
- Plans

E158 Spectrometer:

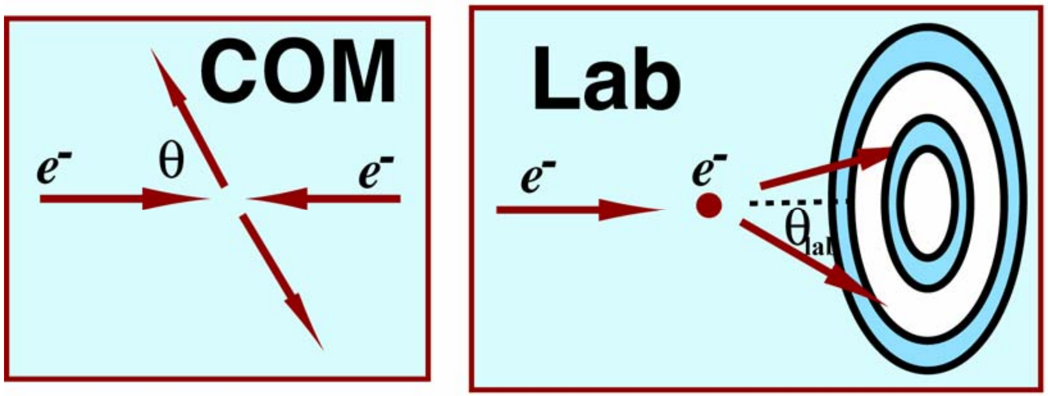
Concept: ***Makis Petratos, Paul Souder, KK***

Simulations: ***Marcus Spradlin, David Relyea***

Implementation: ***Peter Bosted, Ray Arnold***

Collimation: ***Dieter Walz***

Møller Kinematics

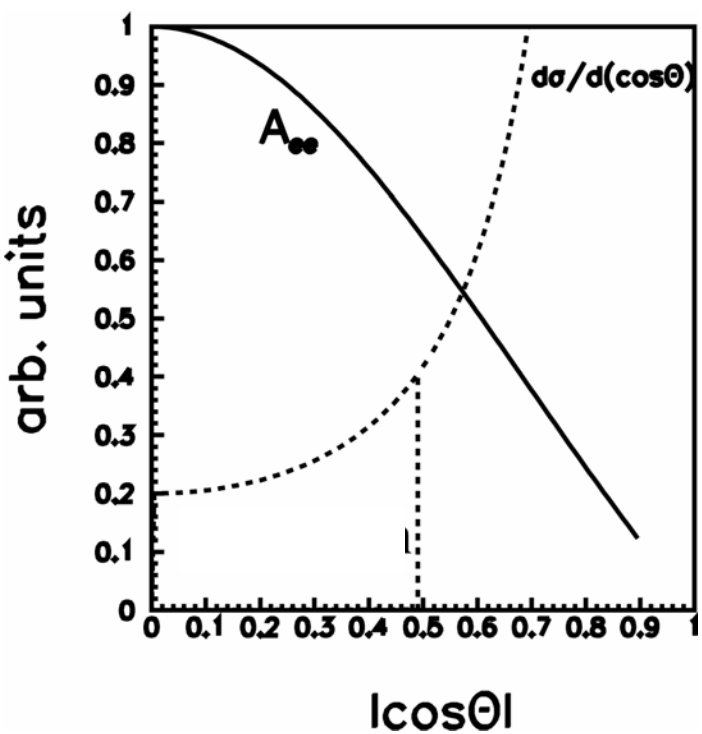


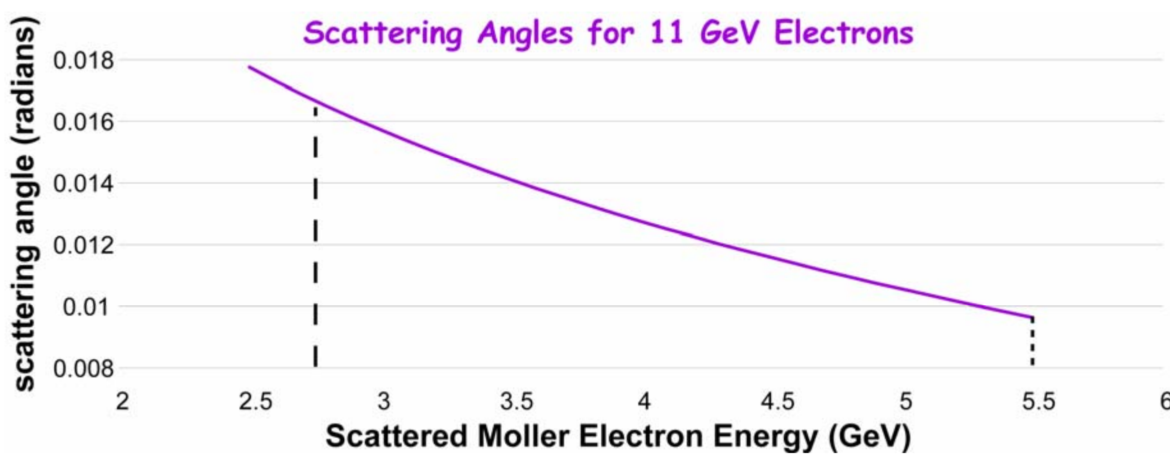
- *Identical particles*
- *Full range of azimuth*
- *Choose backward COM angles*

$$E' = \frac{E_{beam}}{2}\left(1 + \cos\Theta\right)$$

11 GeV in: 2.75 to 5.5 GeV out

$$\theta_{lab} = \sqrt{2m_e\left(\frac{1}{E'} - \frac{1}{E_{beam}}\right)}$$





Why Quadrupoles?

- Exploit energy-angle correlation
- Full range of the azimuth (statistics, statistics, statistics…)
- Compact ring focus downstream
  - **Small detector footprint**
  - **Total absorption counter has advantages**
- Potentially cheaper
- Worked once (E158)
- Some backgrounds more easily handled
- E158 Quads effectively provide "double" strength
  - **For fixed B field, bending angle goes like 1/p**
  - **Average momentum smaller by a factor of 4**
  - **Scattering angle larger by a factor of 2**

Contact Interaction Limits

leptonic

LEP and LEPII: ***18 TeV for Λ_{VV}***

8 TeV for Λ_{LL}

E158: ***12 TeV for Λ_{LL}***

A 500 GeV ILC will reach 40 TeV for Λ_{VV}

20 TeV for Λ_{LL}

Semi-leptonic

Tevatron: ~ 15 TeV for Λ_{VV}

LHC: ~ 30 TeV on Λ_{AA}, 50 TeV for Λ_{VV}

Much weaker limits on Λ_{LL}: this is the window for APV, Qweak, PVDIS

Benchmark: ***20 TeV for Λ_{LL}*** ⇨ $\delta(\sin^2 \vartheta_W) \leq 0.00035$

In PV Møller Scattering

Rates

(Done last night with realistic parameters)

