Fermilab
DOE Review

Steve Geer
April 1997

Muon Collider
Detector and Backgrounds

- Introduction
- Backgrounds
- Detector considerations
- Summary

Introduction

- Since muons decay, background levels at a muon collider are expected to be high.
- Understanding the backgrounds levels and how these backgrounds affect the performance of a strawman detector is a crucial part of assessing the feasibility of doing physics at a muon collider.
- Therefore, within the muon collider collaboration, there has been a significant effort devoted to:

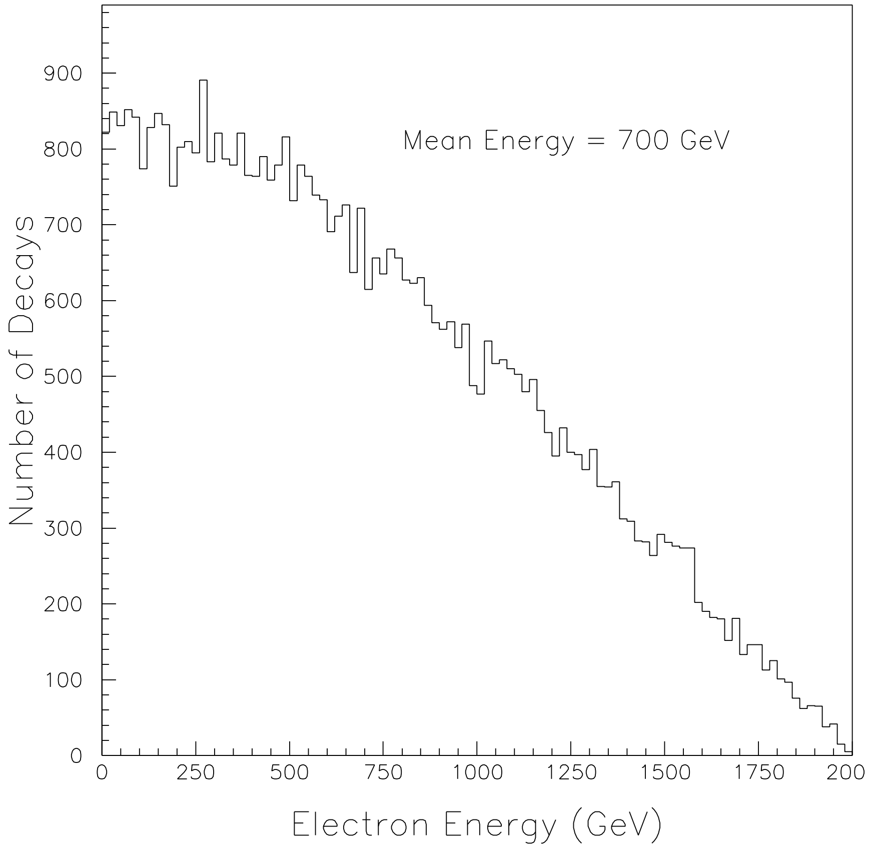
  (i) Designing the final focus to minimize backgrounds in the detector.

  (ii) Understanding the remaining backgrounds in the detector, and identifying the critical background–related detector issues.

  (iii) Developing a feasible strawman detector and assessing its performance in the predicted backgrounds.

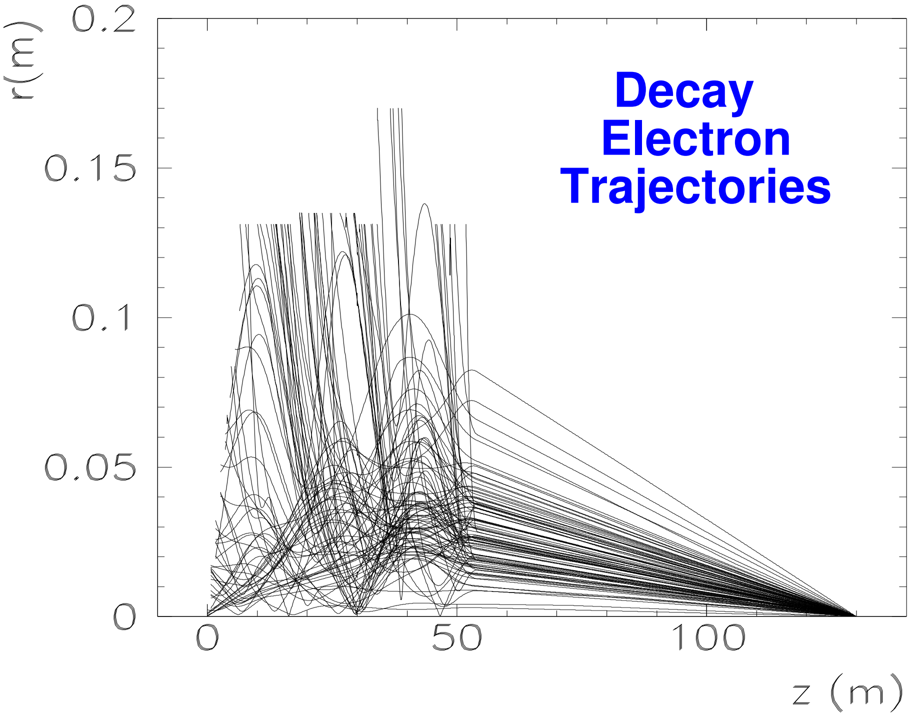
Fermilab people (M. Atac, A. Bross, T. Diehl, S. Geer, C. Johnstone, P.Lebrun, N. Mokhov, R. Rajendran, A. Tollestrup) in collaboration with BNL people (D. Benary, S. Kahn, D. Lissauer, M. Murtagh, F. Paige, V. Polychronakos, P. Rehak, I. Stumer, V. Tchernatine), and R. Roser (Univ. Illinois).

