Readiness for electron running

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DOE Review

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Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Introduction

HPS is the first experiment to place

- Silicon strip detector at 1.5 mm from the beam,
- Trigger counter at 2 cm from the beam.

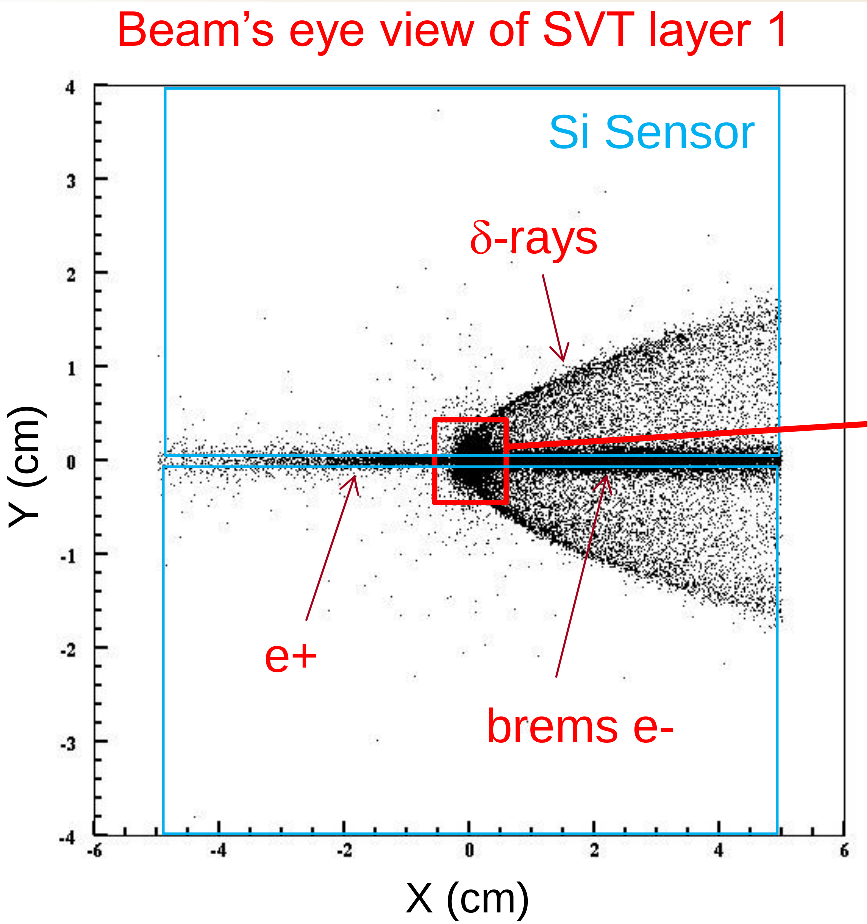
Successful electron running is critically dependent on

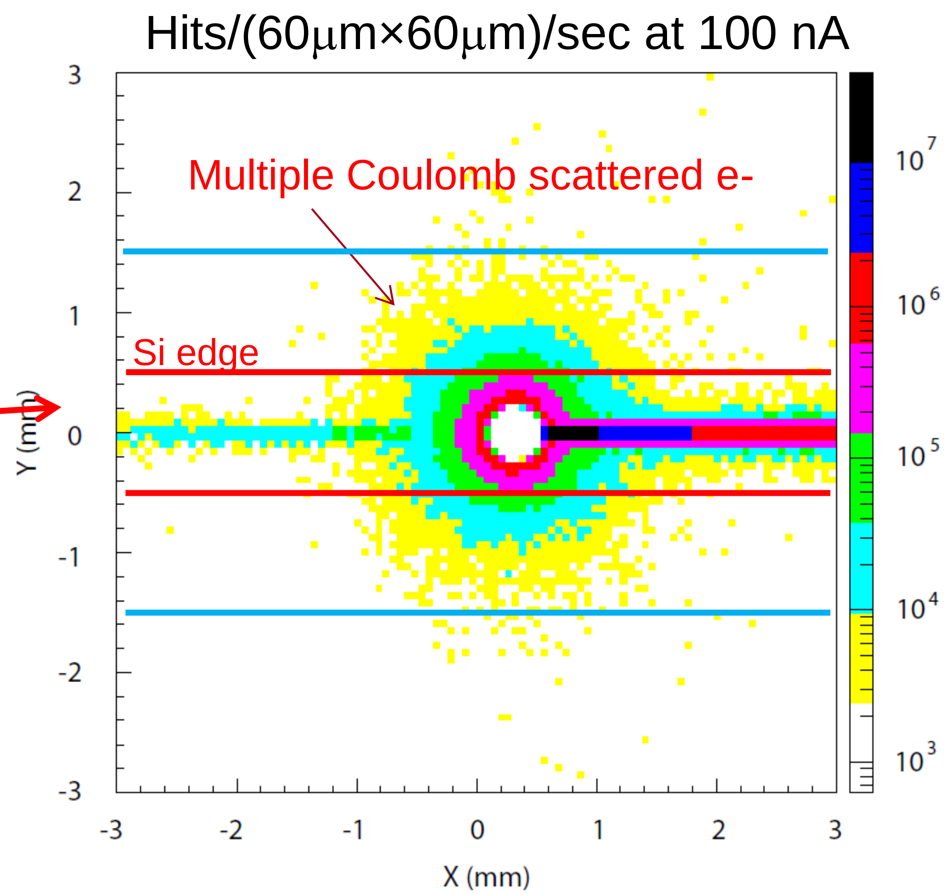
- Understanding the beam background,
- Controlling the beam.

