Muon Collider MDI Developments - Higgs Factory

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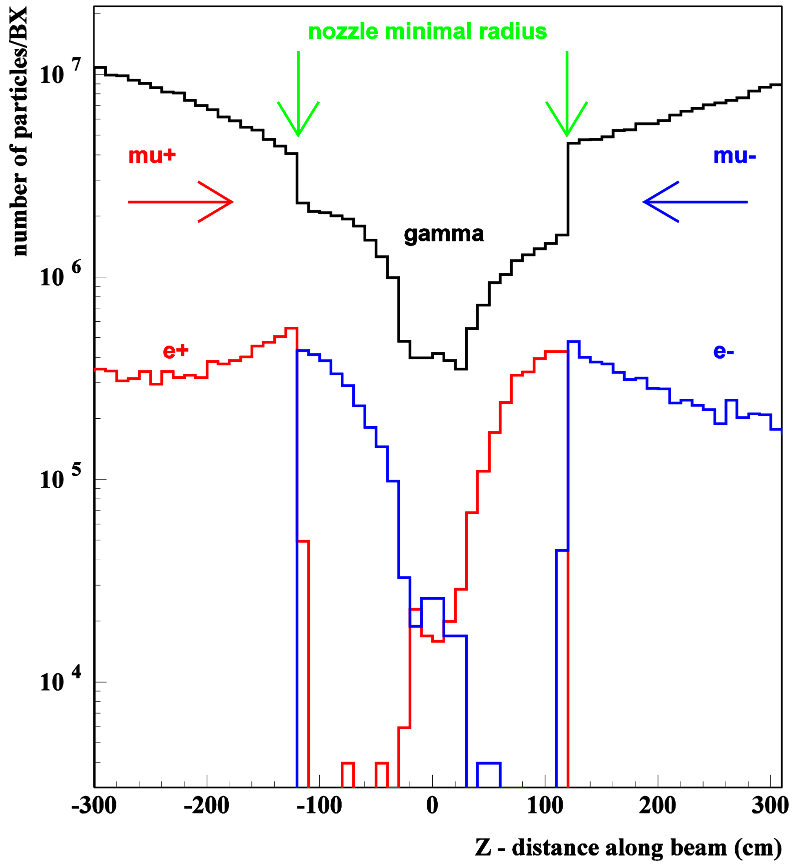
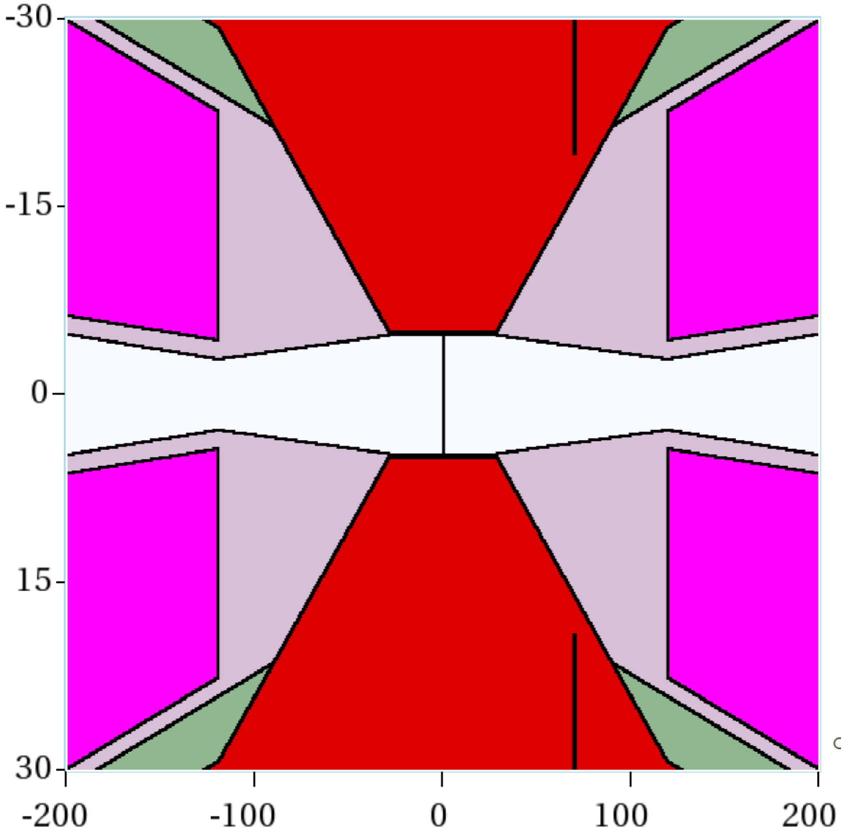
Outline

- How to optimize inner surface of shielding
- Where is background produced
- Comparison background load with SLAC and EGS
- Hits in vertex and tracker detector
- Copper instead tungsten
- Conclusion

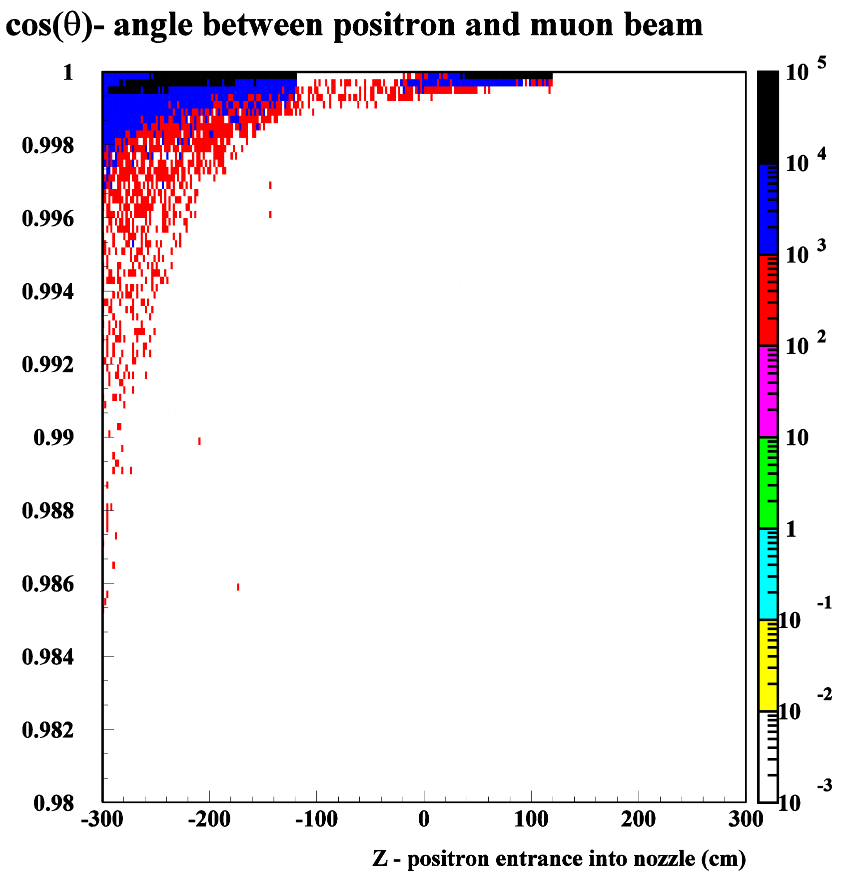
Where Background Hits Nozzle INNER surface-v3

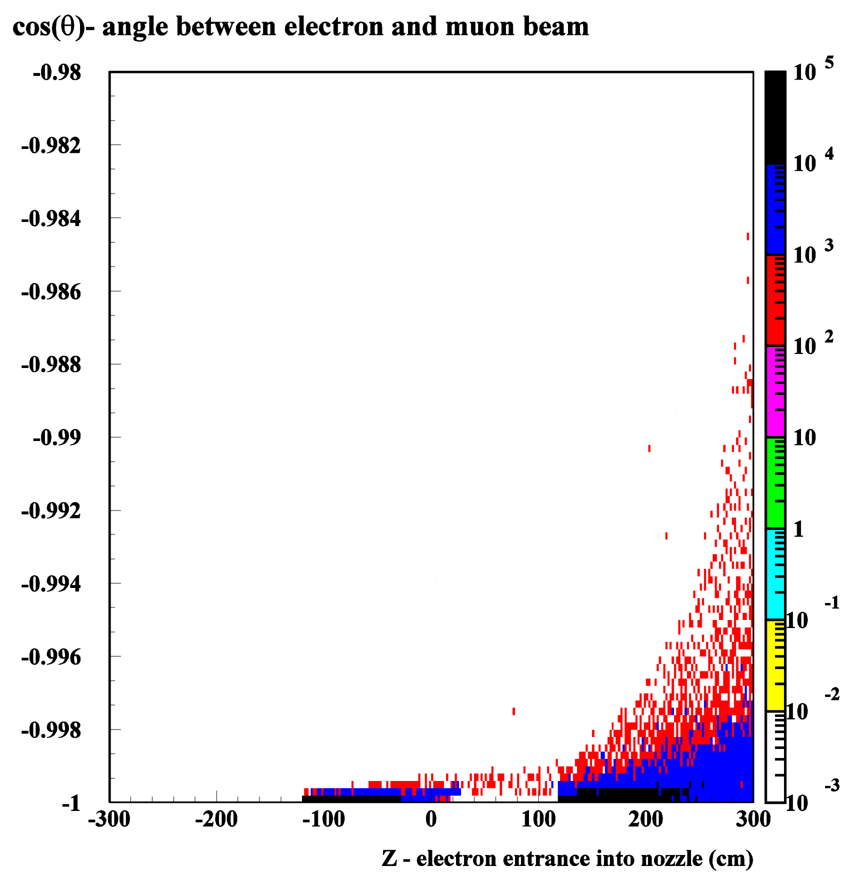
2.2 10^5 decay e+- through
Be beam pipe (25 GeV/c)