Extrapolate from E158: 48.3 GeV → 10.5 μBarn

Thick 150 cm LH_2 target; real spectrometer geometry

For 11 GeV: 46 μBarn → acceptance not quite up to $|\cos\Theta|\sim 0.5$

→ 50 μBarn

90 μA → 186 GHz —4000 hrs→ $\delta(A_{exp})$ = 0.61 ppb

Instrumentation noise: 10% (25% for E158)
Background dilution: 5% (8% for E158)
Beam Polarization: 85%

$\delta(A_{PV}) = 0.83$ ppb → $\delta(\sin^2\theta_W) = 0.00026$ $\delta(Q_W^e) = 2.25\%$

Conclusions:

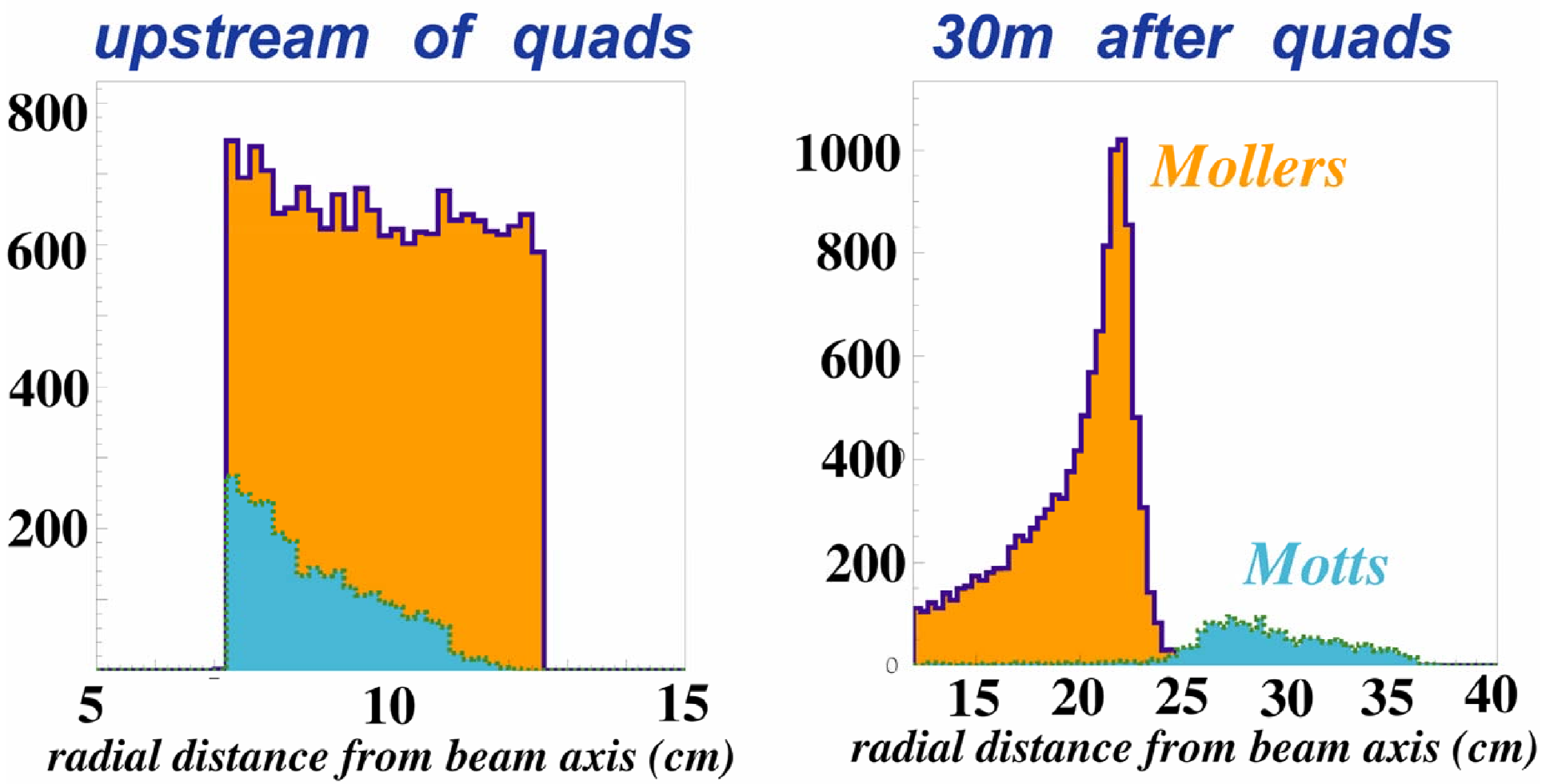
- Must get aggressive on systematic errors
- Incremental improvements on factors above