I will talk about

- How much we understand the beam background,
- How important the Test Run was,
- How we control the beam.

Beam Background from the Target



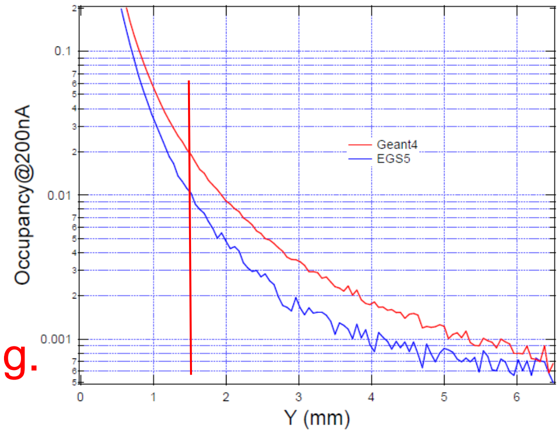


Multiple Coulomb scattered e-'s are dominant background.
- ~80% SVT layer 1 occupancy
- >99% ECal occupancy

Multiple Scattering Models

Geant 4

- Urban Model based on two simple functions:
  - Gaussian at small angles
  - $1/(1-\cos\theta+b)^{d}$ at large angles
    - ".. d is not far from 2." d=2 in Rutherford scattering.



EGS5

- Moliere scattering integral formulated by Bethe.
  - Asymptotically approaches Gaussian at small angles
  - Asymptotically approaches Rutherford single scattering at large angles
  - Uses small angle approximation

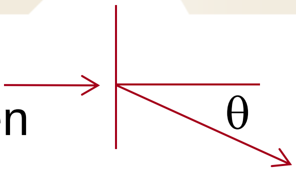
Goudsmit-Saunderson Model

- Most general multiple-scattering model applicable to any angle.