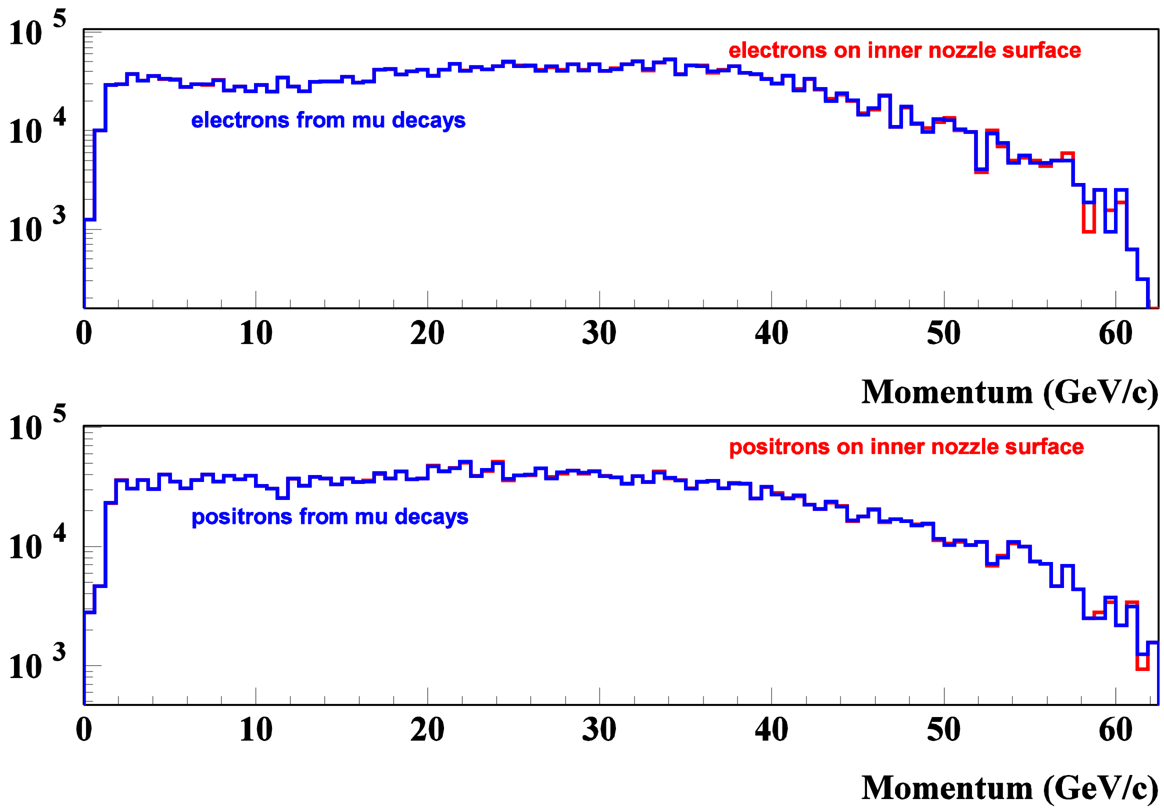


Angle between electron/positron and beam as function of nozzle entrance point



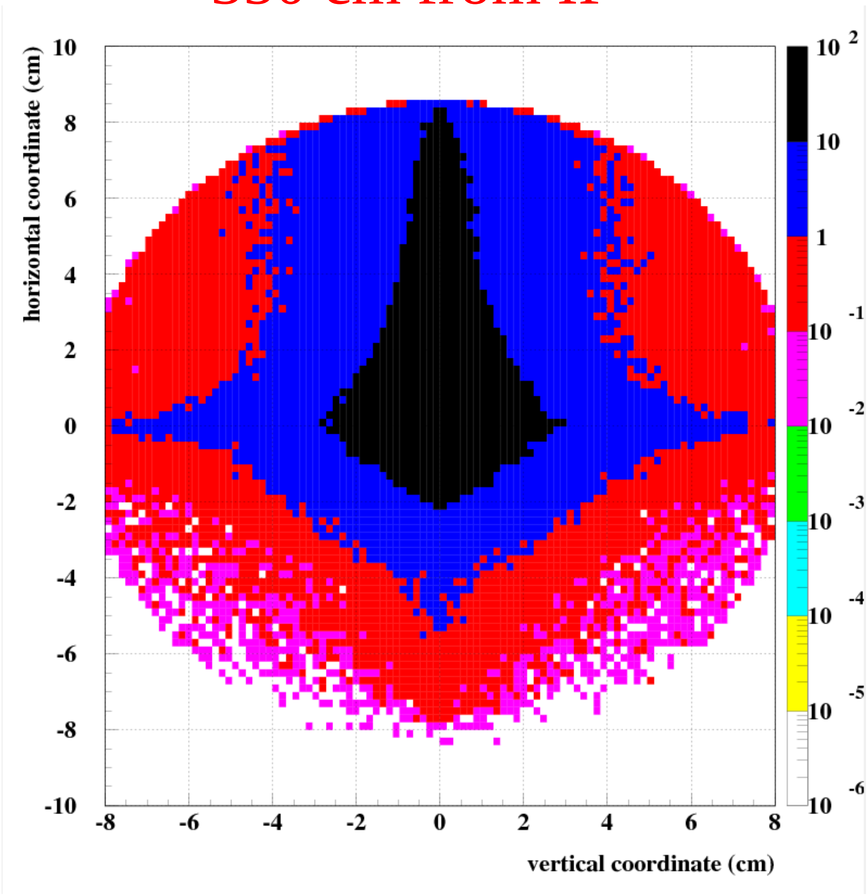


Momentum spectra of electron from muon decay and momentum spectra of electron entered into nozzle (|z|<120 cm)

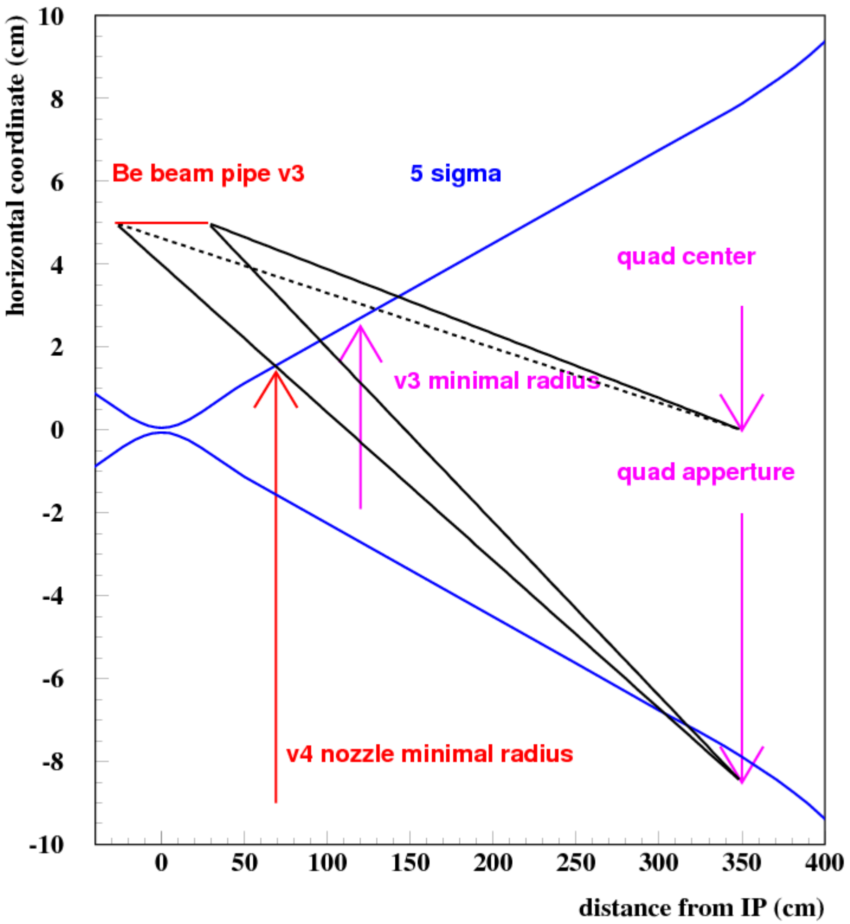


How to choose minimal nozzle radius?

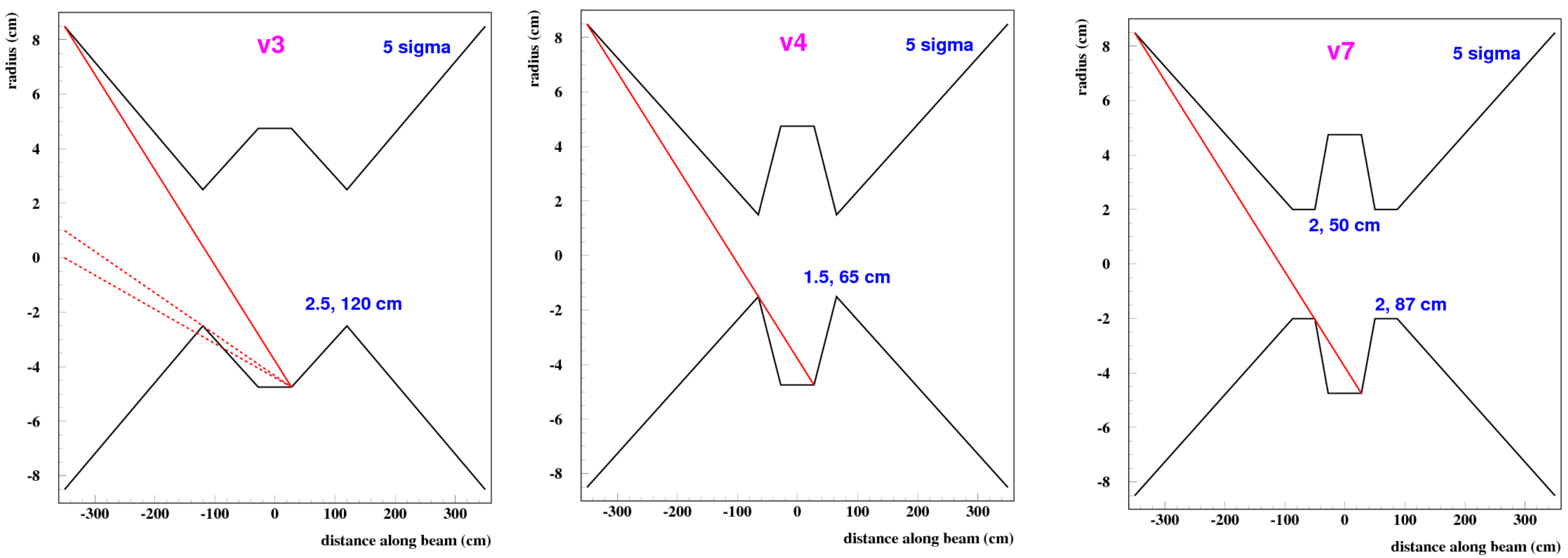
electron distribution after first quad
350 cm from IP