Backgrounds

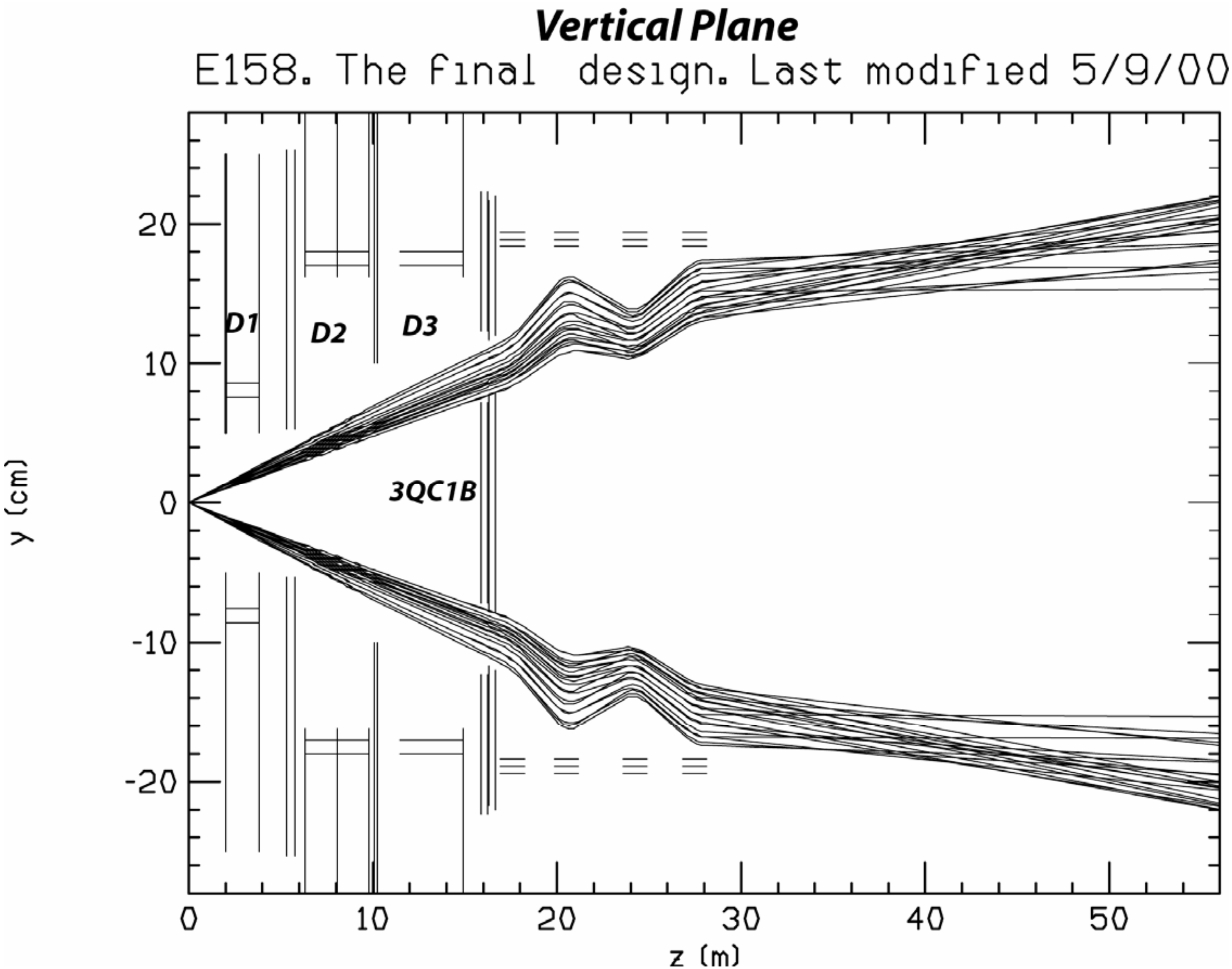
- "irreducible" electron background
  - Elastic electron proton scattering
  - Inelastic electron proton scattering
- "Pions"
  - Very small relative flux
  - Have to rule out by direct measurement
- "neutrons"
  - PMT Photocathode
  - Beam halo (upstream "junk")
  - Synchrotron photons

Quadrupole Concept (48 GeV)

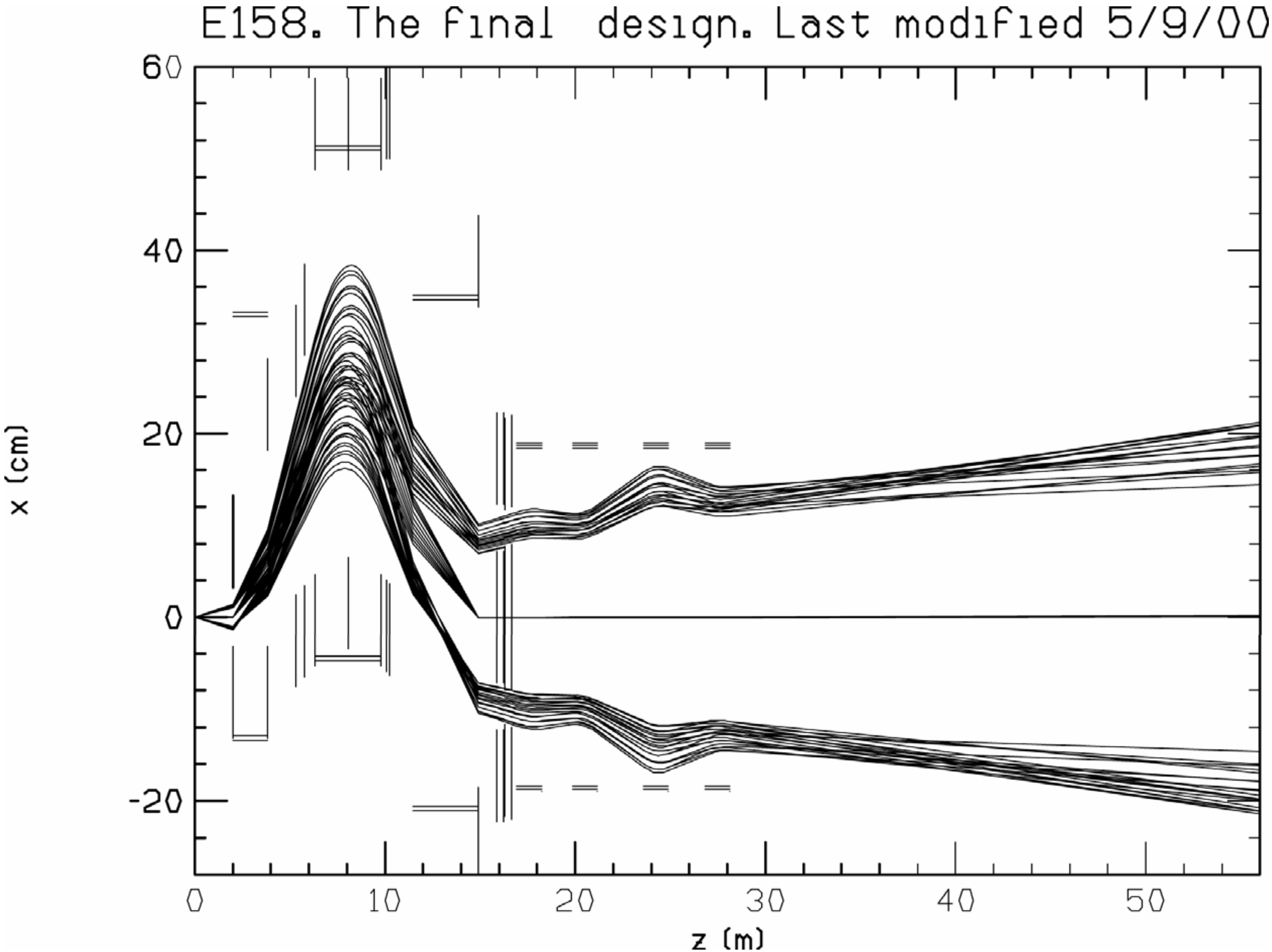
- *primary, beam, signal and background are symmetric about quadrupole axes*
- *Mollers focused, Motts defocused*
- *full range of the azimuth*