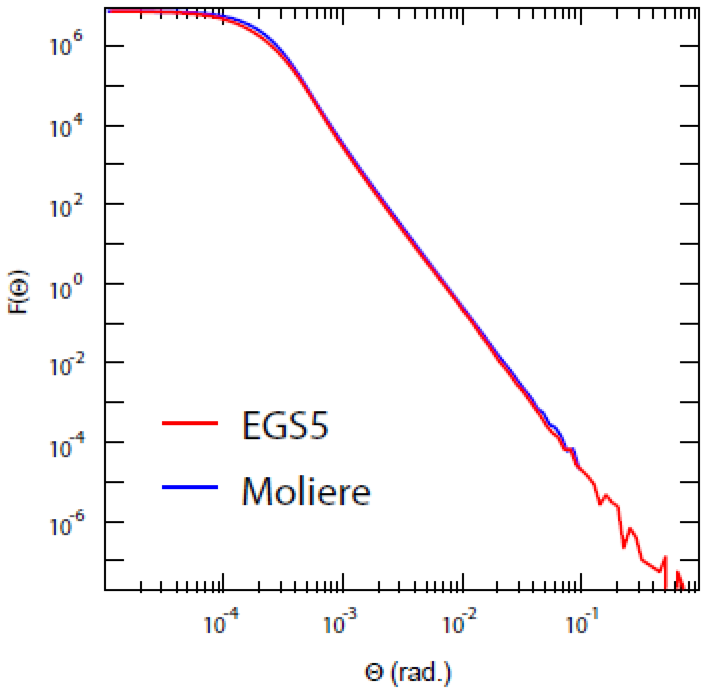
Multiple scattering

$$\frac{d\sigma}{d\Omega} \approx F(\theta)2\pi d(\cos\theta)$$

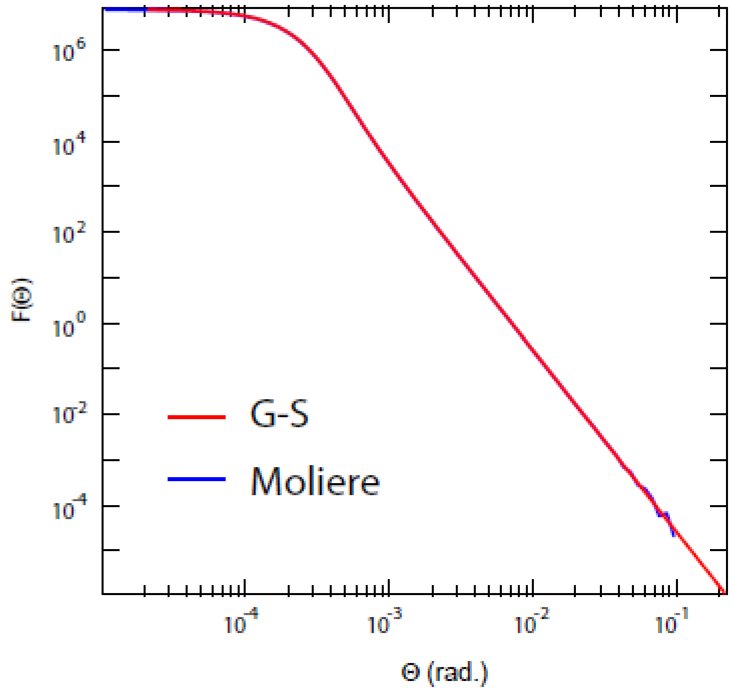
2.2 GeV
0.125% r.l. Tungsten



Moliere integral vs. EGS5

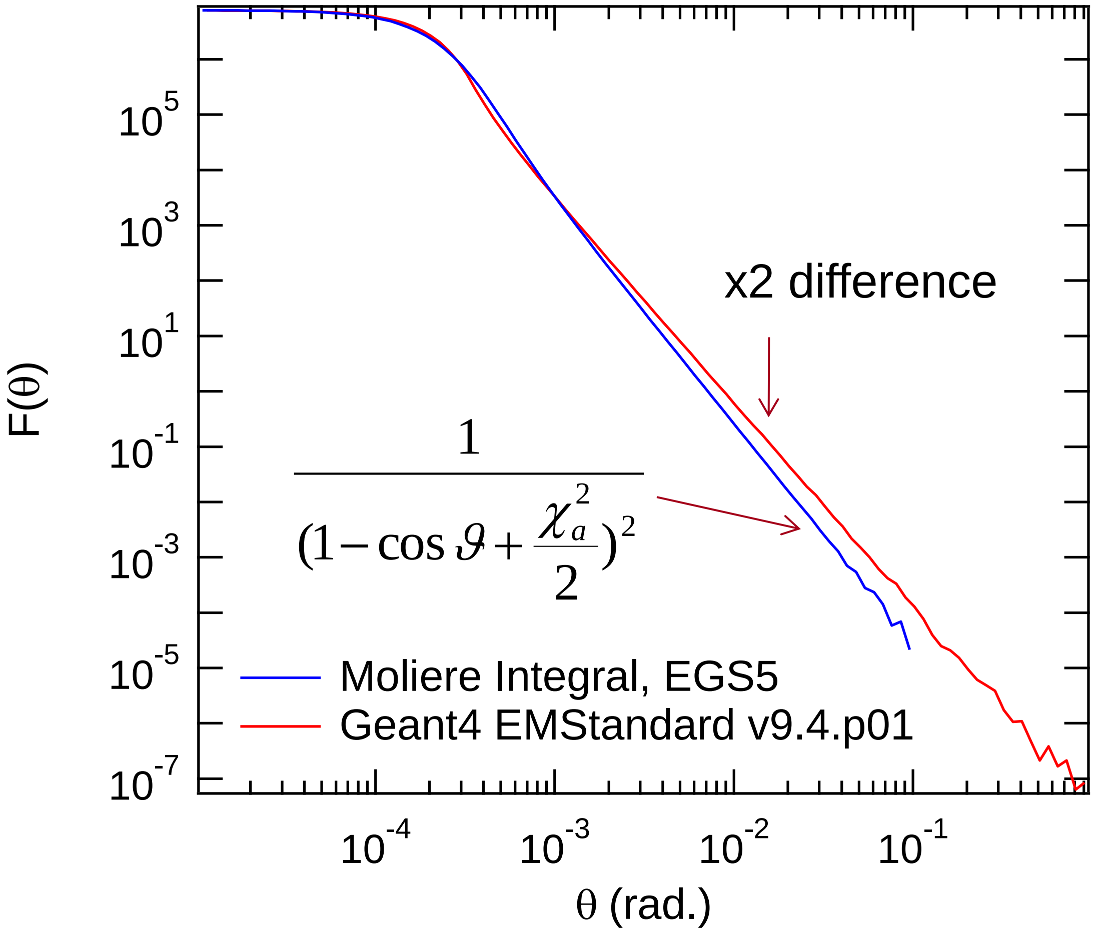


Moliere integral vs. Goudsmit-Saunderson



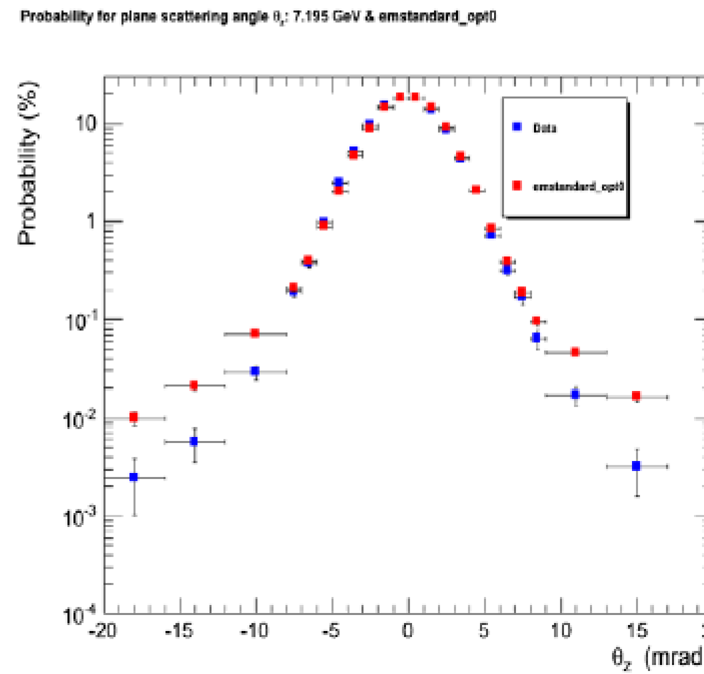
Multiple Scattering

EGS5 vs. Geant4