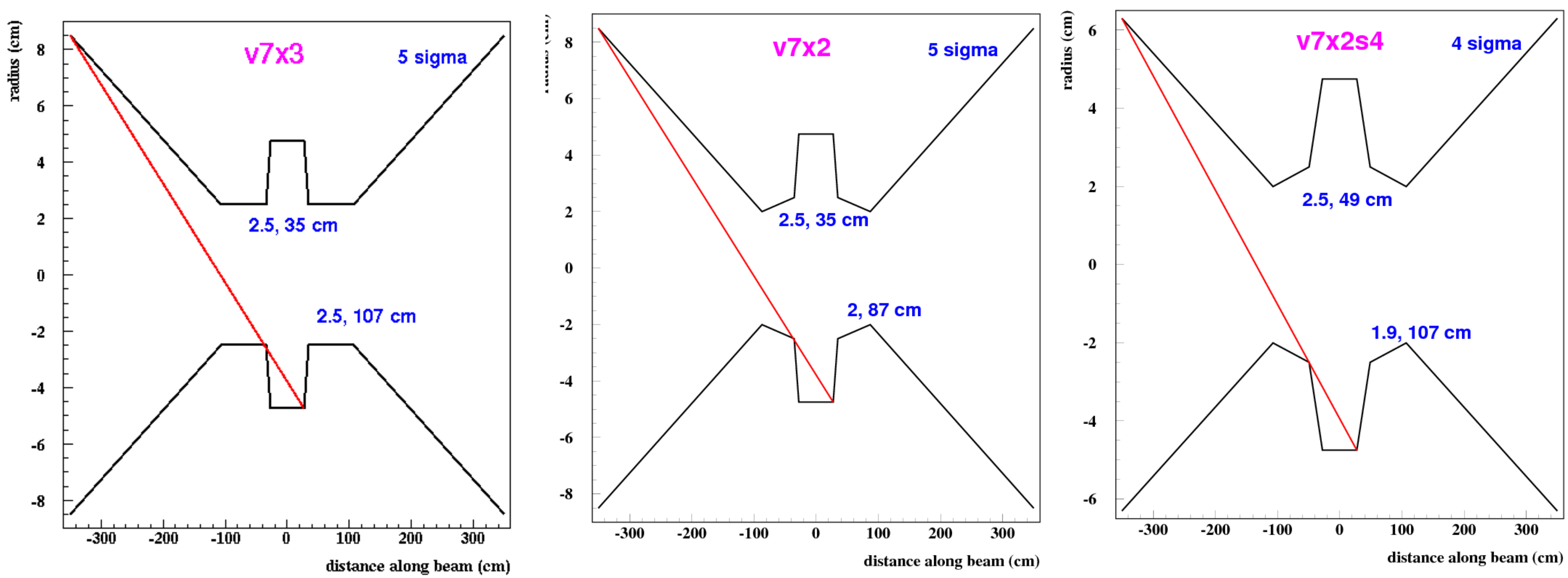
minimal nozzle radius



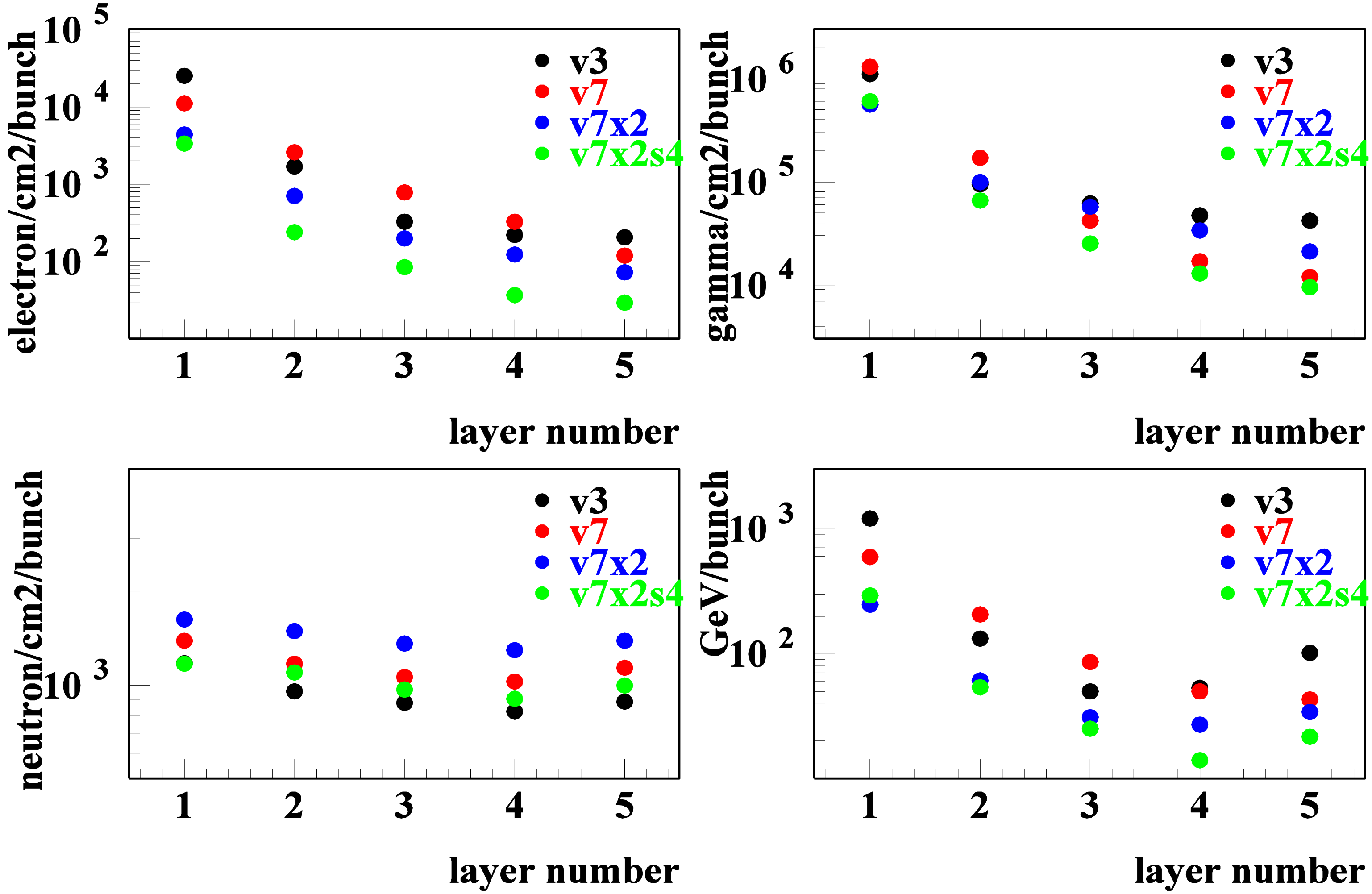
Nozzle geometry - considered setups



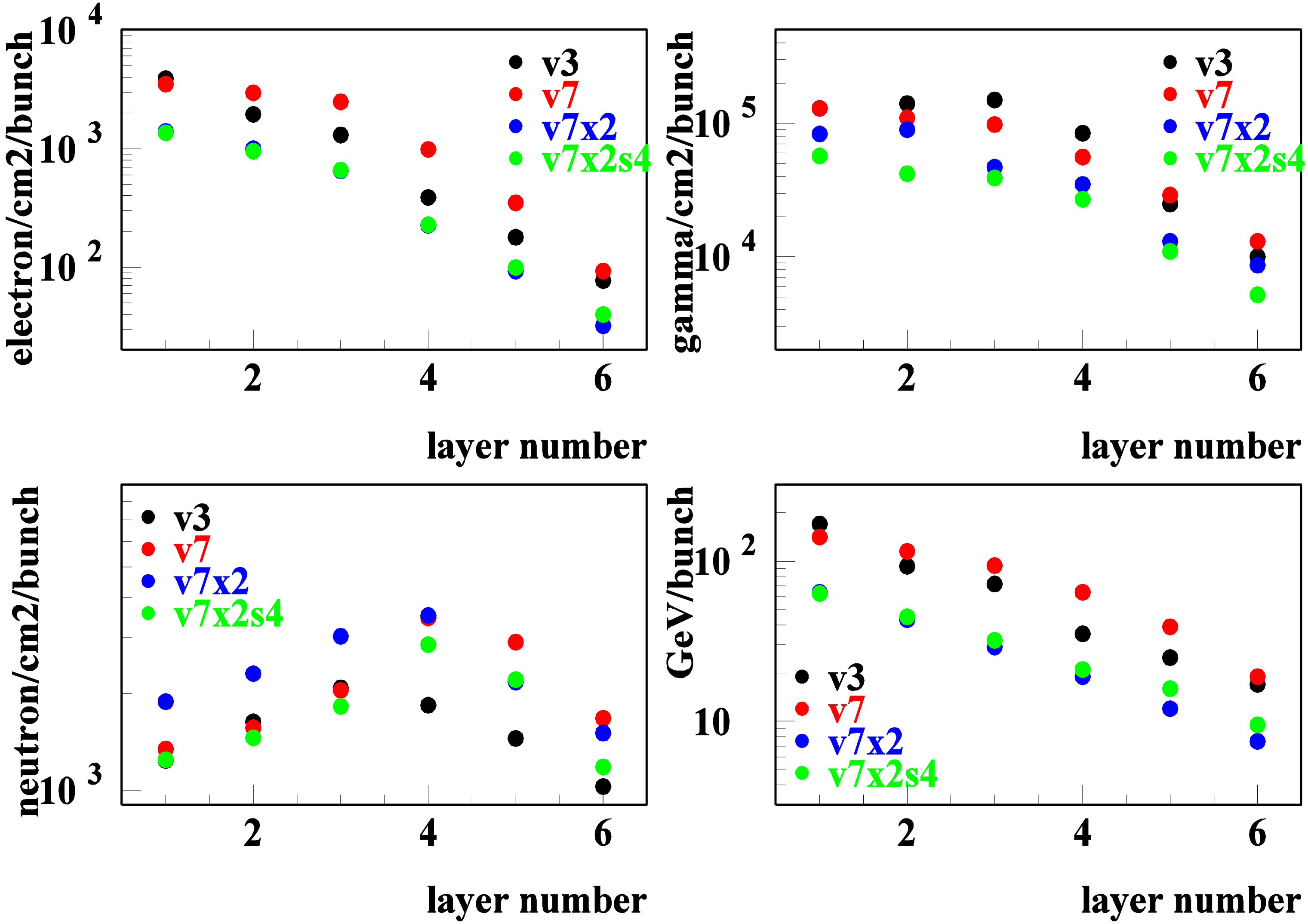
Nozzle geometry - 2 vertex setups



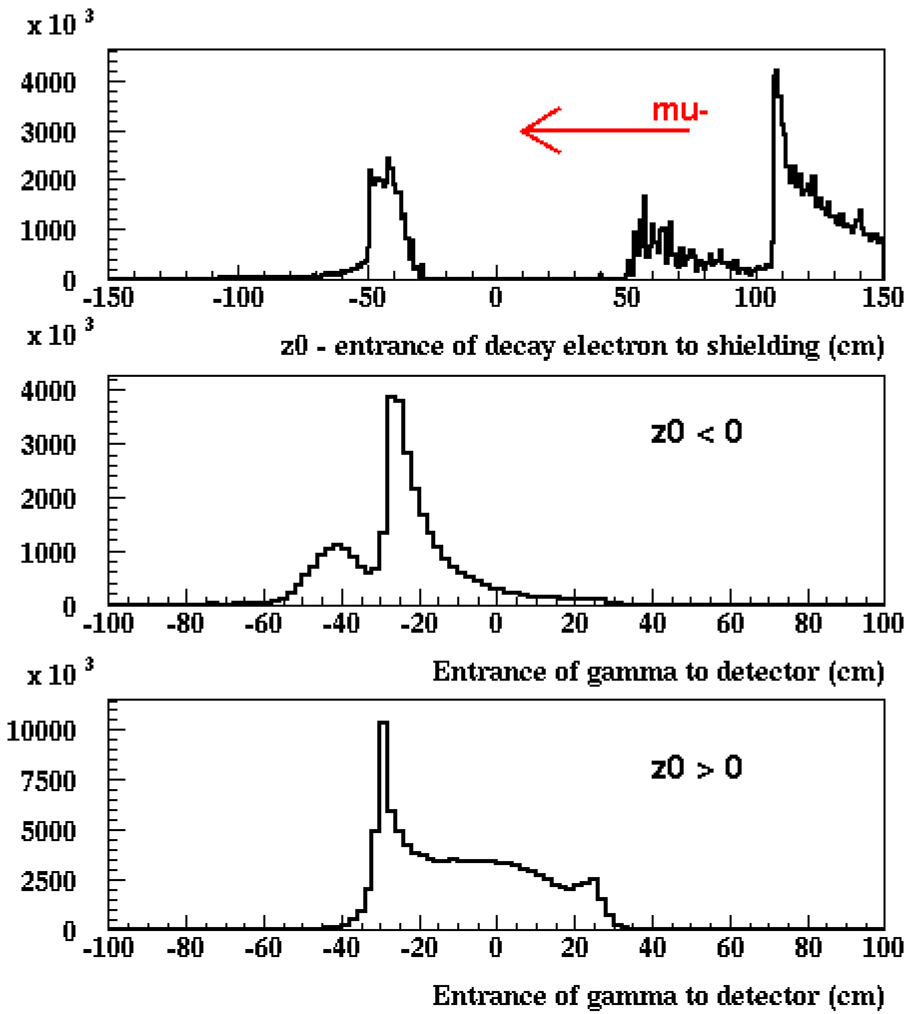
Vertex Barrel

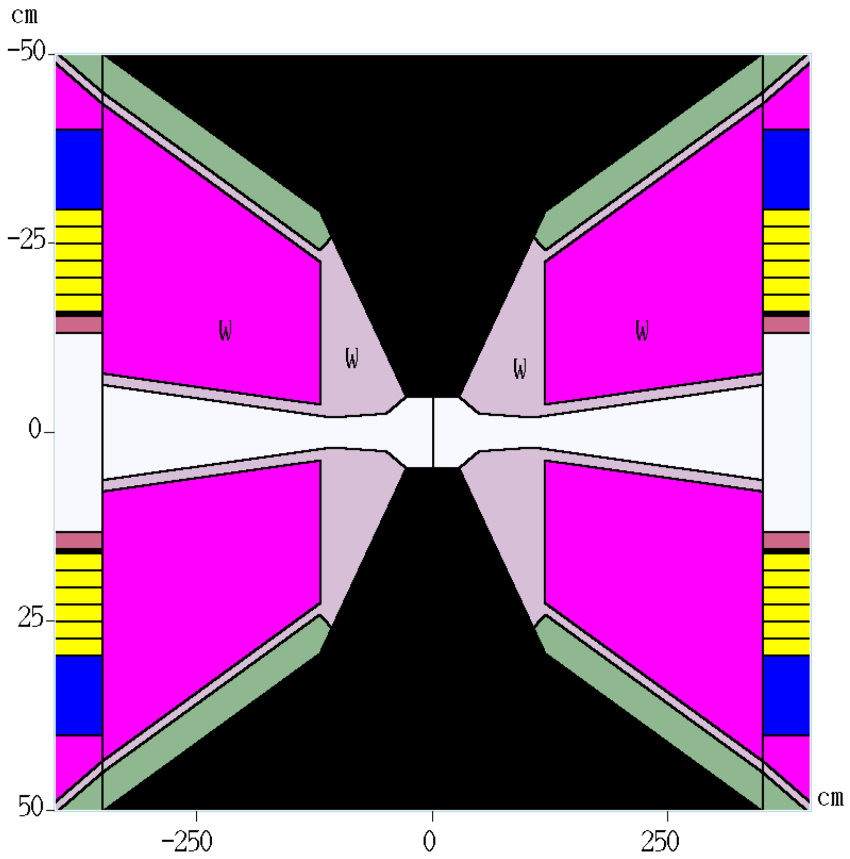


Vertex Endcap



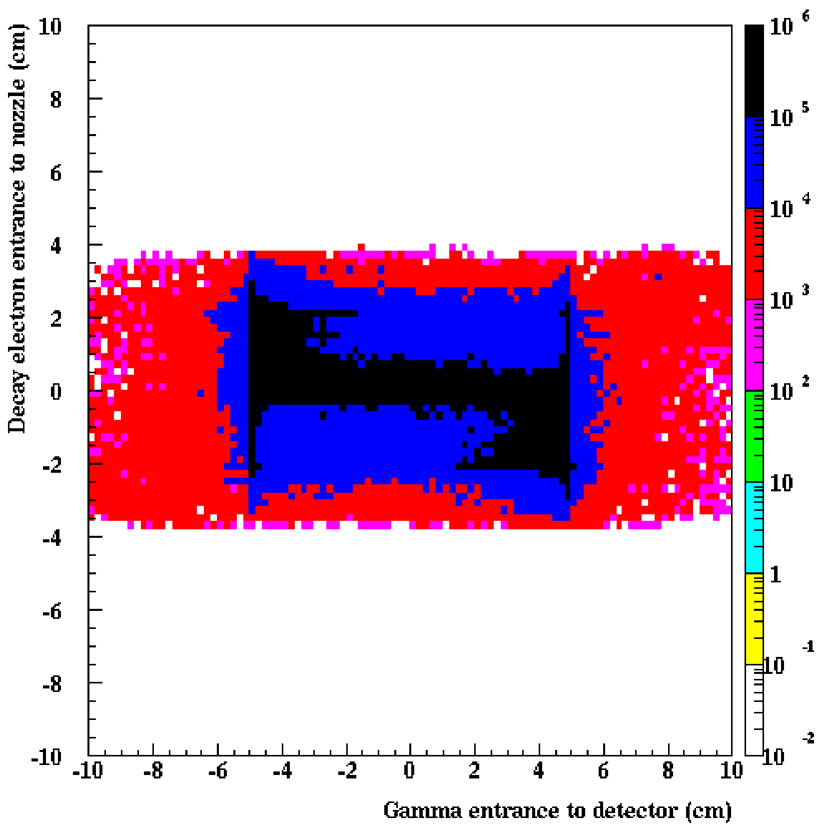
Decay electrons on inner surface produce gammas in detector



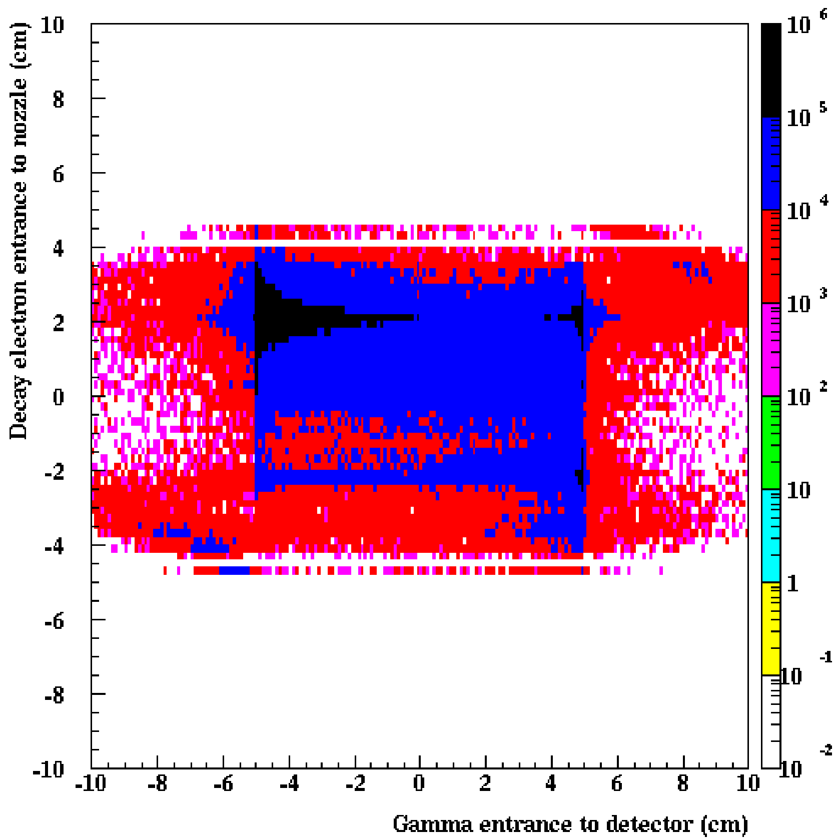


Gamma flux: entrance to detector vs electron entrance to nozzle.
Beam pipe – 5 cm radius, nozzle minimal radius – 2 cm

vertical coordinate



horizontal coordinate