Ray Trace in the Vertical



Dipole Chicane

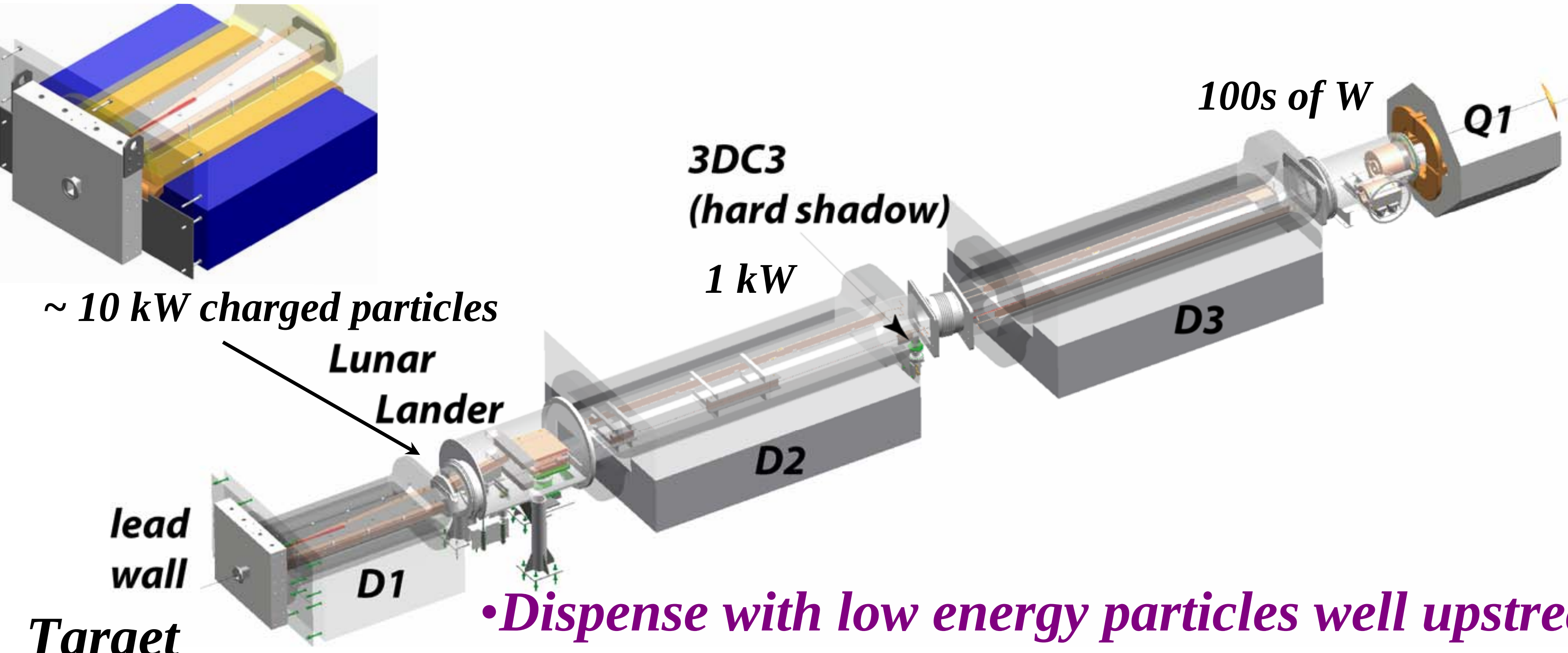


Collimation

150 cm LH_2: 18% radiator ⇨ ~ 1 MW beam begins to shower!

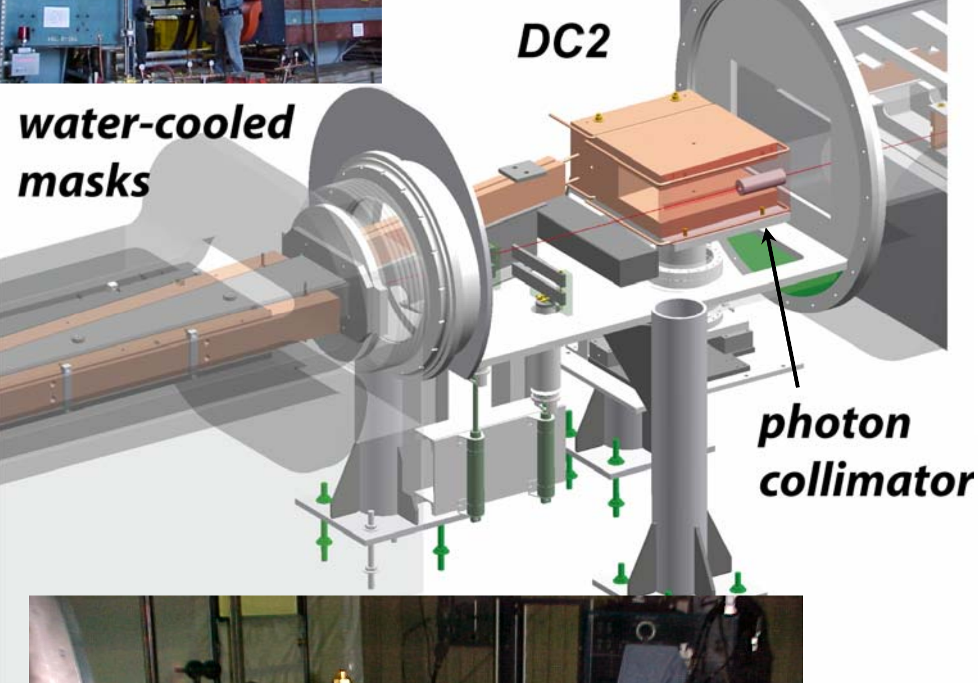
~ 150 kW photon beam (must go to beam dump)

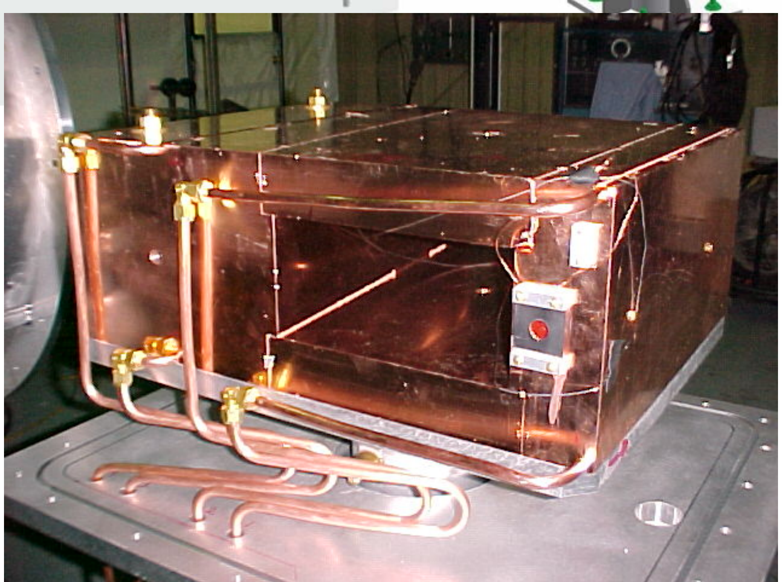
Don't try to stop photons: you just make them mad