Ivanchenko (G4 Developer)

Geant4 vs. Data

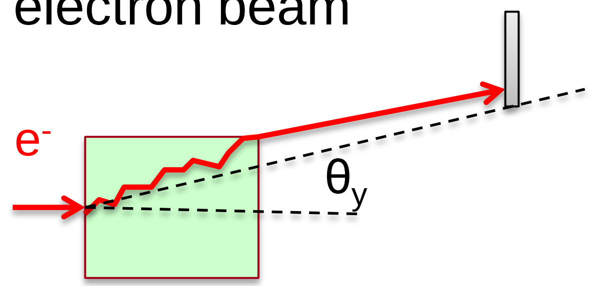


- Urban model overestimates tail,

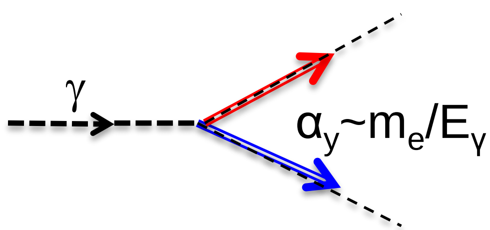
Data are consistent with Moliere

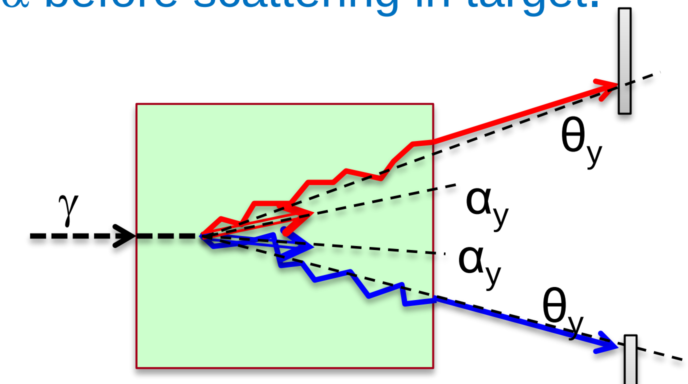
Testing Multiple Scattering Model with the Test Run

Multiple scattering in electron beam



With photon beam e+e- is produced at angle α before scattering in target.