Muon Decay Backgrounds



2 x 2 TeV Muon Collider

- 2×10^{12} muons/bunch
- 2×10^{5} decays / m
- Mean decay electron energy = 700 GeV

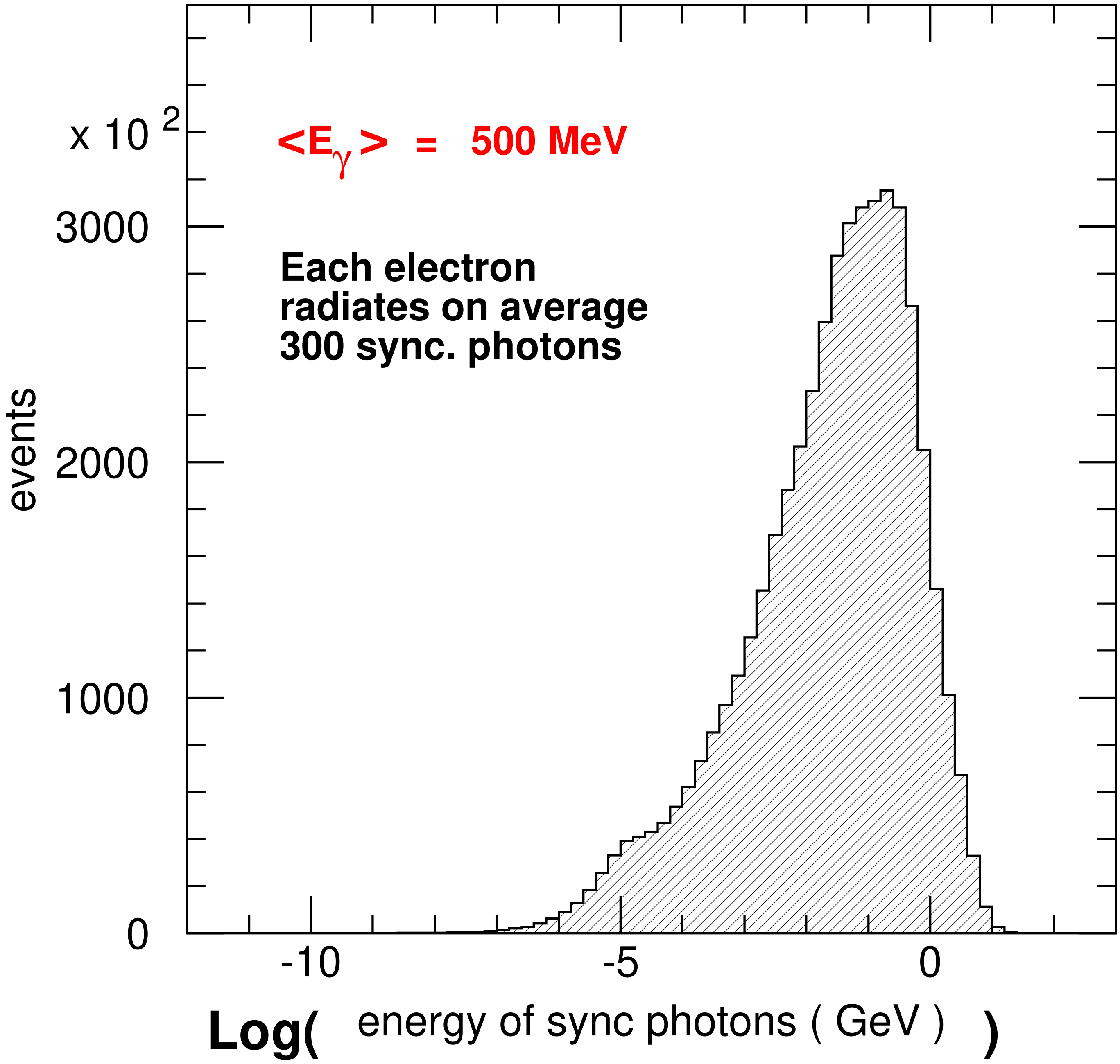


Electron decay angles are O(10) microradians.

Therefore, in the final focus section, decay electrons tend to stay in the beampipe until they see the final focus Quad fields etc.

Synchrotron Radiation

- **The decay electrons radiate synchrotron photons as they propogate through the fields in the final focus region, loosing on average about 20% of their energy:**



- **However, the resulting background in the detector region is small compared with other backgrounds.**

Background List

Decay Backgrounds:

Two detailed complementary calculations have been performed: GEANT calculation (I. Stumer, BNL), MARS calculation (N. Mokhov, FNAL). The assumed final focus system and shielding configurations assumed for the two calculations are similar in general, but the details are very different.