Maximum at positive (negative) entrance to nozzle and negative (positive) entrance to detector – backscattering from nozzle jaws!

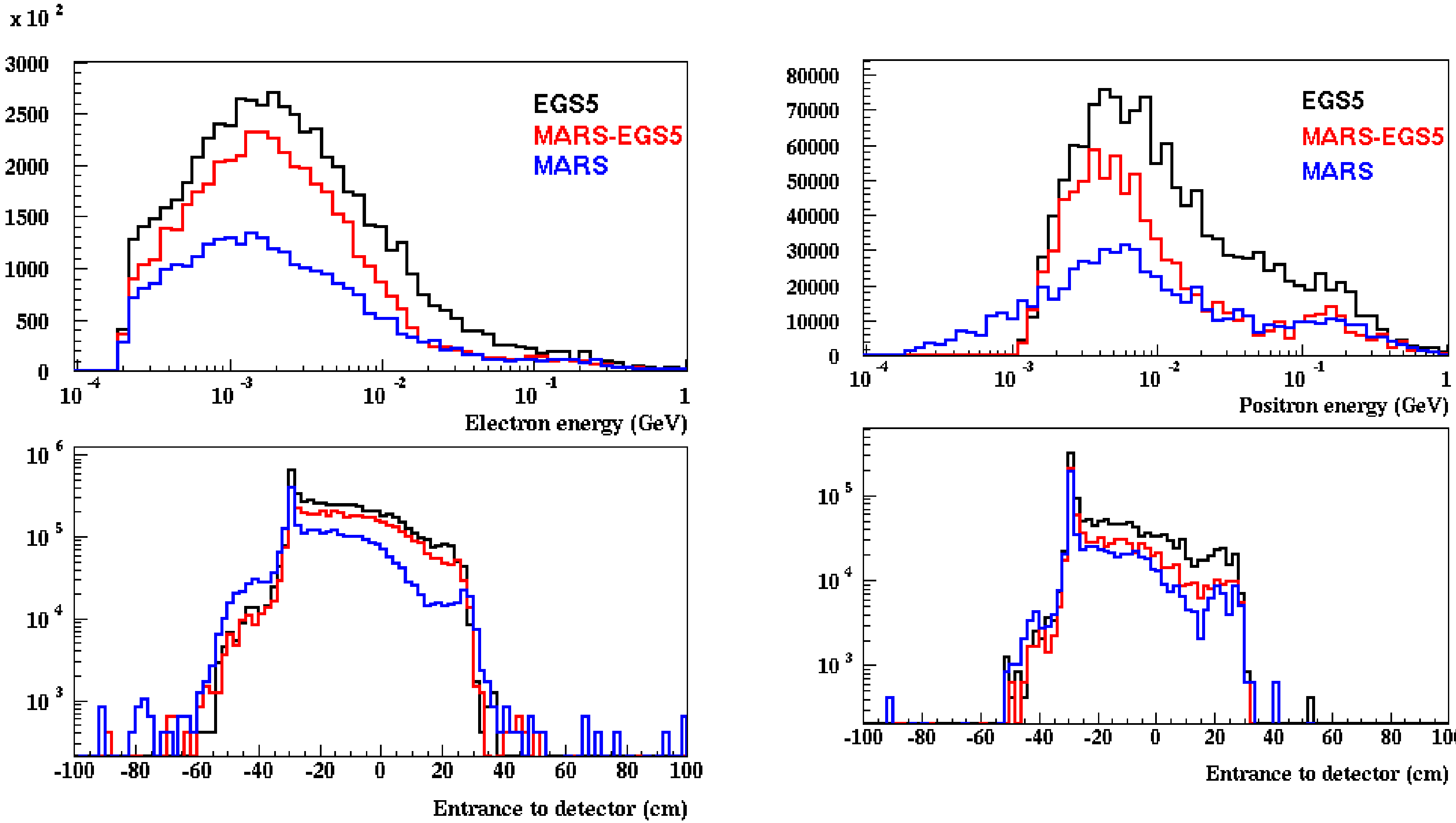
Number of particles entering detector per bunch X-ing. ch. Hadron > 1 MeV; γ,e > 0.2 MeV; neutron> 0.1 MeV

SLAC team (T. Markiewicz, T. Maruyama) – Winter meeting, 2014 compare their FLUKA simulation with MARS. For unknown reason they make comparison with v7 setup, not with v7x2s4 setup which shown in their report. So, they got ~2 times more neutrals and ~10 times more e+- than MARS. MARS agrees with EGS for neutrals and underestimate e+- about 3 times.