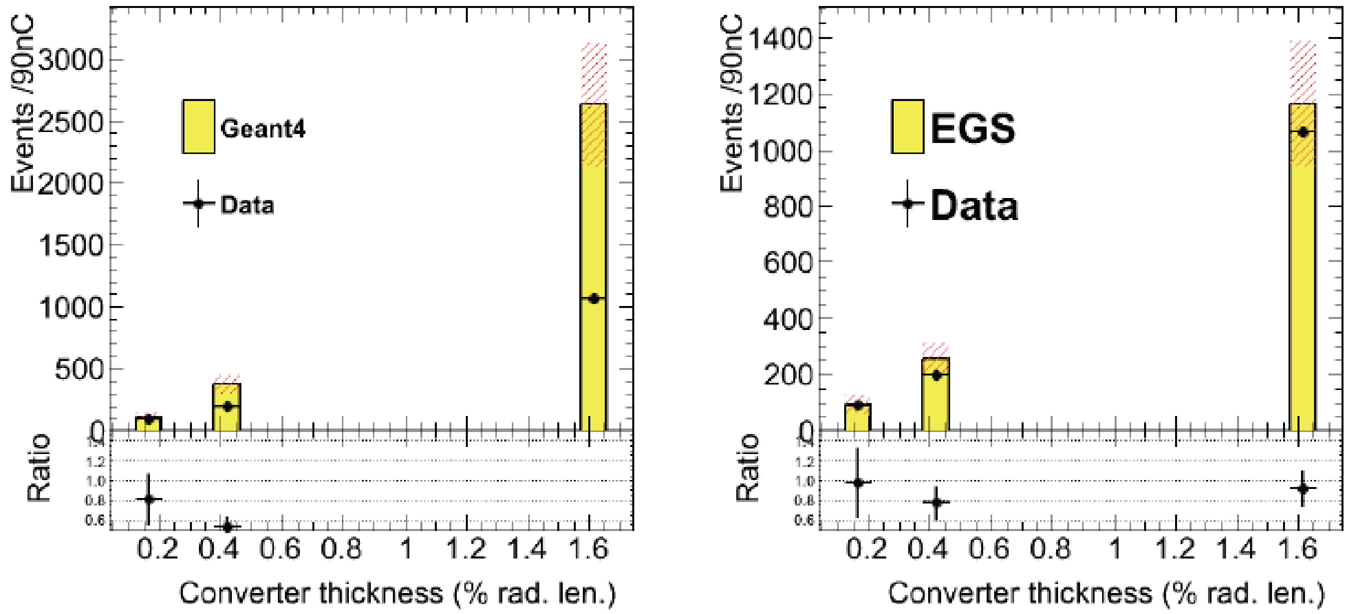


Measure a convolution of pair prod. angle and multiple scattering

- Comparable in size; only interested in multiple scattering contribution
- Different target thickness change multiple scattering contribution.

Absolute Trigger Rates with ECal

Trigger Rates vs. Target Thickness is very sensitive to multiple scattering.



- Verify Geant4 overestimation at large angles
- EGS5 agree with data to within 10%

Further confidence in estimating the multiple Coulomb scattering background.

Beam background from the Target

Souce	Effect on Detector	Simulation/Estimation
Multiple Coulomb Scattering	SVT occupancy SVT radiation Ecal occupancy Ecal trigger	EGS5/Geant4
Bremsstrahlung photons $\gamma \rightarrow$ e+e- (two-step tridents) energy degraded electrons	Ecal occupancy Ecal trigger Neutrons on FPGA	EGS5/Fluka
Moller scattering (δ-rays)	SVT occupancy	EGS5
Hadron production	SVT occupancy Ecal trigger	Geant4/Fluka
X-ray generation Inner shell ionization followed by x-ray transition	SVT occupancy	EGS5/Geant4 NIST x-ray database

Physics background

Tridents e-Z $\rightarrow$e-Zγ*, γ*$\rightarrow$ e+e-	SVT occupancy Ecal trigger	MadGraph

SVT Occupancy at 6.6 GeV

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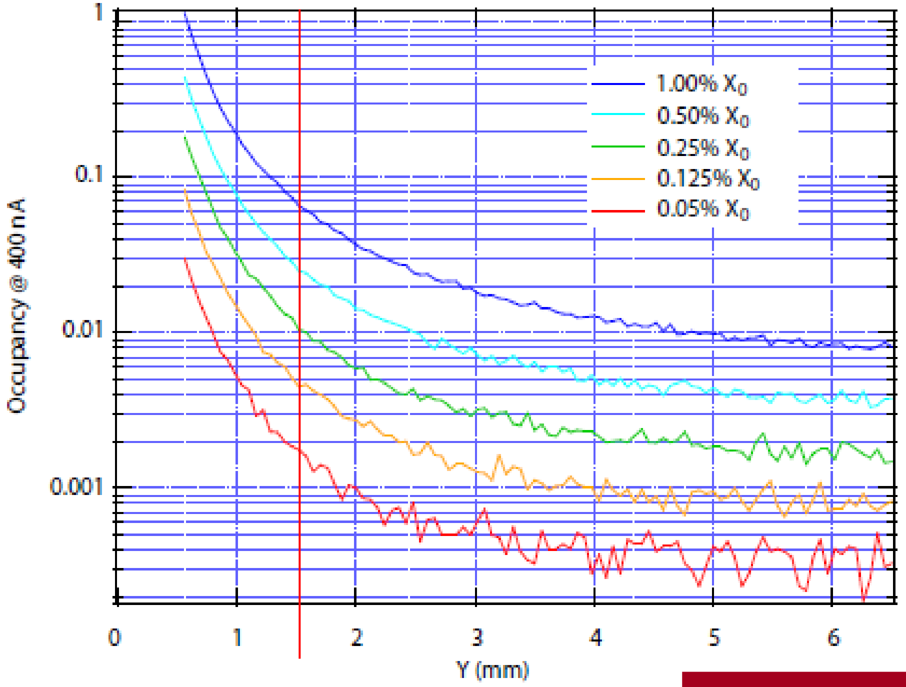
SVT Layer 1 Occupancy in 8 ns time window