Both the GEANT and MARS calculations track all particles through the final focus and 2 Tesla detector solenoidal fields and fully simulate:

- Electron showers
- Synchrotron radiation
- Photonuclear interactions
- Bethe–Heitler muon pair production

Beam Halo:

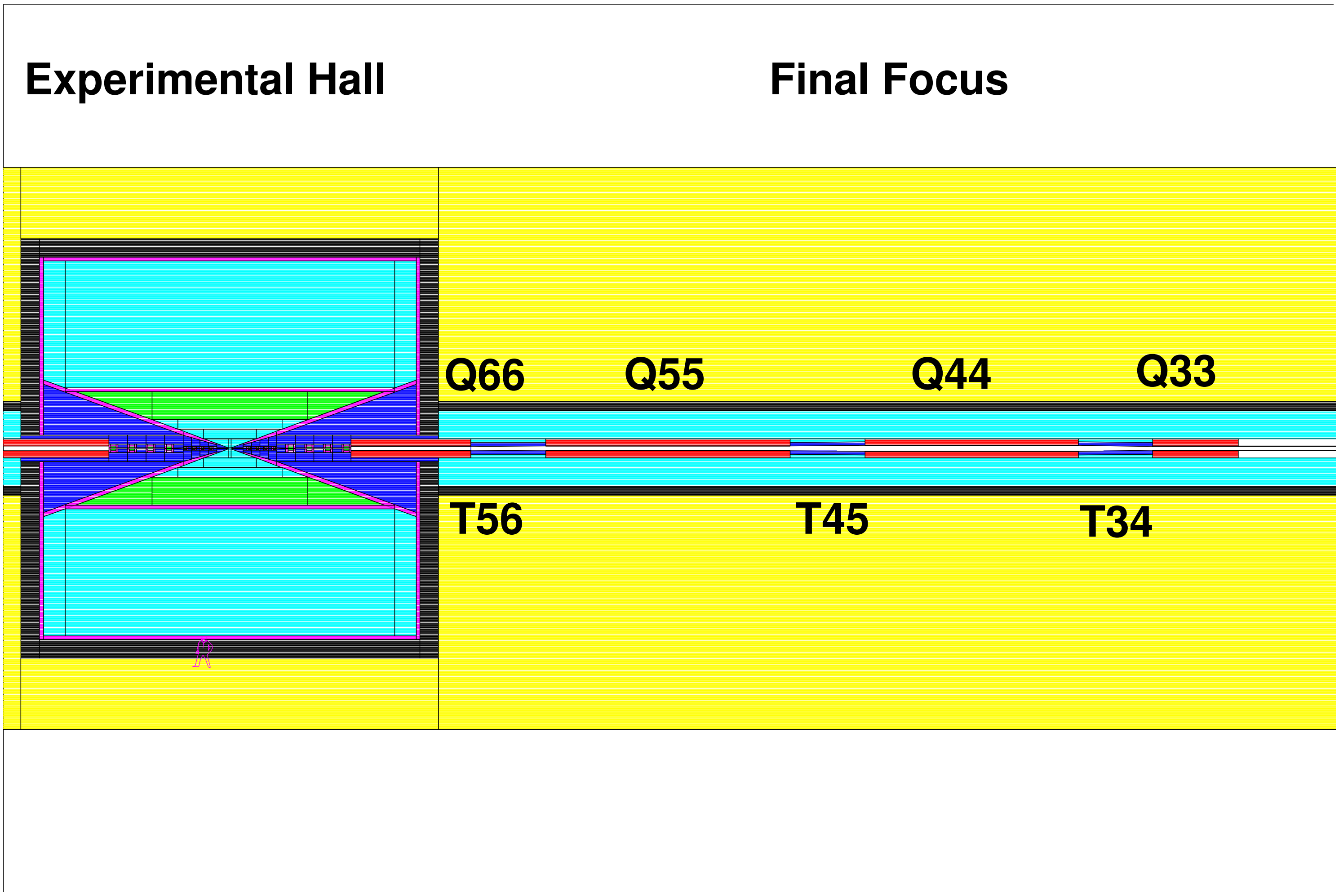
Beam halo model and beam scraping design being developed, but no results yet.

Beam–Beam Interactions:

Believed to be small compared with other backgrounds

GEANT Calculation: The last 130m is simulated

The Final 50m

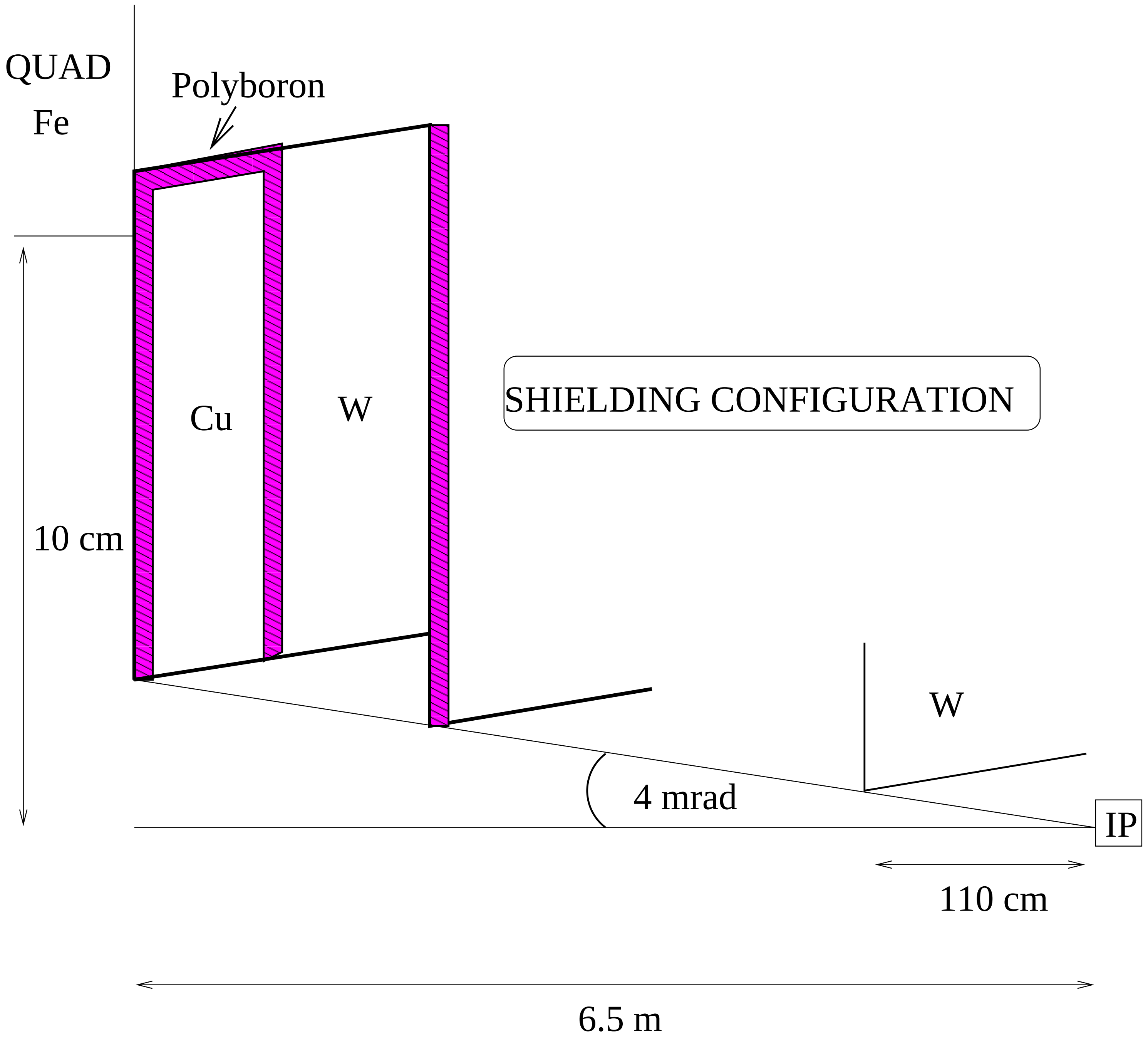


- 4 QUADS: Q33, Q44, Q55, Q66

- Snowmass configuration: 3 Toroids to deflect Bethe–Heitler muons and scrape backgrounds (inner aperature = 4σ): T34, T45, T56

- Post–Snowmass configuration: Toroids removed and dipoles added to straight section .... this reduces backgrounds by an order of magnitude (except for the Bethe–Heitler muons).