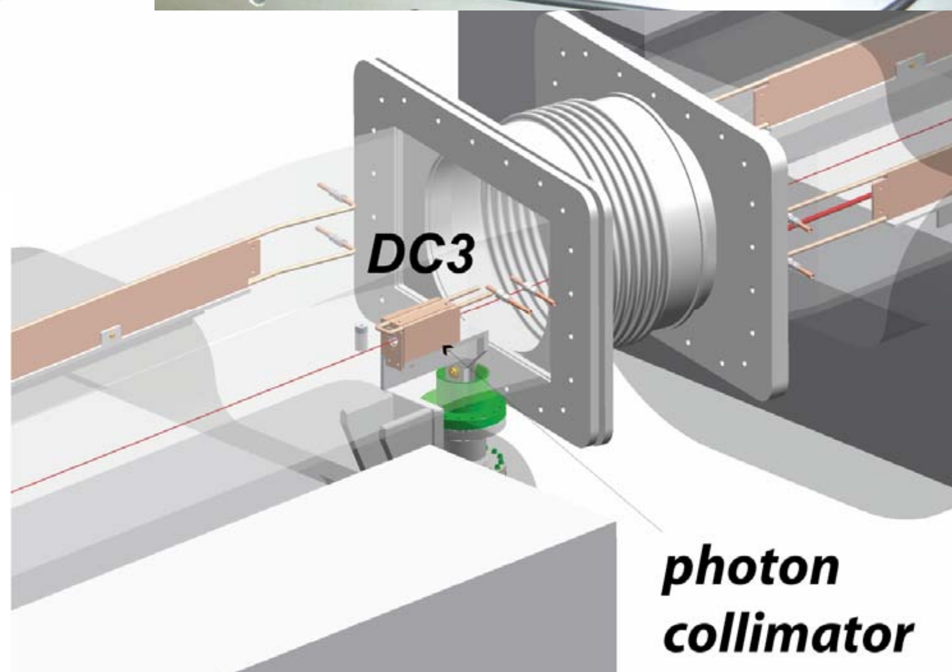


- *Dispense with low energy particles well upstream*
- *Tungsten at edges, otherwise copper*
- *Alignment & beam tune non-trivial*
- *Beam containment requires careful coordination*