Beam Current to yield 1% Occupancy

Target Thickness (% X_0)	Beam Current (nA)	$(T\bullet I)^{1/2}$ ~$S/\sqrt{B}$
1.0	60	7.7
0.5	170	9.1
0.25	430	10.4
0.10	1330	11.6
0.05	2860	11.9

Run Condition

Beam energy (GeV)	Target Thickness (% X0)	Beam Current (nA)
6.6	0.25	450
2.2	0.125	200
1.1	0.125	50

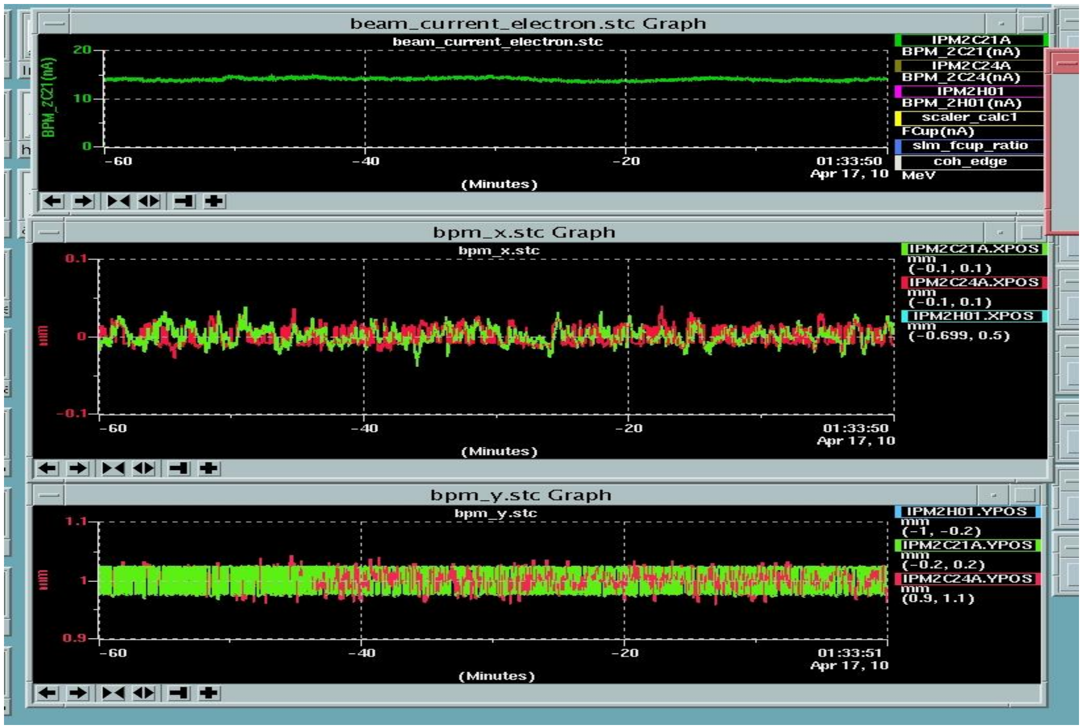
Ecal Trigger rates

Sample	Trigger Rate (kHz)
1.1 GeV beam background	15.7 ± 0.4
1.1 GeV beam background + tridents	18.3 ± 0.4
2.2 GeV beam background	11.2 ± 0.3
2.2 GeV beam background + tridents	15.8 ± 0.4
6.6 GeV beam background	10.2 ± 0.3
6.6 GeV beam background + tridents	12.6 ± 0.4
6.6 GeV beam background + tridents + pions (FLUKA)	13.4 ± 0.4
6.6 GeV beam background + tridents + pions (G4)	13.5 ± 0.4