Shielding Configuration Implemented in GEANT Background Calculation



GEANT RESULTS

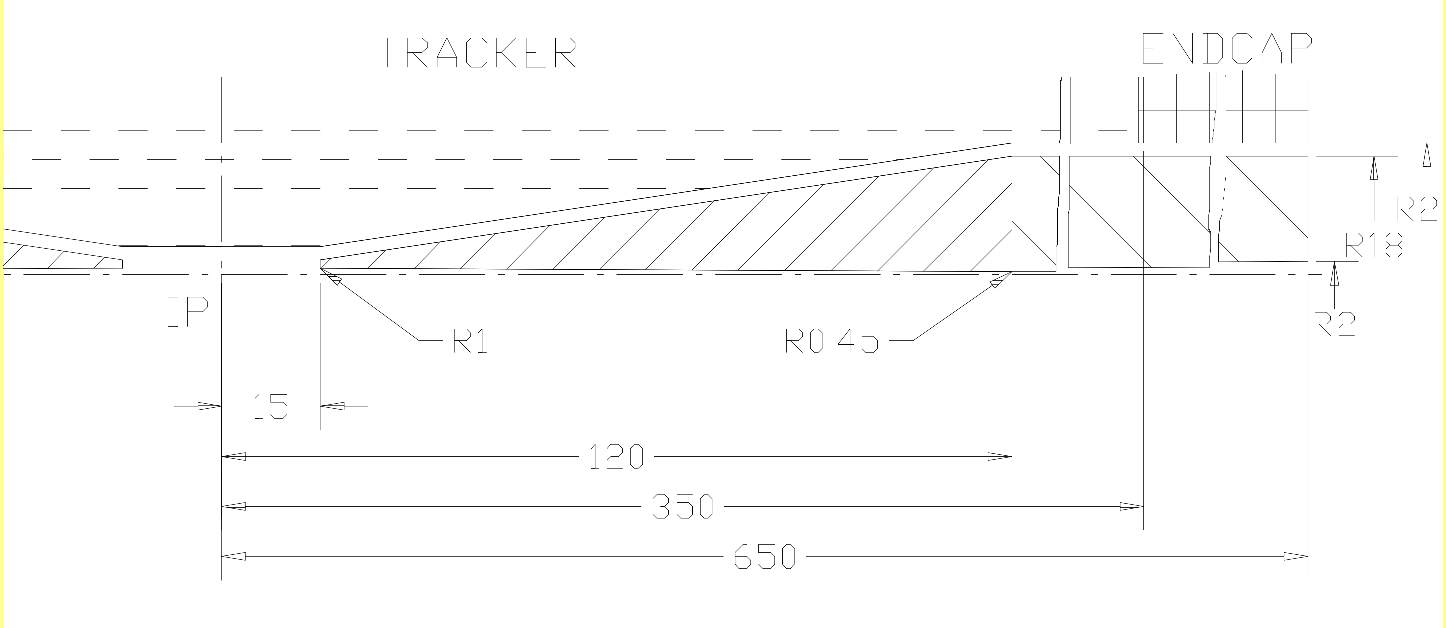
Radial fluxes / cm^2 per crossing

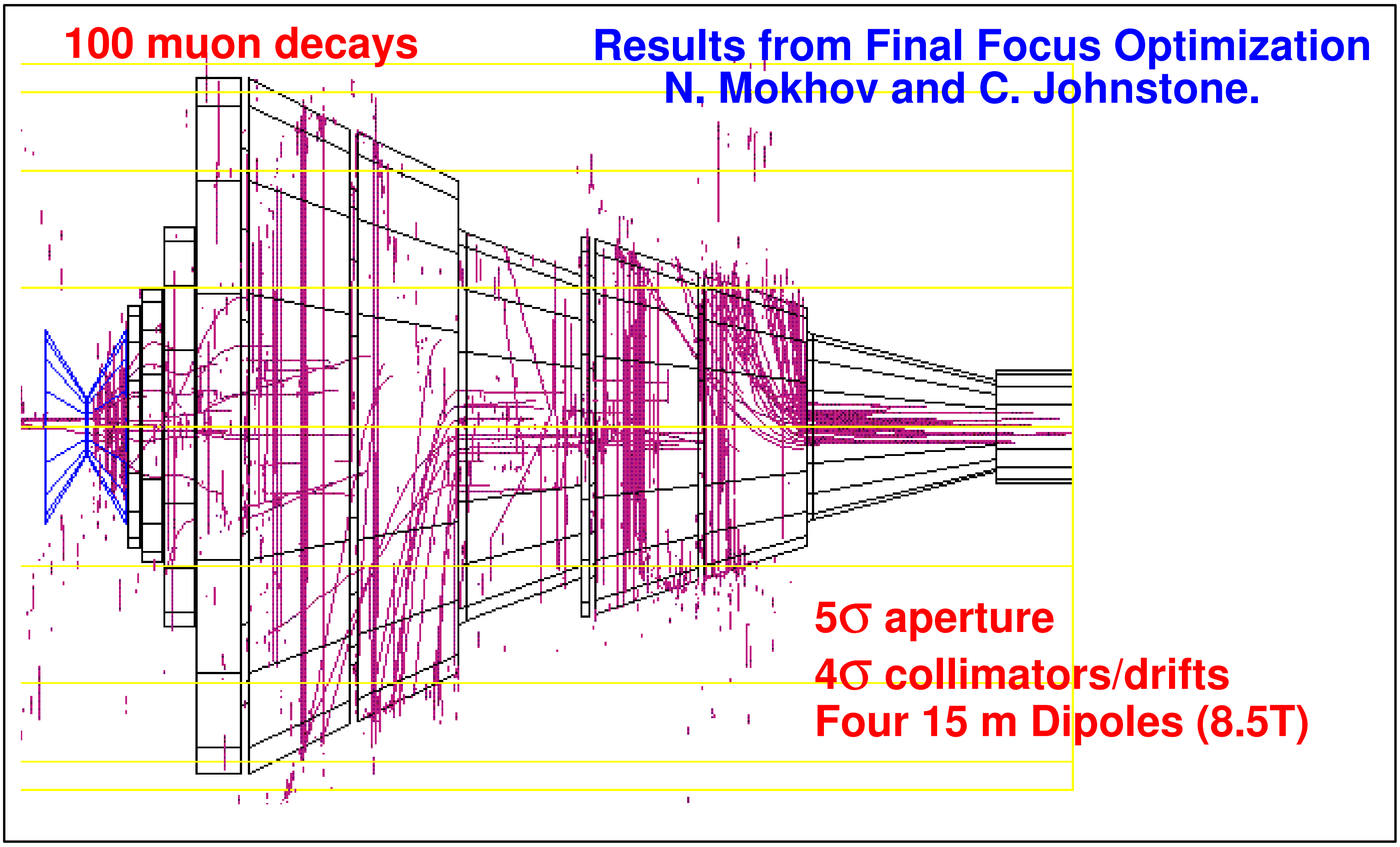
radius (cm)	Snowmass						Post–Snowmass					
	γ	n	p	π	e	μ	γ	n	p	π	e	μ
5	16900	1600	1.7	9.5	84.	1.5	2700	120	0.05	0.9	2.3	1.7
10	4800	1400	1.4	4.5	9.4	0.5	750	110	0.20	0.4	–	0.7
15	2200	1400	1.1	2.1	2.1	2.3	350	100	0.13	0.4	–	0.4
20	1250	1400	1.9	1.3	–	0.3	210	100	0.13	0.3	–	0.1
50	440	1500	4.2	0.2	–	0.06	70	120	0.08	0.05	–	0.02
100	160	360	0.8	0.04	–	0.01	31	50	0.04	.003	–	0.008
calo						0.002						0.003
muon						0.0002						0.0003

Work on optimizing the final focus and shielding since Snowmass has resulted in about an order of magnitude reduction in the calculated photon, neutron, proton, pion, and electron backgrounds

MARS Calculation

Uses a somewhat different shielding configuration than the GEANT calculation:



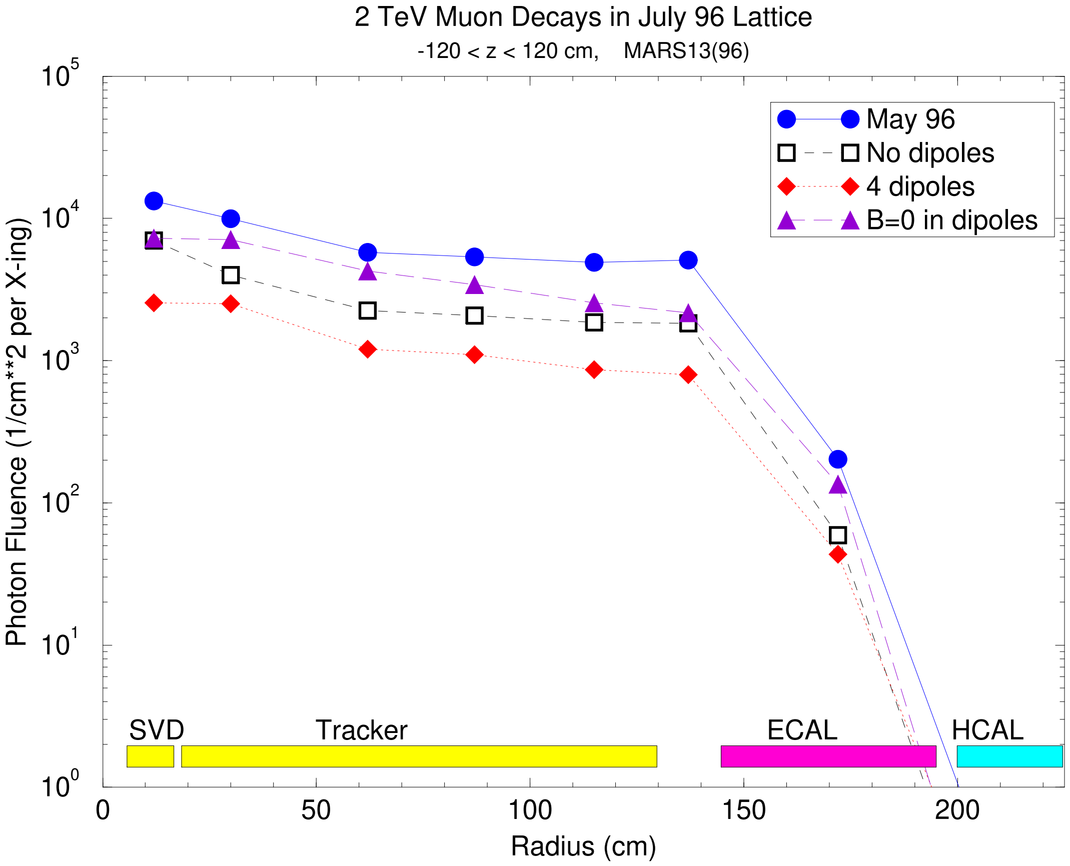


100 muon decays

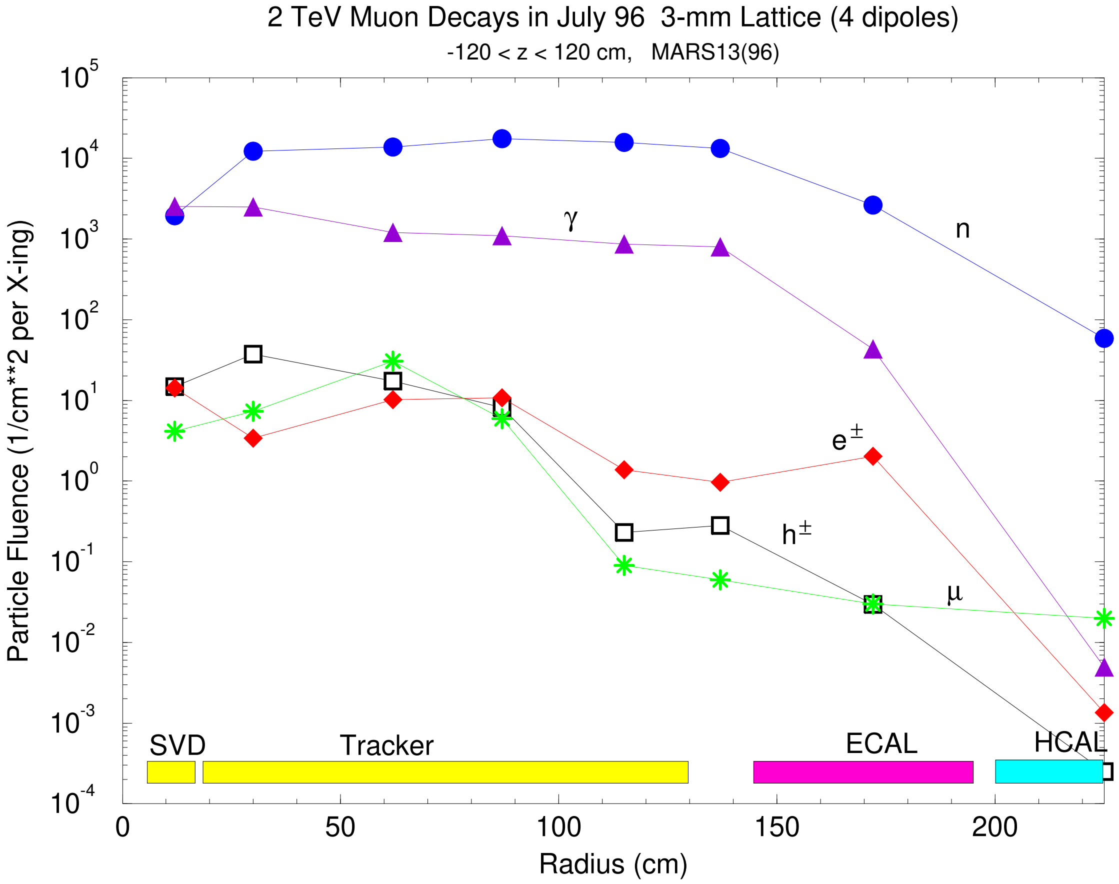
Results from Final Focus Optimization
N. Mokhov and C. Johnstone.