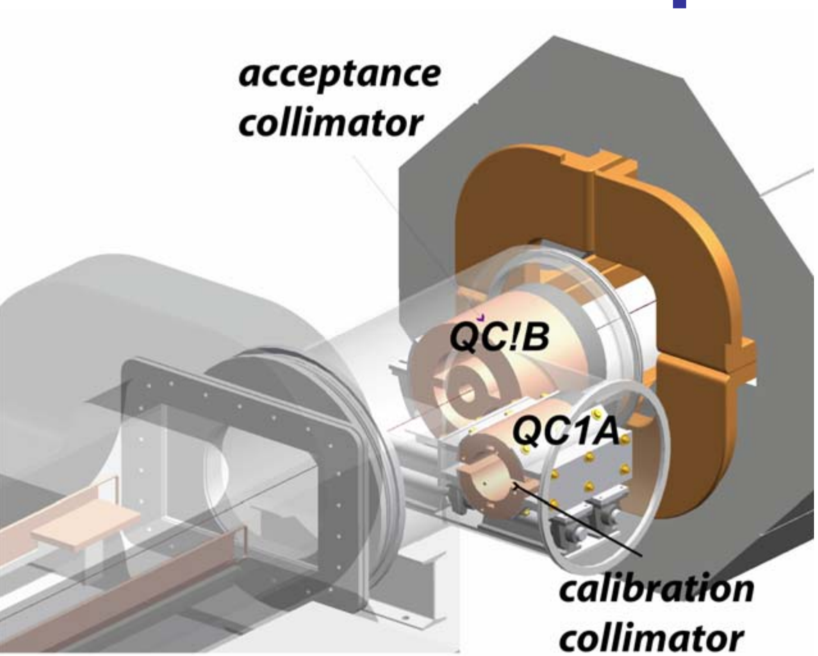
E158 Primary Collimators

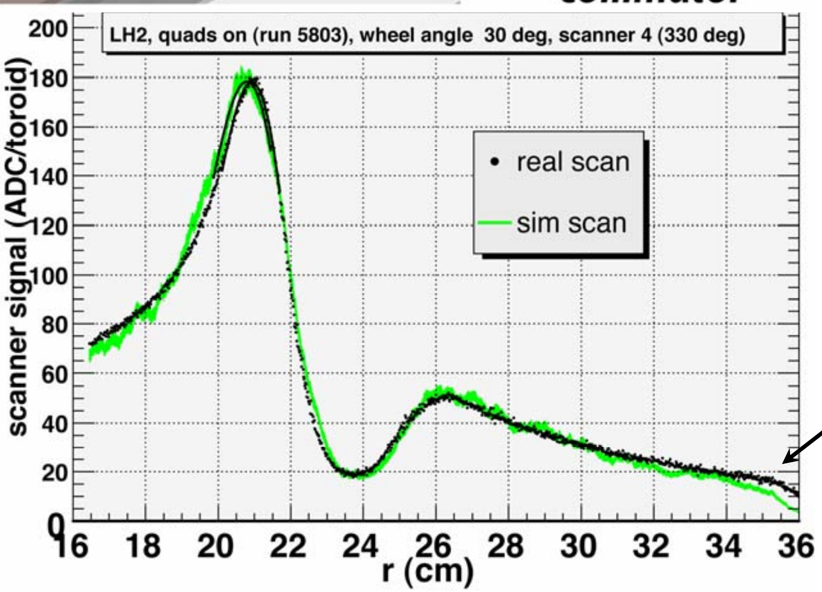




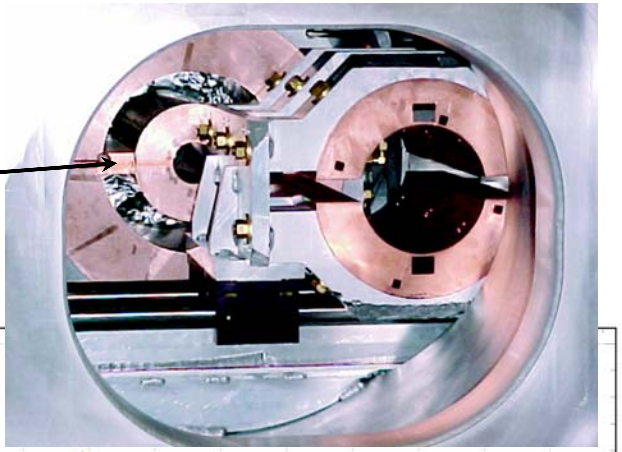


Acceptance Collimator



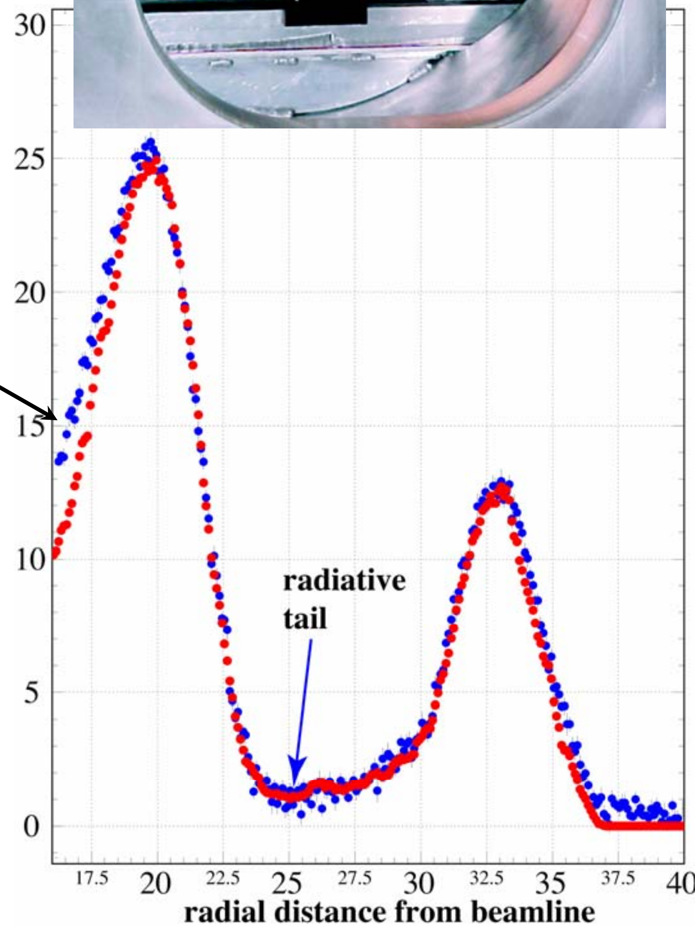


Synchrotron "spoke"

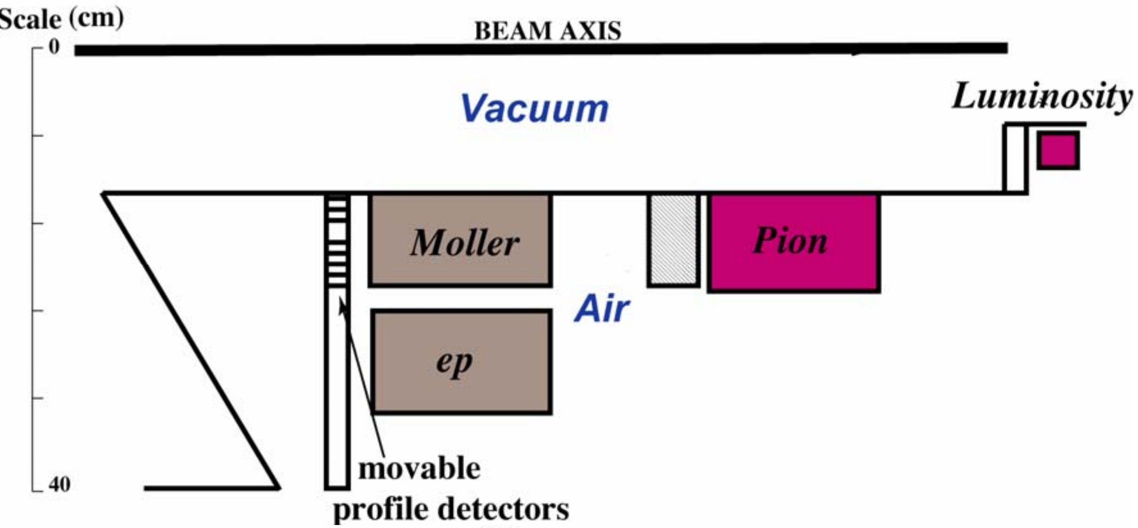


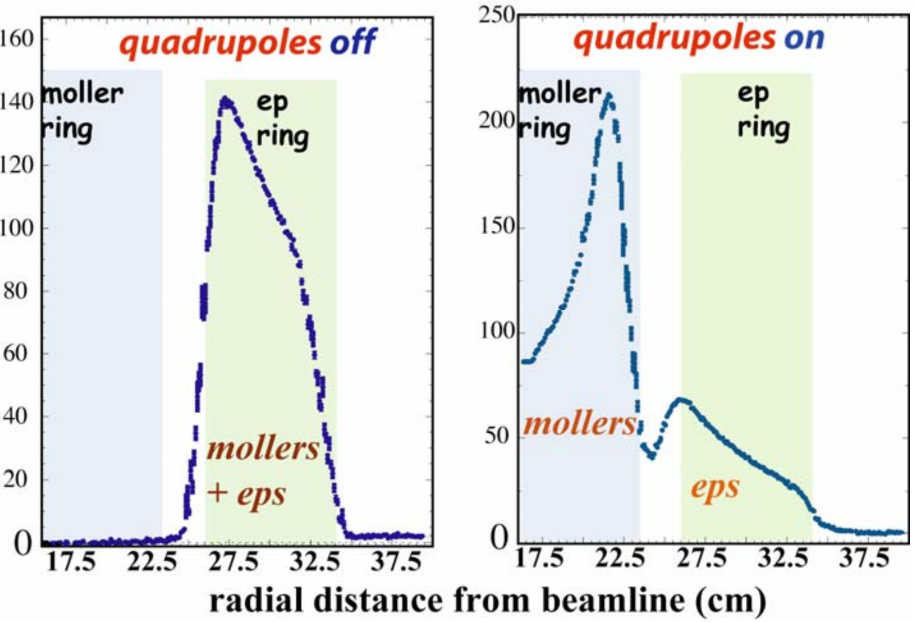
Higher moments

Alignment

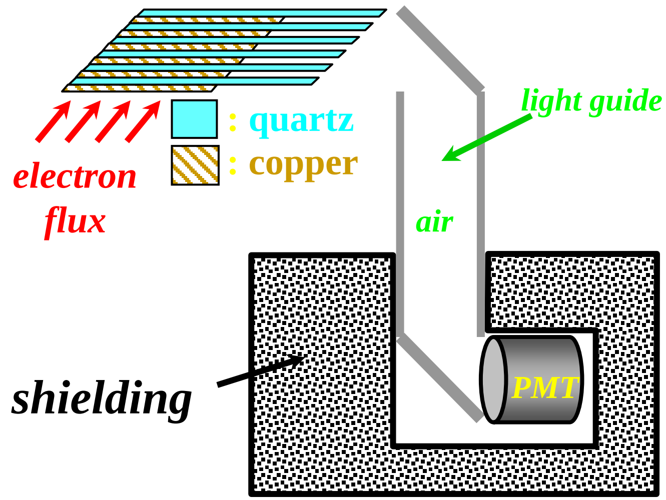


Detector Concept





Basic Idea:

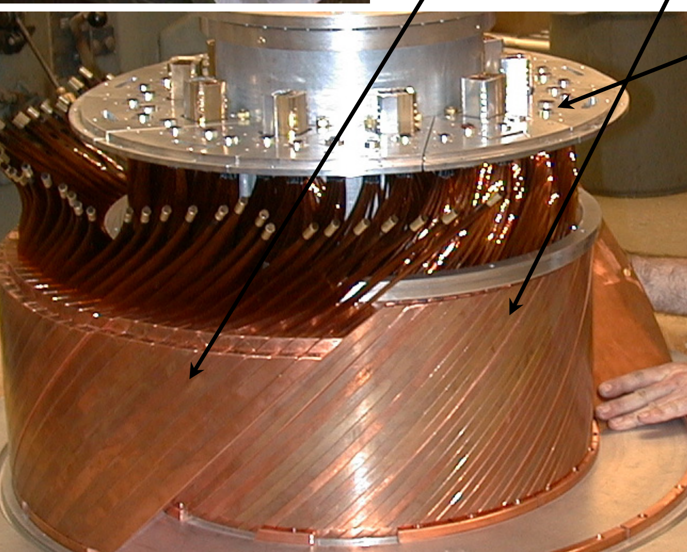


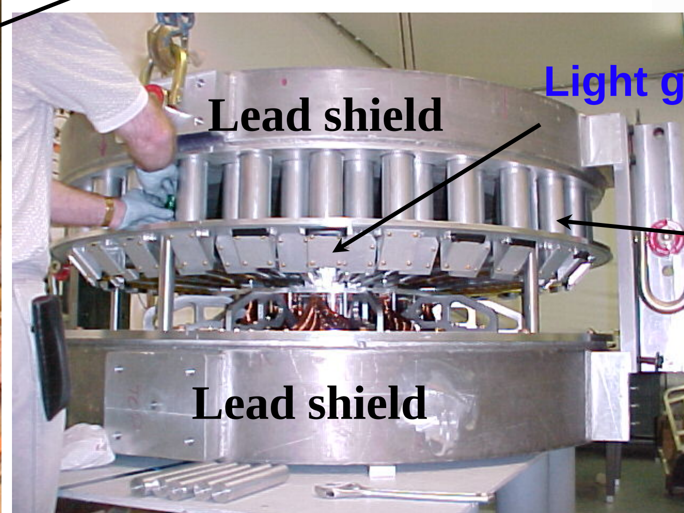
- 4 integrating detectors
  - Moller electrons
  - Elastic e-p electrons
  - "pions"
  - "luminosity"
- Scanning detector for optics

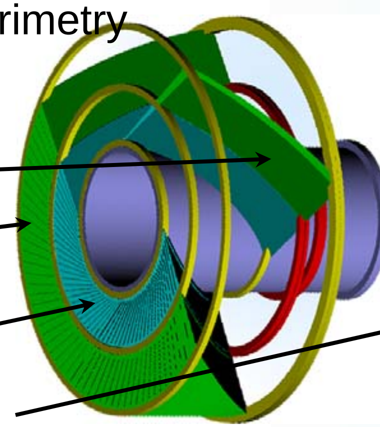
Integrating Calorimeter

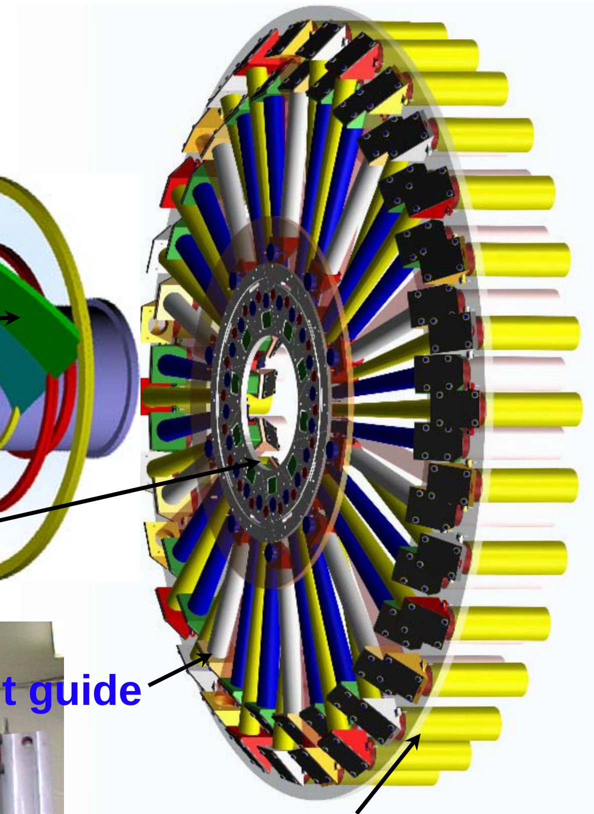
- *20 million 17 GeV electrons per pulse at 120 Hz*
- *100 MRad radiation dose: Cu/Fused Silica Sandwich*

-State of the art in ultra-high flux calorimetry
-Challenging cylindrical geometry