	SLAC	v7	v7x2s4	MARS-EGS
Photon	6.7×10^8	5.6×10^8	3.0×10^8	3.0×10^8
Electron	4.0×10^7	3.5×10^6	3.0×10^6	1.0×10^7
Neutron	6.6×10^7	6.4×10^7	4.0×10^7	3.9×10^7
Charged hadron	2.5×10^4	1.7×10^4	1.4×10^4	1.9×10^4

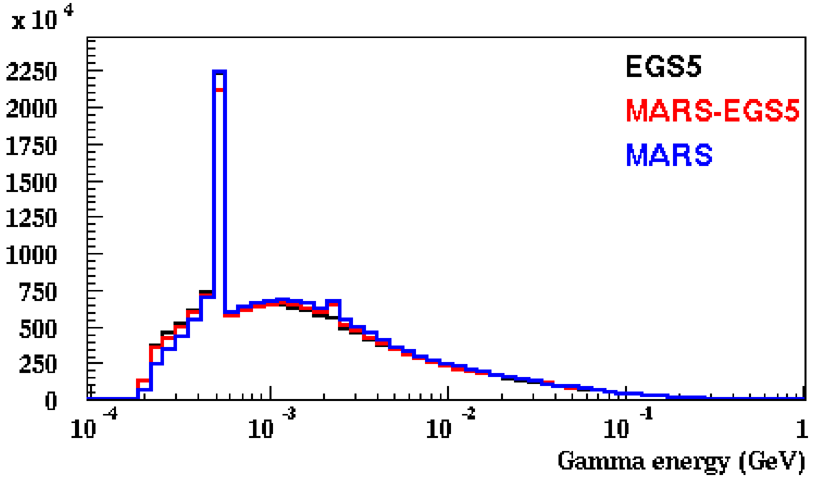
MARS vs MARS-EGS5 vs EGS5

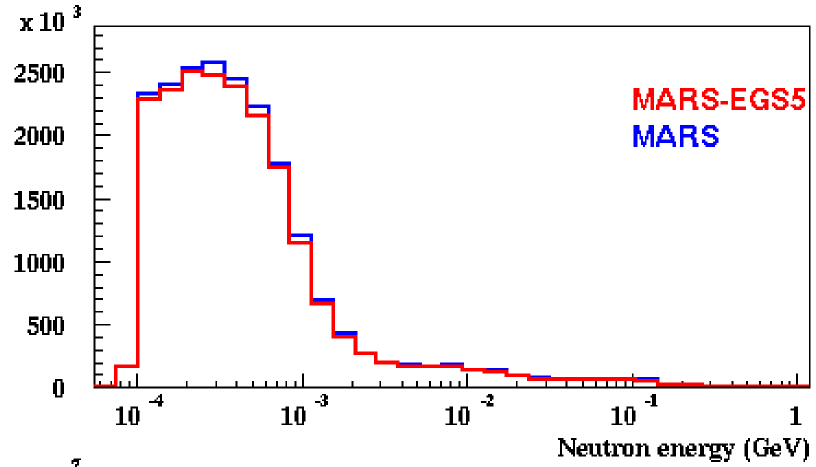
EGS5 - at all energies, MARS-EGS5 – EGS5 at energies < 10 MeV

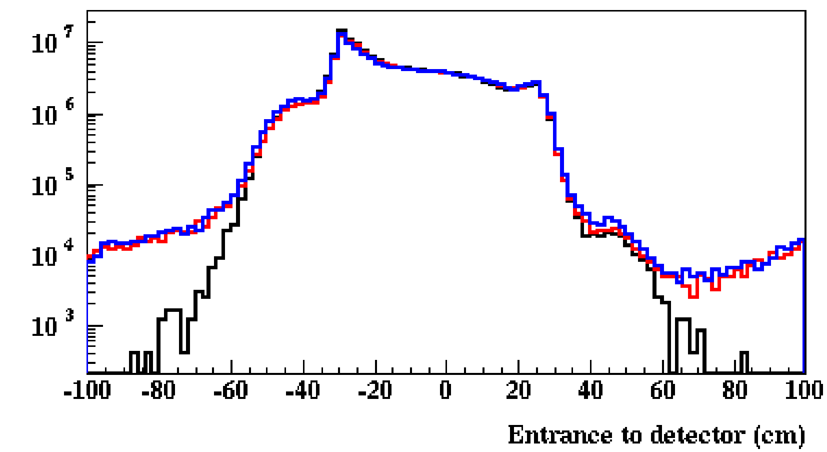


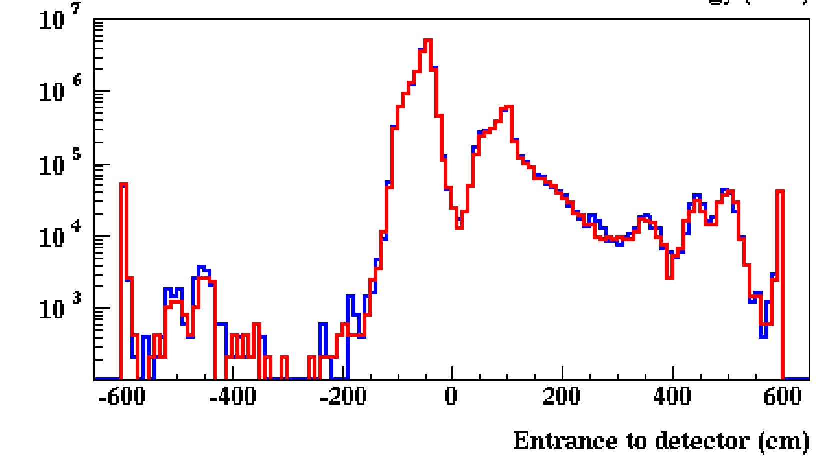
MARS vs MARS-EGS5 vs EGS5 - II

EGS5 - at all energies, MARS-EGS5 – EGS5 at energies < 10 MeV









Hit calculations

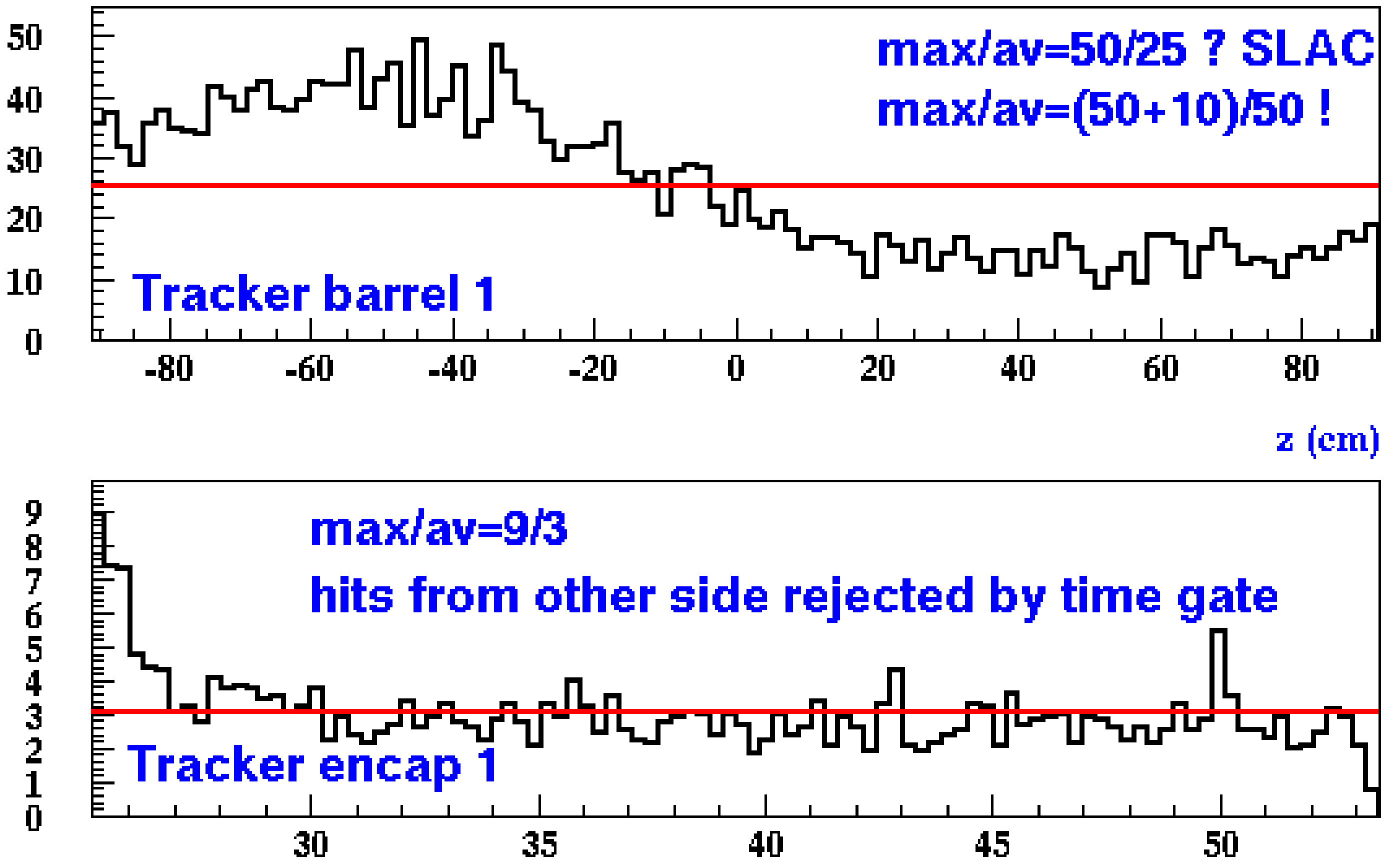
Hit definition: charged track left sensitive volume + charged track is stopped in sensitive volume. To estimate occupancy we need to perform simulation for chosen pixel size. Appropriate electron transport threshold should be determined as function of pixel size.

In MARS minimal energy of produced δ-electron E_d= electron transport threshold. Number of produced δ-electron ~ $1/E_d$. Low energy δ-electron are produced with large angle to δ-electron direction. Electron ranges in silicon: 3 keV – 0.14 µm and 10 keV – 1.5 µm. With 3 keV threshold most of δ-electrons are stopping in same pixel as outgoing track - double counting! 10 keV threshold looks like as estimate from above.