5σ aperture
4σ collimators/drifts
Four 15 m Dipoles (8.5T)

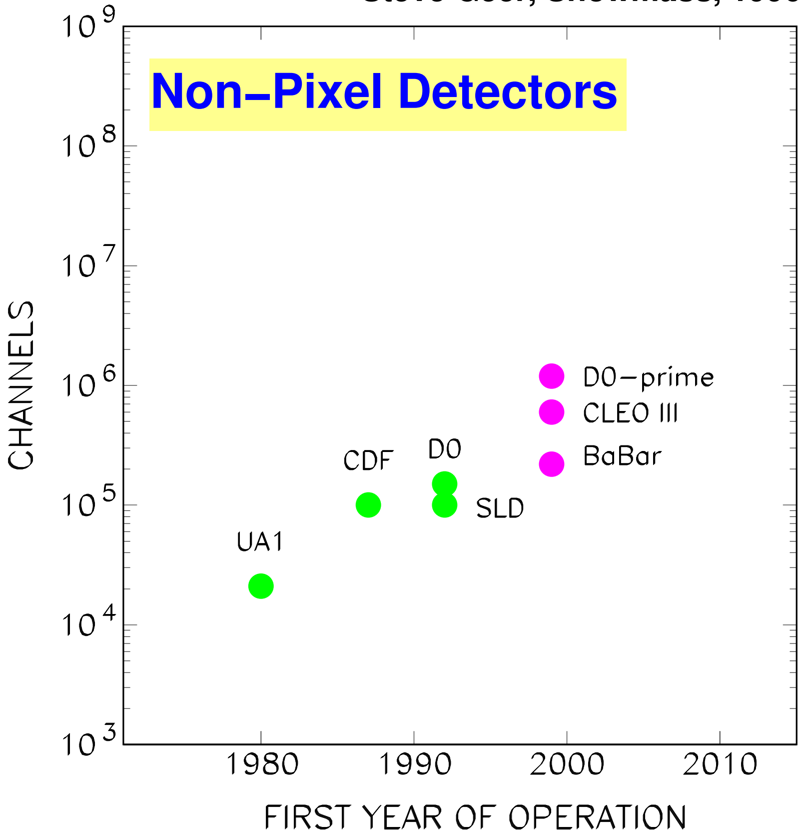
MARS RESULTS



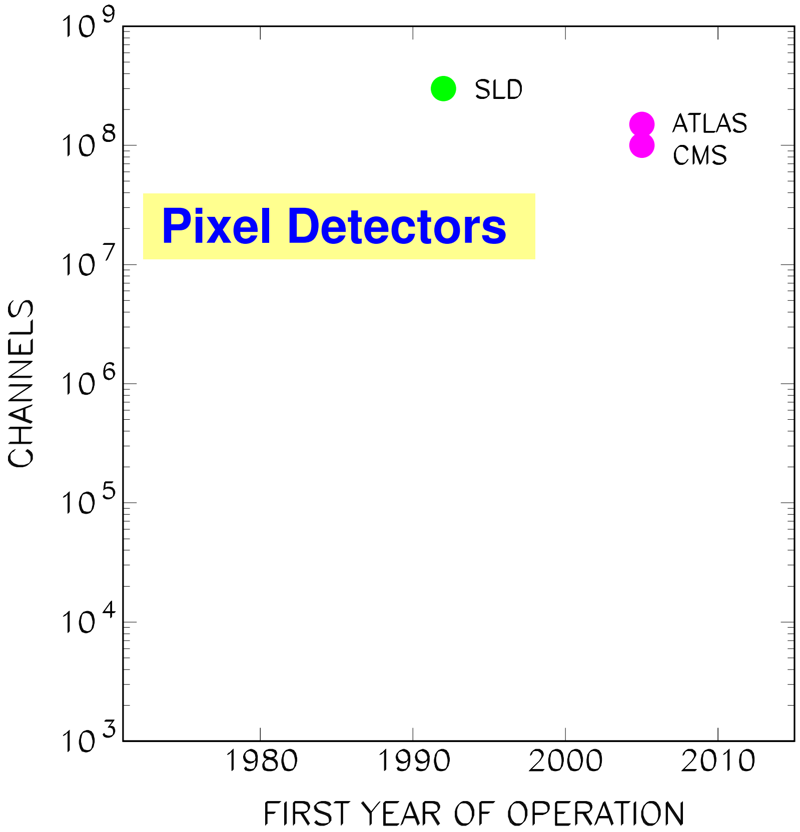
IMPROVEMENTS SINCE SNOWMASS



CURRENT BACKGROUND PREDICTIONS


Steve Geer, Snowmass, 1996

Since backgrounds at a muon collider are large we will want to use a large number of detector channels to achieve reasonable occupancies.


Steve Geer, June 1996

Guess that O(10^7) non–pixel channels and O(10^9) pixels is "reasonable"

Hit Density in a Vertex Detector

- Consider a layer of Silicon at a radius of 10 cm. The GEANT results for the radial particle fluxes per crossing yield:

750 photons/cm^2	–>	2.3 Hits/cm^2
110 neutrons/cm^2	–>	0.1 Hits/cm^2
1.3 charged tracks/cm^2	–>	1.3 Hits/cm^2
TOTAL		3.7 Hits/cm^2

- –> 0.4% occupancy in 300 x 300 μm^2 pixels.
- The corresponding numbers at 5cm radius are 13.2 Hits/cm^2 –> 1.3% occupancy.
- This doesnt sound too bad. For comparison, SLD has about 40 Hits/cm^2 on the inner layer of their CCD detector.