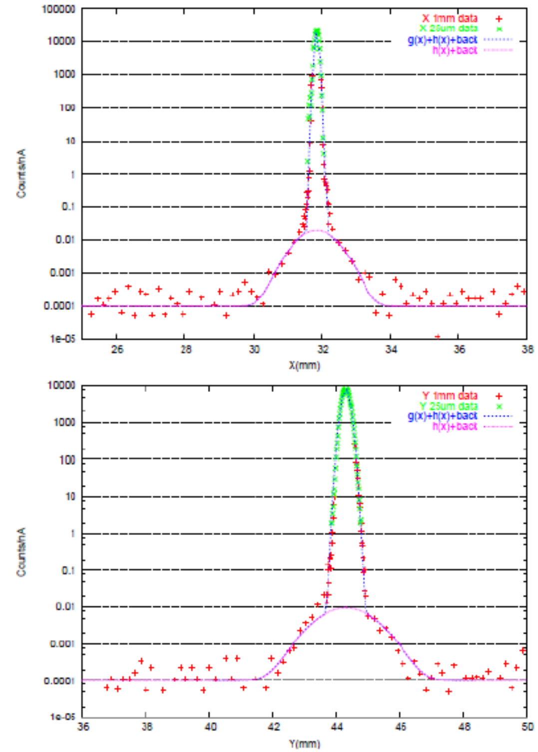
The HPS trigger system is designed to handle trigger rates above 50 kHz.

CEBAF Beam Stability and Beam Halo

Beam is stable within 30 μm.



Beam halo is <10^{-6}.



Clean and stable beam was demonstrated during the 6 GeV era.

We are confident that similar performance will be achieved in the 12 GeV machine.
However, since we are getting a brand new beam in 2014, we are taking
a conservative approach.

Beam Offset monitor and Protection Collimator

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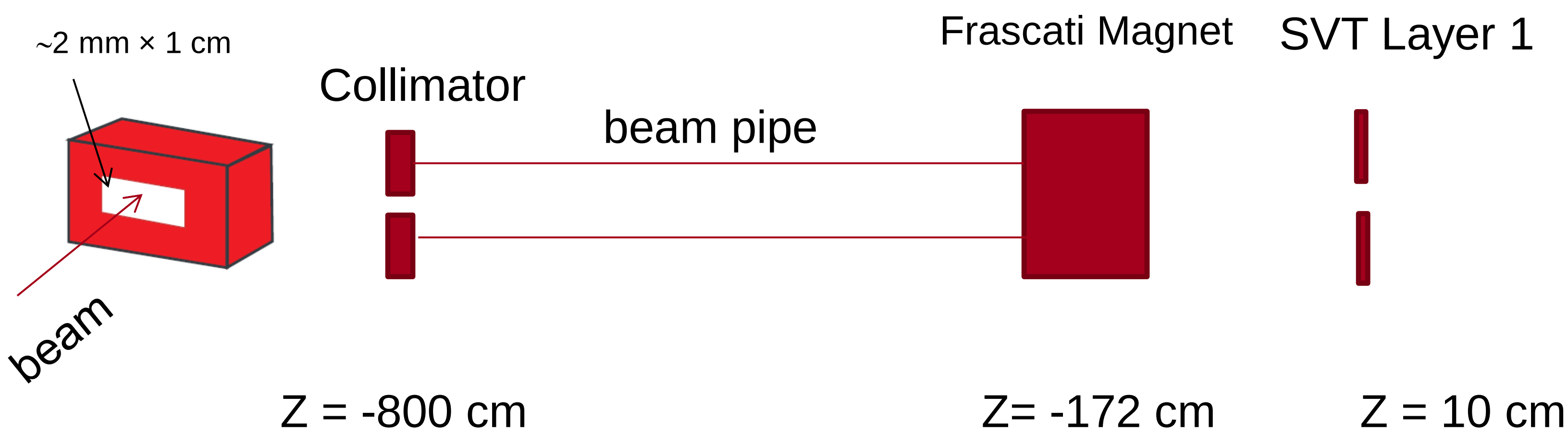
Beam halo counter and beam offset monitor

- Continuous and fast monitoring the beam condition
- If there is a significant orbit deviation, the fast shutdown system (FSD) will shut off the beam in ~40 μsec.