92% of hits are produced by gammas, 5% by neutrons, 3% by electrons

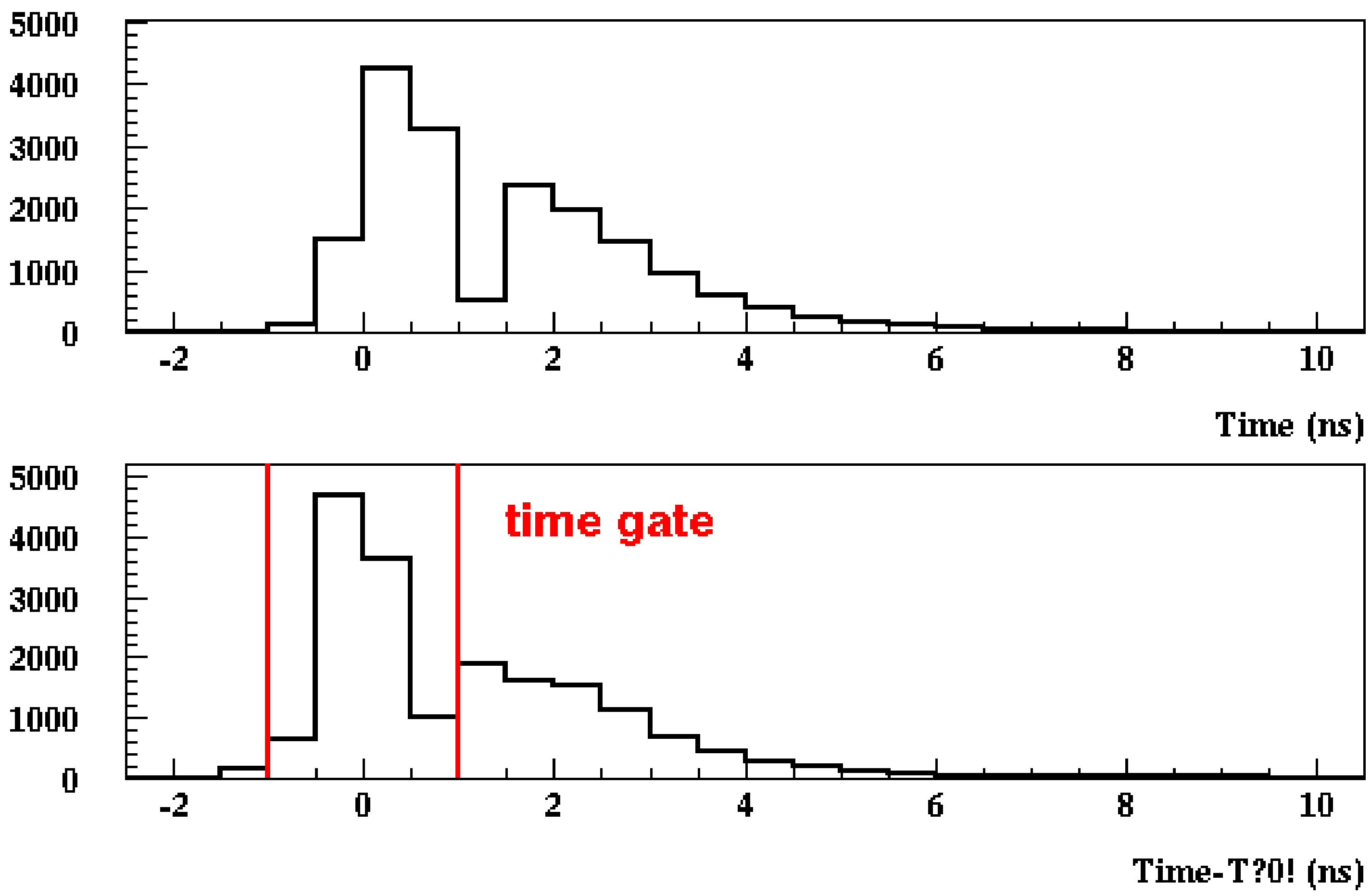
Maximum to average

Barrel: mu- and mu+ hit distributions have maximum at different place: maximum to average is lower than in one beam calculation.
Endcap: both beam have maximum at low radius, but hits from same side are rejected by time cut



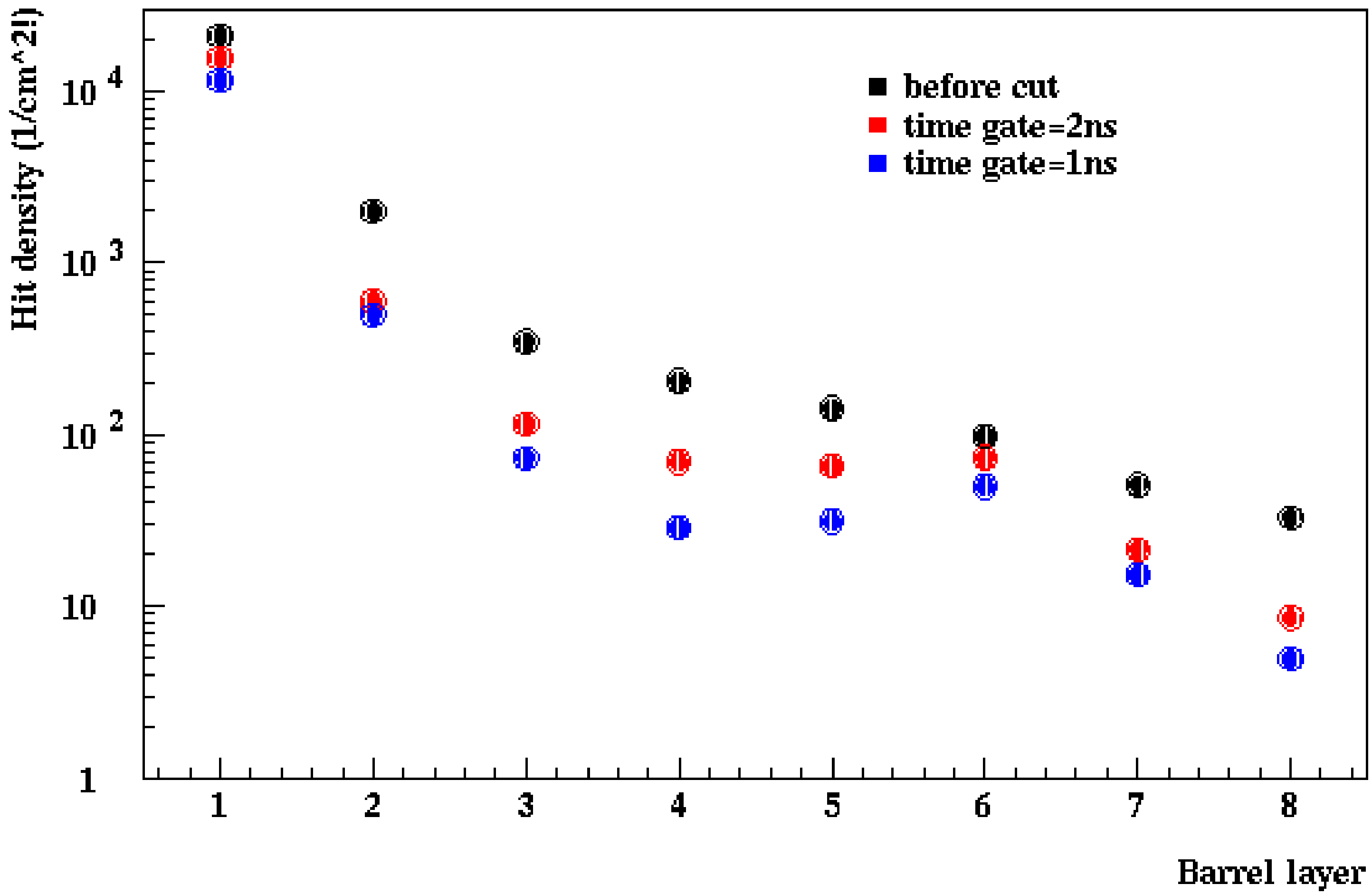
Time cut

It is natural to consider TOF-T0 instead TOF, where T0 – time of flight of IP photon form IP to hit coordinate. Time gate 1-2 ns looks like reasonable – see next talk.