Radiation Dose in Silicon Vertex Detector

- Consider a silicon layer at a radius of 10 cm. The dose due to non–ionizing energy loss can be calculated from the MARS or GEANT results (which give consistent results) taking into account particle type, energy spectra, and fluxes.

$$\phi_{\text{NIEL}} = \phi_{\mathbf{p}} + \phi_{\pi} + 0.5\phi_{\mu} + 0.1\phi_{e} + \\ + \phi_{\text{n > 0.1 MeV}} + 0.01\phi_{\gamma}$$

- –> ϕ_{NIEL} = 240 per cm^2 per crossing.

MARS predictions for 1 year (= 10^7 secs) of operation:	
2 x 2 TeV muon collider	7 x 10^{13} cm
LHC at 10^{34} $\text{cm}^{-2}\text{s}^{-1}$ (CMS)	8 x 10^{13} cm

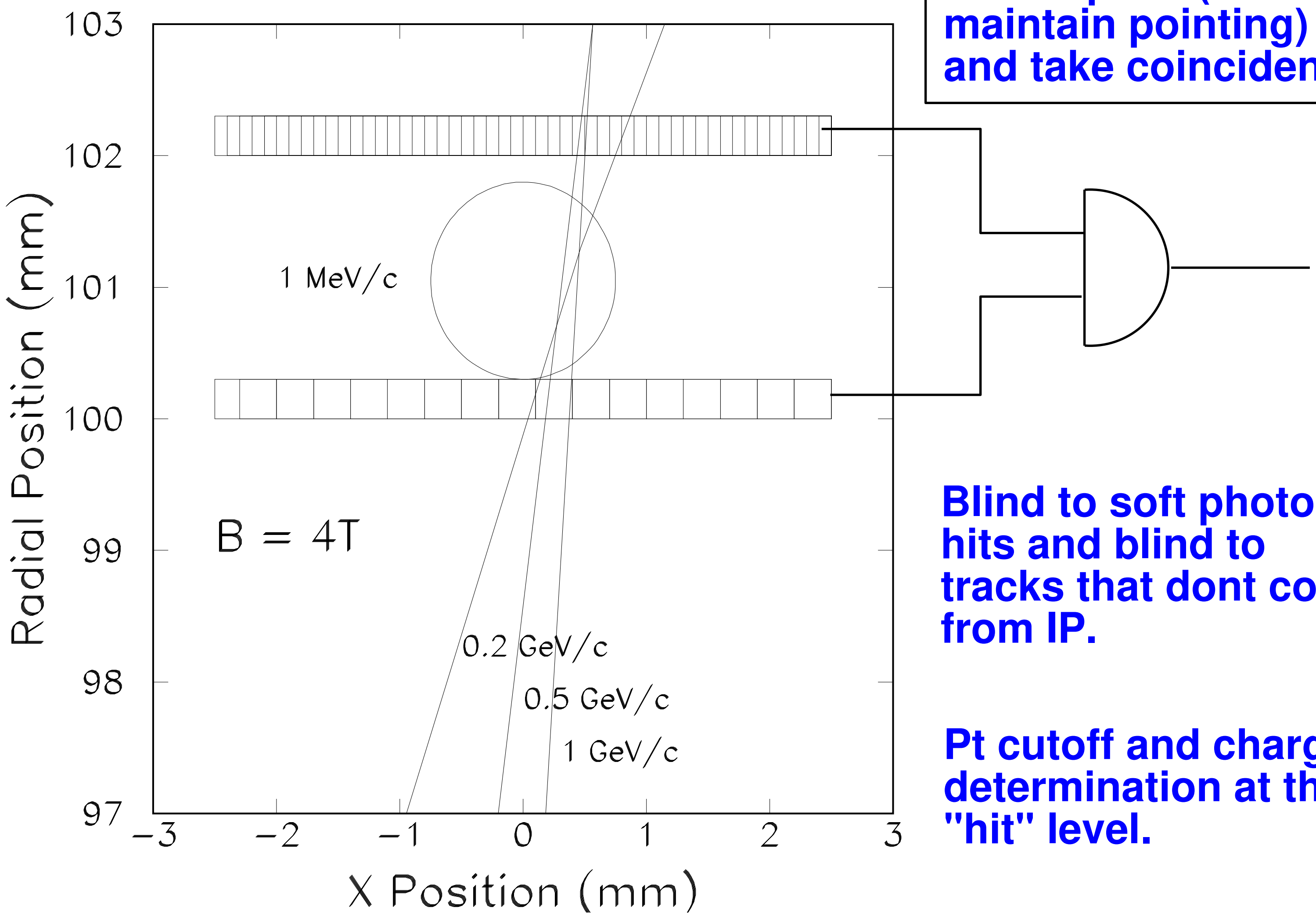
Pixel Microtelescope

Steve Geer
Jay Chapman

- Most of the background hits in a silicon vertex detector close to the muon collider IP arise from very low energy (~ 1 MeV) photon interactions.

- At Snowmass we thought of a possible way of screening out these background hits to facilitate:
  - Getting the first layer at the smallest viable radius
  - Developing a track trigger

Clock two layers out at variable clock speed (to maintain pointing) and take coincidence.



Blind to soft photon hits and blind to tracks that dont come from IP.

Pt cutoff and charge determination at the "hit" level.