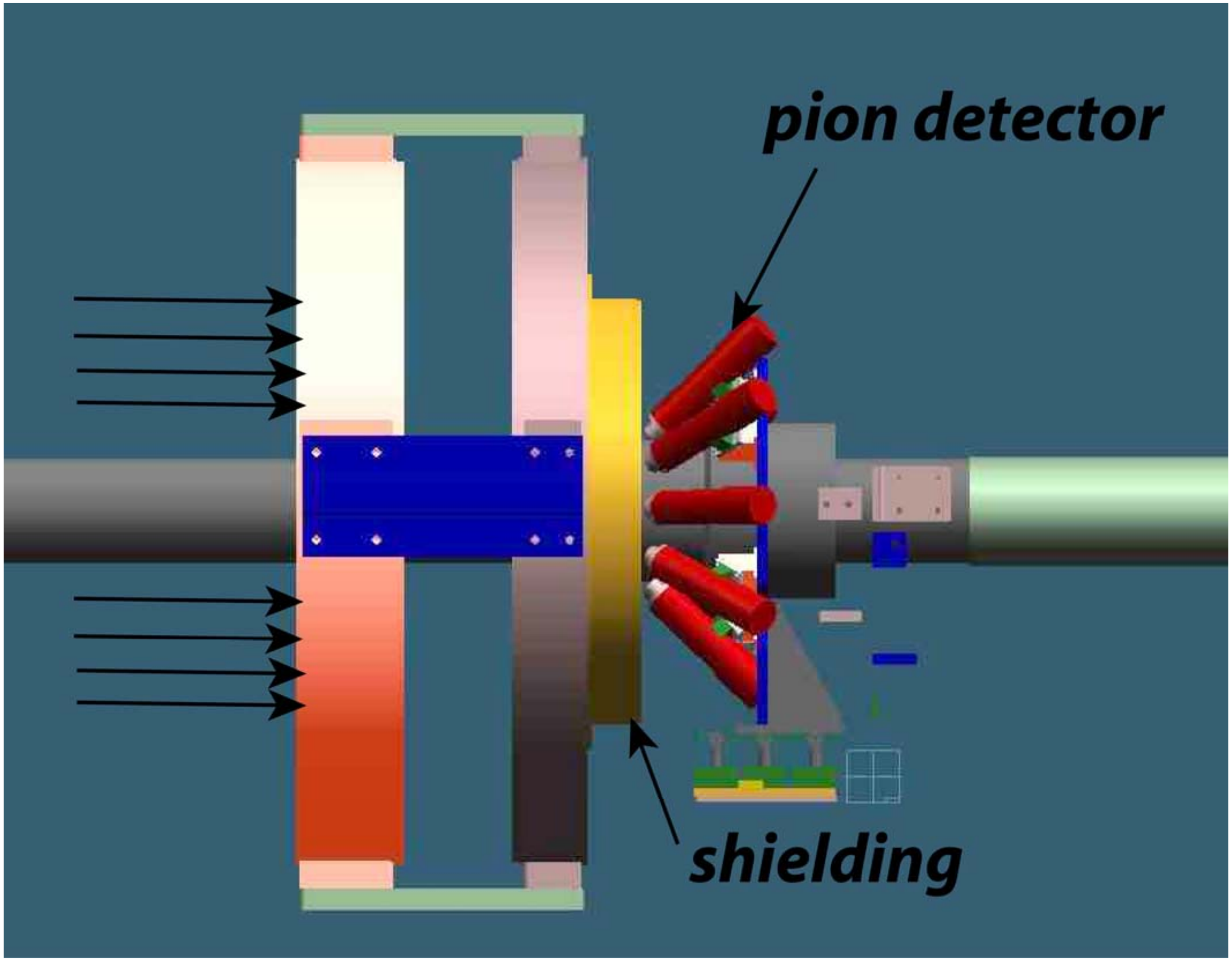








Pion Detector

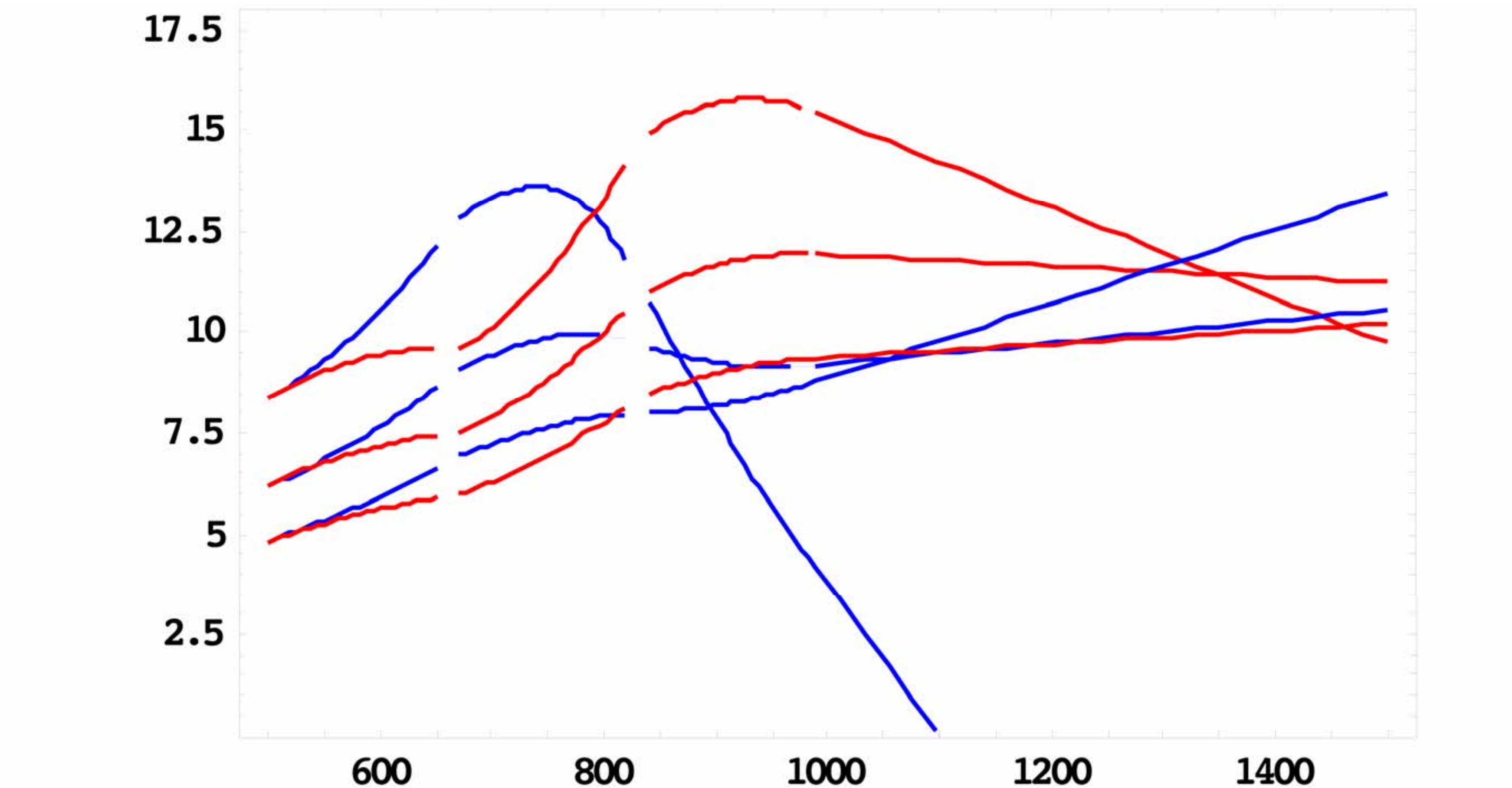


- ~ 0.5 % pion flux
- ~ 1 ppm asymmetry
- < 5 ppb correction

First 11 GeV Try

Umass graduate student Luis Mercado:

- GEANT simulation
- Raytrace program in Mathematica



Current Plans

- Produce viable ray-trace for signal in narrow ring
- Keep total apparatus at 25 m
- Keep elastic ep as far away as possible
- Photon background via detailed simulations
- Fractional improvements to improve statistics
- Other background estimates
- Several months with half-time (student + postdoc)

Conclusions

- ***Quad concept might be viable***
- ***Might be critical to obtain statistics***
- ***Several months of work required to unearth show-stoppers***