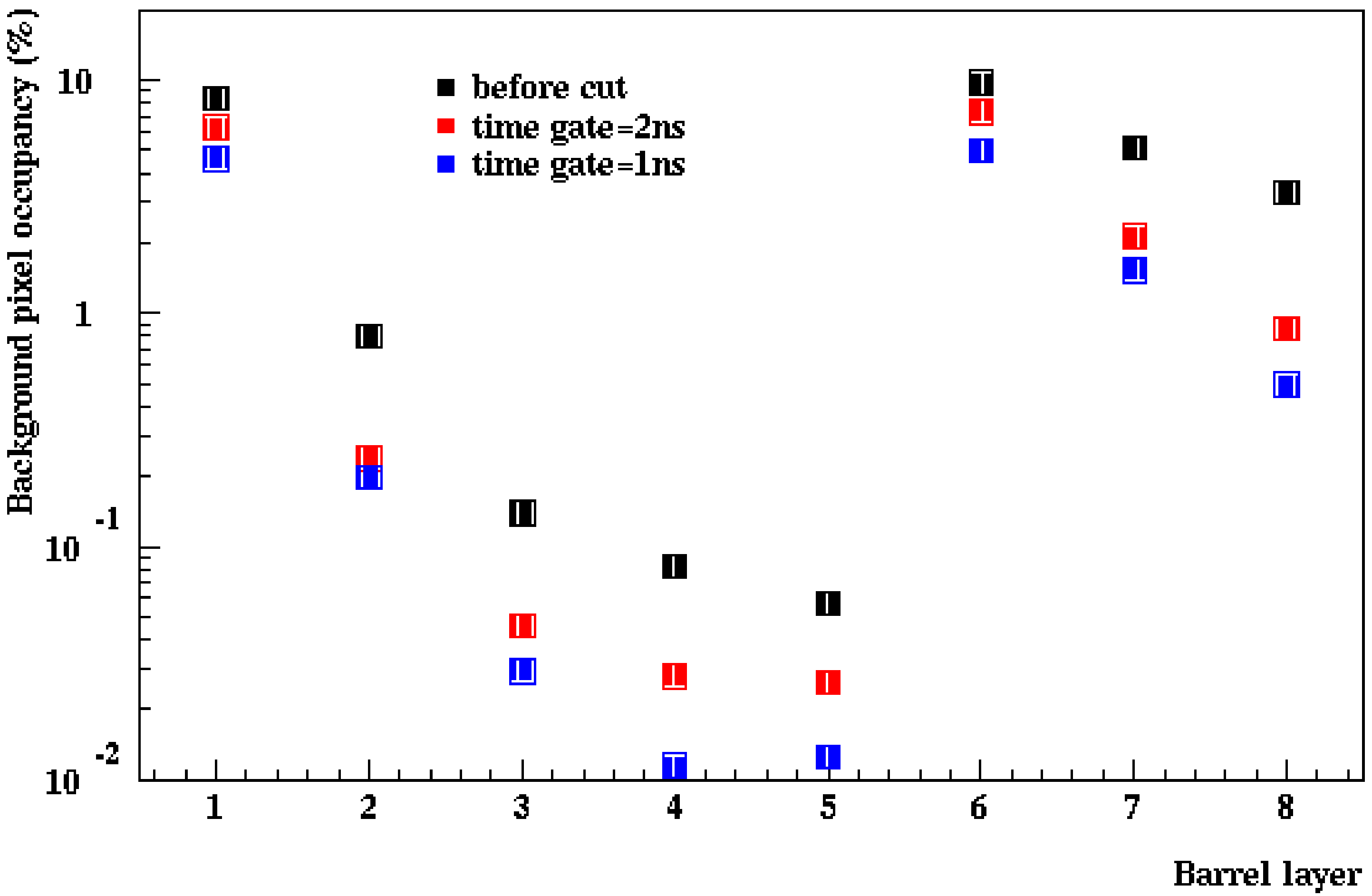
Hit density in barrel vs timing cuts

Layer 1-5 are VXD barrel, 6-8 are Tracker barrel



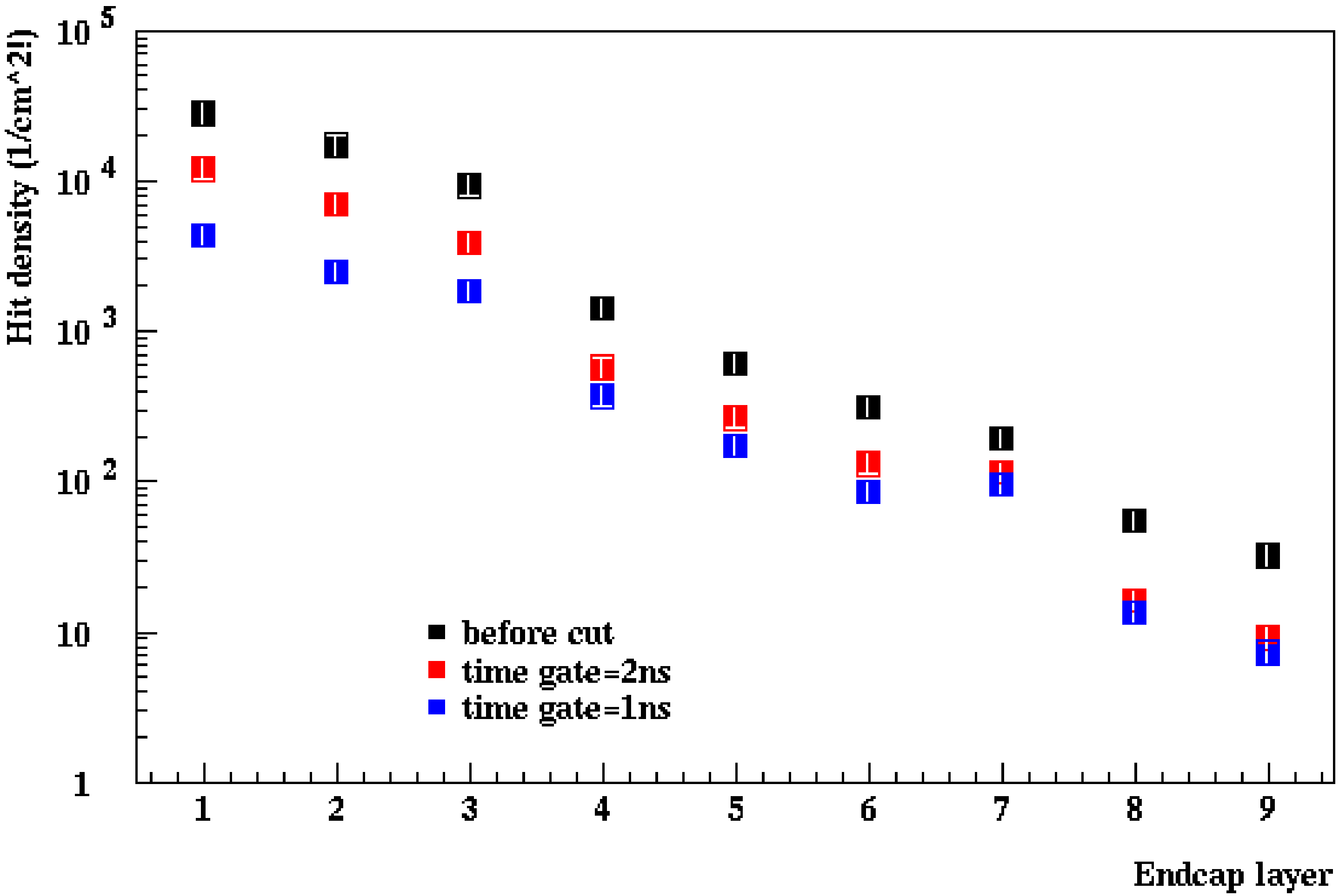
Pixel occupancy in barrel vs timing cuts.
Pixel - 20x20 μm in VXD and 1000x100 μm in Tracker

Layer 1-5 are VXD barrel, 6-8 are Tracker barrel



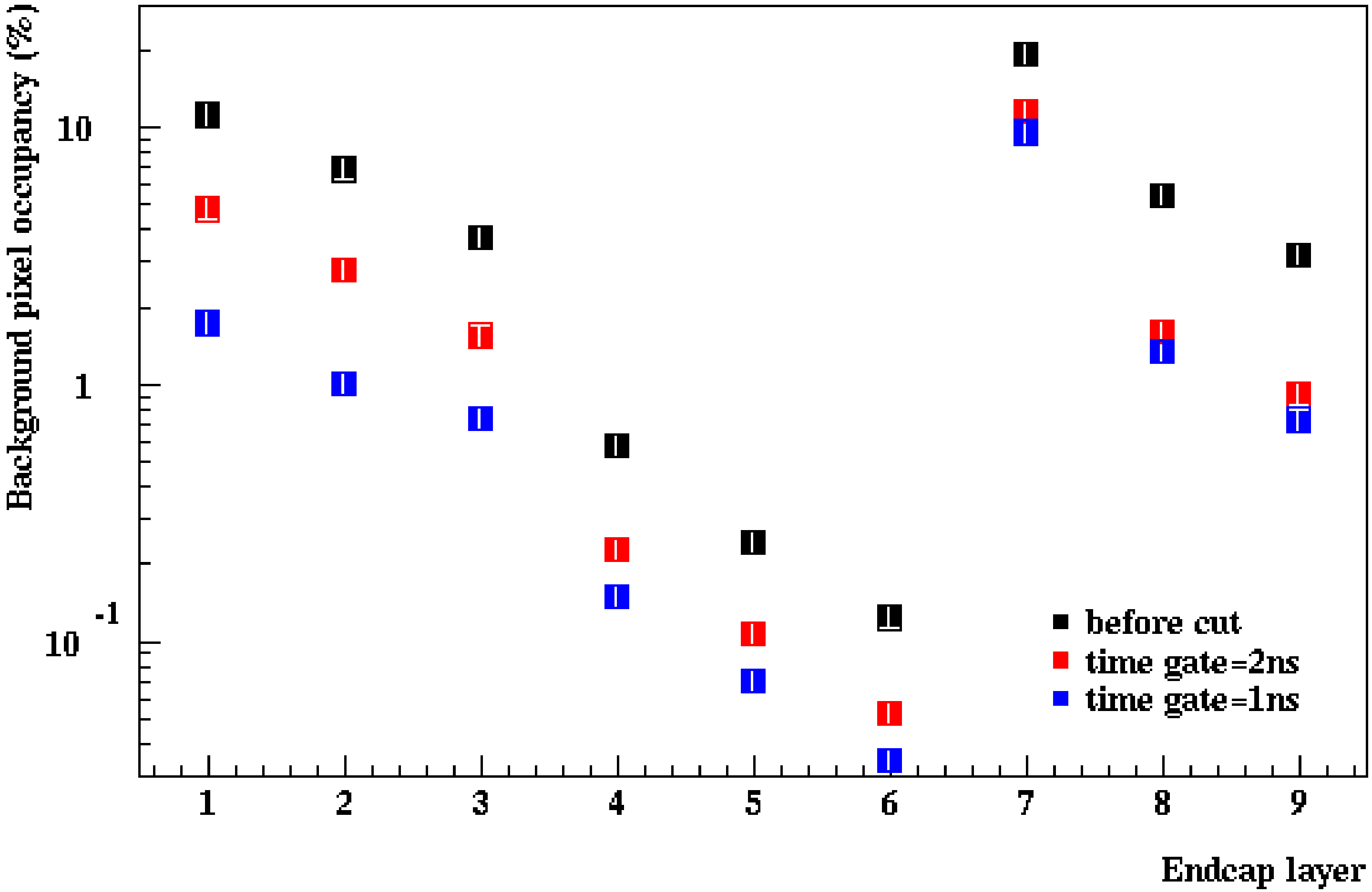
Hit density in endcap vs timing cuts

Layer 1-6 are VXD endcap, 7-9 are Tracker endcap



Pixel occupancy in endcap vs timing cuts.
Pixel - 20x20 μm in VXD and 1000x100 μm in Tracker

Layer 1-6 are VXD endcap, 7-9 are Tracker endcap



Comparison with SLAC hit calculations

SLAC team (T. Markiewicz, T. Maruyama) – Winter meeting, 2014
Hit occupancy in Tracker Barrel - 110%. They considered :

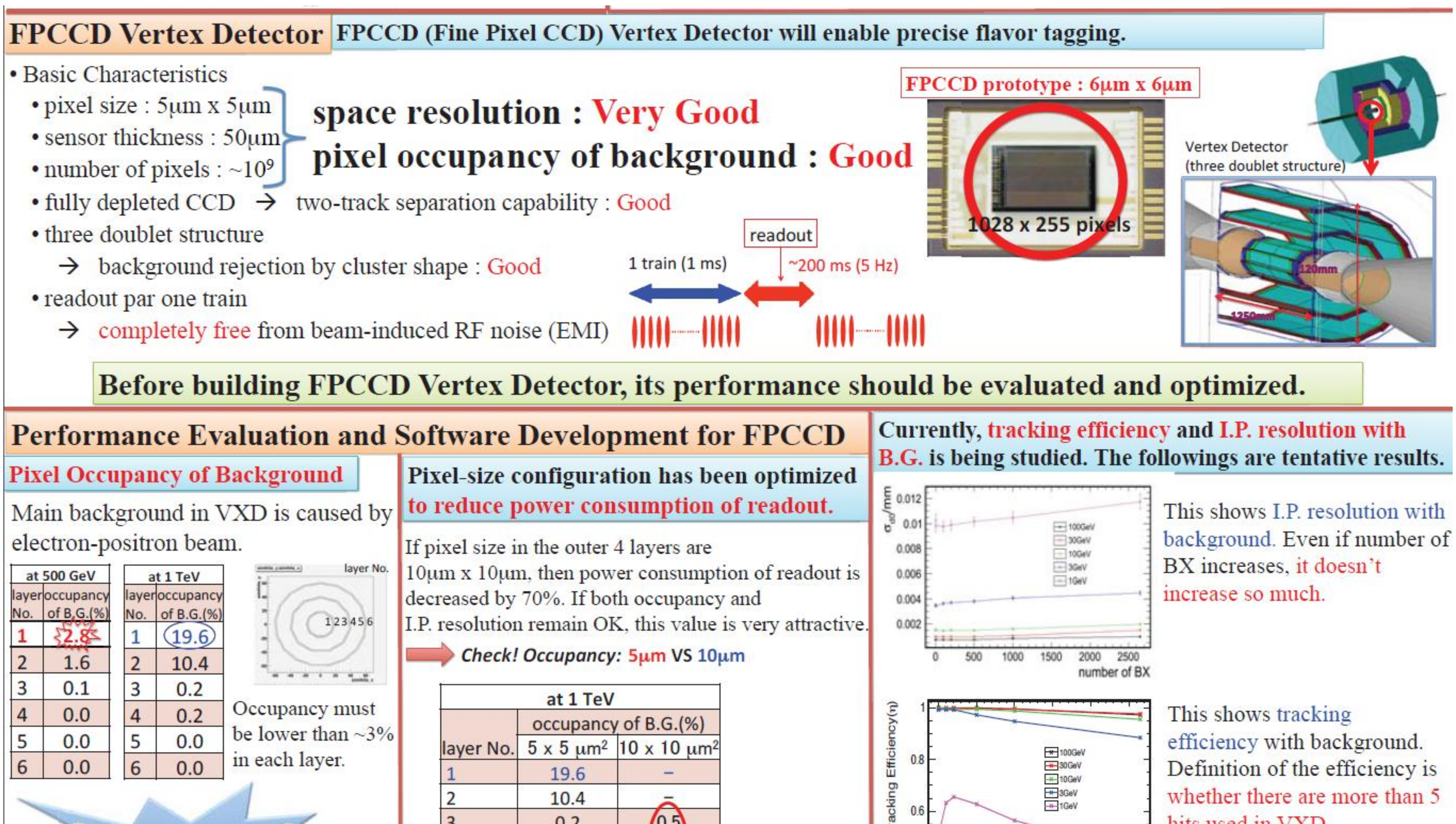
- 5 times larger strip
- do not take into account that max/av ratio in barrel from TWO beams is about two times smaller than for ONE beam
- consider 320 µm pixel thickness, MARS - 200 µm in barrel and 100 µm in tracker
- have 2 times larger number of gamma which determine background

SLAC tracker barrel occupancy -110%/5/2/1.6(?)/2=3.4 -5.5%
MARS tracker barrel occupancy ~ 5%

SLAC tracker endcap occupancy - 35%/5/3.2(?)/2= 1.1 -3.5%
MARS tracker endcap occupancy ~ 10%

ILC experience – Tatsuya Mori (Tohoku University)

Important numbers: pixel size 5-10 μm and occupancy < 3%



FPCCD Vertex Detector — FPCCD (Fine Pixel CCD) Vertex Detector will enable precise flavor tagging.

- Basic Characteristics
  - pixel size : 5μm x 5μm
  - sensor thickness : 50μm
  - number of pixels : ~10^9

  → space resolution : Very Good
  → pixel occupancy of background : Good
  - fully depleted CCD → two-track separation capability : Good
  - three doublet structure
    → background rejection by cluster shape : Good
  - readout par one train
    → completely free from beam-induced RF noise (EMI)

FPCCD prototype : 6μm x 6μm

1028 x 255 pixels

readout

1 train (1 ms)

~200 ms (5 Hz)

Vertex Detector (three doublet structure)

Before building FPCCD Vertex Detector, its performance should be evaluated and optimized.