Protection collimator

- Protect SVT from direct beam exposure.
  - 1.1×10^{8} e-'s in 40 μsec with σy ~ 50 μm at 6.6 GeV
- Beam halo suppression

SVT Protection Collimator

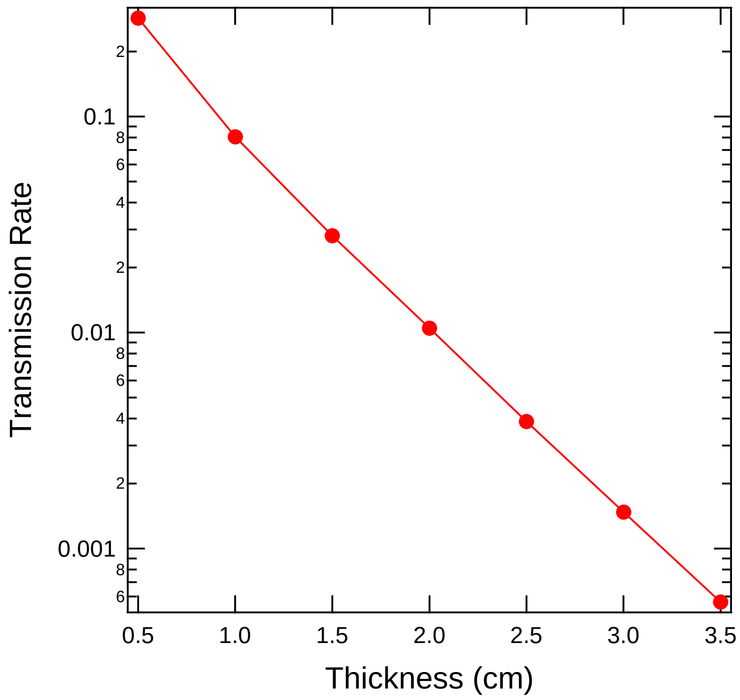


- Collimator by itself is not very effective as collimation makes electrons “angry”.
- Collimator combined with the Frascati magnet is very effective in sweeping out low energy particles. Only particles above 1 GeV are potential background.

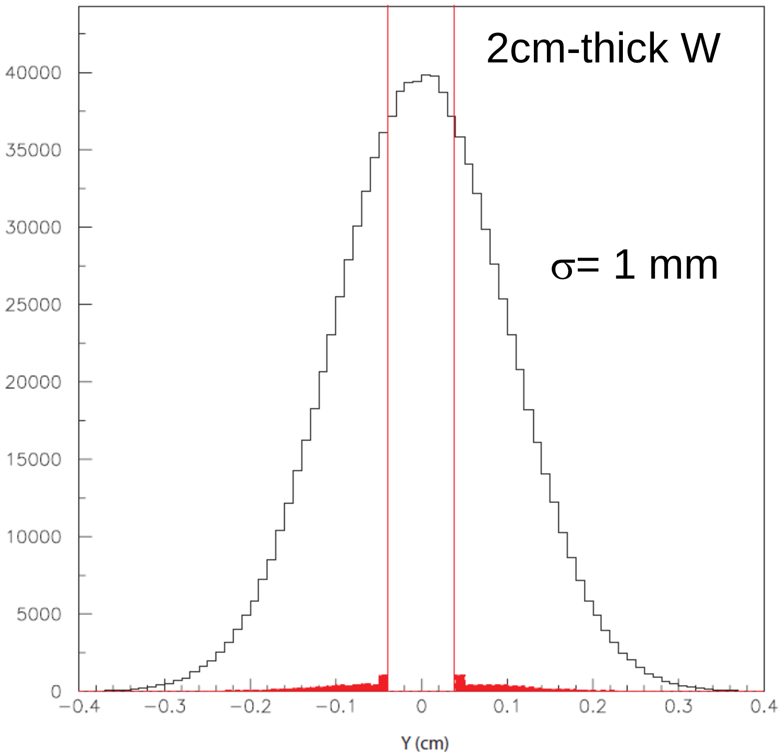
Collimator simulation

Errant beam can be blocked.

Beam survival rate at 6.6 GeV



10^{-4} halo in |Y| > 0.5 mm can be reduced to 2×10^{-6}



Beam-induced EM fields

RF power in I_{avg} = 200 nA	30 nW
Direct beam field	
Voltage drop in Si strip spacing	1.7 mV (t < 1 ps)
Induced voltage from image charge	33 μV
Wake field	
Transition radiation from target	
Incoherent	35 mW ($\theta \sim 1/\gamma$)
Coherent	480 nW

Beam-induced EM fields are small because the bunch charge is small in CW machine.

Summary

Multiple Coulomb scattering is the dominant background.

- We understand the multiple scattering model.
- Test Run trigger rate is consistent with the EGS5 prediction.

Extensive studies have been made on the beam background.

Beam control system will be installed.

- Beam halo monitor and beam offset monitor
- Fast beam shutdown system

Protection collimator will be installed

- To protect SVT from direct beam exposure,
- To suppress beam halo.

HPS will be ready to take electron beam when the beam is delivered to Hall B in 2014.