Performance Evaluation and Software Development for FPCCD

Pixel Occupancy of Background

Main background in VXD is caused by electron-positron beam.

layer No. (at 500 GeV)	occupancy of B.G.(%)
1	2.8
2	1.6
3	0.1
4	0.0
5	0.0
6	0.0

layer No. (at 1 TeV)	occupancy of B.G.(%)
1	19.6
2	10.4
3	0.2
4	0.2
5	0.0
6	0.0

Occupancy must be lower than ~3% in each layer.

Pixel-size configuration has been optimized to reduce power consumption of readout.

If pixel size in the outer 4 layers are 10μm x 10μm, then power consumption of readout is decreased by 70%. If both occupancy and I.P. resolution remain OK, this value is very attractive.

Check! Occupancy: 5μm VS 10μm

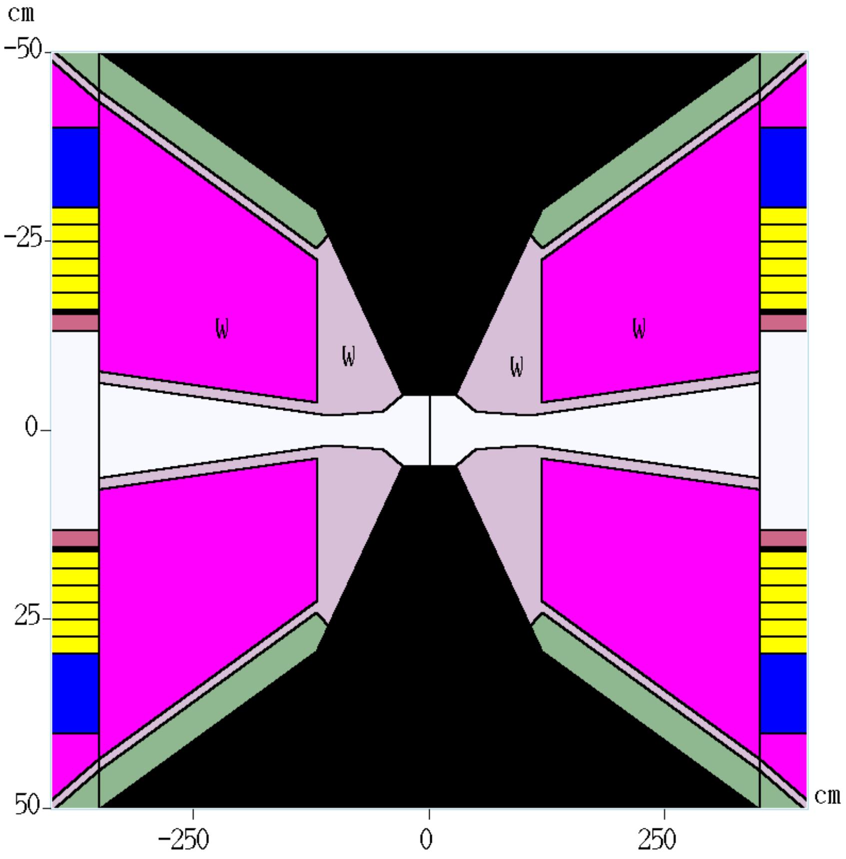
at 1 TeV		
	occupancy of B.G.(%)	
layer No.	5 x 5 μm²	10 x 10 μm²
1	19.6	–
2	10.4	–
3	0.2	0.5

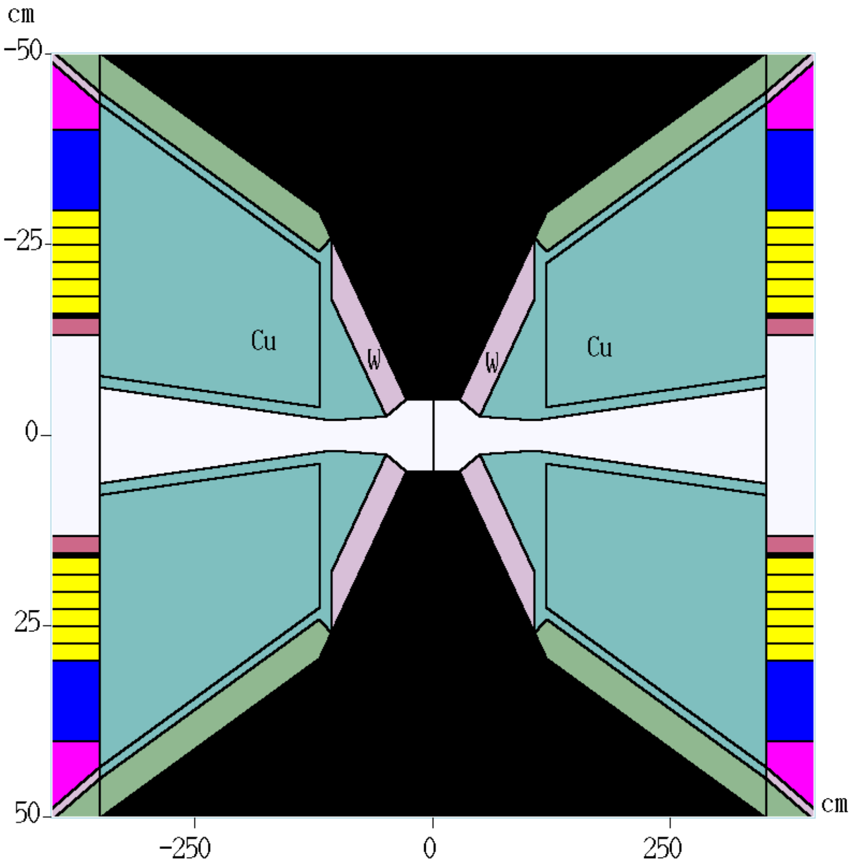
Currently, tracking efficiency and I.P. resolution with B.G. is being studied. The followings are tentative results.

This shows I.P. resolution with background. Even if number of BX increases, it doesn't increase so much.

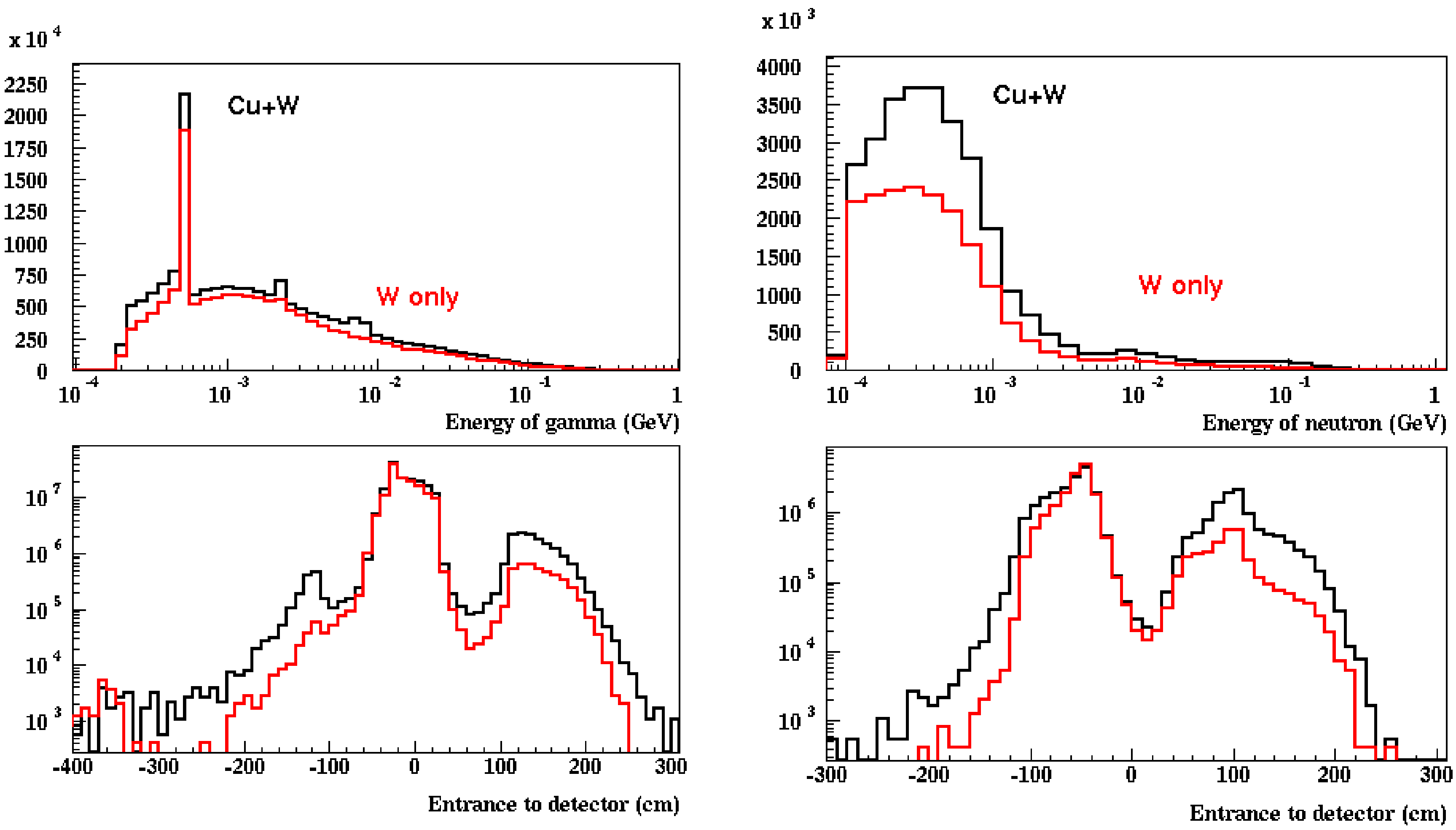
This shows tracking efficiency with background. Definition of the efficiency is whether there are more than 5 hits used in VXD.

Cooper instead tungsten?





Cooper instead tungsten?



Summary

Background load is heavily depend on configuration of inner surface of shielding nozzle. Optimization of cone tips position is described.

Background is mainly produced in electromagnetic shower developed by high energy electrons very near to surface in strong magnetic field. Yield of particles created at large angles or/and backward should be simulated. This is not simple task even for recently developed codes.

Neutral background yields calculated by SLAC team about two times higher than obtained using MARS and MARS-EGS5. More comprehensive study is needed to clarify origin of this difference.

Hit loads in vertex and tracker detectors are simulated. Estimated occupancies looks like acceptable, except first layers where its could reach 5-10%.

It is shown that most of tungsten in shielding nozzle can be changed to copper without significant rise of background load.

Backup

Simple estimate of occupancy

Simulations were performed with MARS background files in EGS5 mode with 3, 10, 20, 30 keV thresholds. Number of charged tracks leaving detector weakly depends on E_d , number of stopped tracks is proportional ~ $1/E_d$. Low energy δ-electron are produced with large angle to δ-electron direction. Part of them is stopped in same pixel as track going from this pixel. To avoid double counting we need to choose adequate electron transport threshold. Electron ranges in silicon:
3 keV – 0.14 μm, 10 keV – 1.5 μm, 20 keV – 5 μm, 30 keV – 10 μm.

Probability to stop in neighbor pixel:

	energy < 10 keV	energy < 3 keV
5 μm	30%	2.8%
10 μm	15%	1.4%
20 μm	8%	0.7%

10 keV is close to estimated from above

20 kev is minimal estimate for 5 μm

30 kev is minimal estimate for 10 μm

10 keV estimate is only 30% large than 30 keV estimate in simulation.

Be beam pipe- black hole