Mass production in ILCRoot simulation for muon collider MARS background

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Outline

- **ILCRoot mass production of simulated hits for MARS background and IP muons and protons in different geometries (Si VXD and Si Tracker) – to study double layer criteria for MARS background suppression**
- **VXD+Tracker Barrels material budget in ILCRoot**
- **Fractions of producing hits IP and MARS n, g in comparison with material budget**
- **Conclusions/Plans(ILCRoot <--> LCSIM)**

ILCRoot mass production simulation

- **ILCRoot mass production of simulated hits for MARS background, IP muons and protons - completed**
  - input MARS background data for (750 + 750) GeV μ+ μ- beams with $2*10^{12}$ muons/bunch each (http://www-ap.fnal.gov/~strigano/mumu/mixture/)
  - using the latest ILCRoot release (ILCrootMuXDetV3 by Vito Di Benedetto) with recent GEANT4 v9.5.1 (neutron timing patch provided by Vito Di Benedetto)
  - only VXD and Tracker hits, the rest of detector as material (includes calorimeters, beam pipe, 10^0 shielding cone etc.) – full layout
  - the hits were simulated in four geometries with VXD and Tracker double layers:
    - 200 μ Si sub-layer, 1 mm and 2 mm space between sub-layers
    - 3.5 T and 7 T magnetic fields
- **Additional ILCRoot simulation completed**
  - to try the new approach for fast Si tracking – use of SiPM (see R. Lipton's talk "Thin, Low Mass Si Trackers" on "Project X Physics Study" workshop, 14-23 June 2012, Fermilab)
  - includes four full layout geometry sets with VXD and Tracker double layers
    - 20 μ Si sub-layer, 1 mm and 20 μ space between sub-layers
    - 3.5 T and 7 T magnetic fields

ILCRoot mass production simulation

- **Each ILCRoot simulation set has sub-sets**
  - all MARS particles and selected MARS particles (n, g and n+g)
  - IP smeared μ+, μ- and p to estimate effective timing cut and φ, θ cuts for double layer criteria
- **More simulation (completed)**
  - with VXD+Tracker only layout (no outside material) for IP and MARS n and g to compare
    - fractions of making hits IP n and g with ILCRoot material budget calculations
    - VXD+Tracker only layout with full layout geometry to estimate the hit contribution of MARS neutrons interacting outside of VXD+Tracker detector

ILCRoot mass production simulation

- **All work was done on General Purpose Grid at Fermilab**
  - it takes 25-30 min (astronomical time) to run ILCRoot for ~ 0.11M MARS particles per job in VXD+Tracker full geometry (to obtain hits only)
  - a few hours (including queue waiting time) for full statistics of ~219M MARS particles (per given ILCRoot geometry set) if divided among ~1975 parallel jobs (submitted simultaneously)
  - AMD Opteron Processor 6128, 2 GHz CPU per slot
- **Results**
  - ILCRoot output files (in ROOT format) per job
    - with hits in VXD and Tracker
    - with primary and non primary tracks parameters
  - these files were converted to simple ROOT trees and chained to all statistics single ROOT trees per geometry set and particle type
  - typical size for all statistics tree with hits is ~18 - 20GB for 200μ+200μ geometry (original MARS text file is ~2GB)
- **Analysis is in progress (timing + double layer criteria study)**

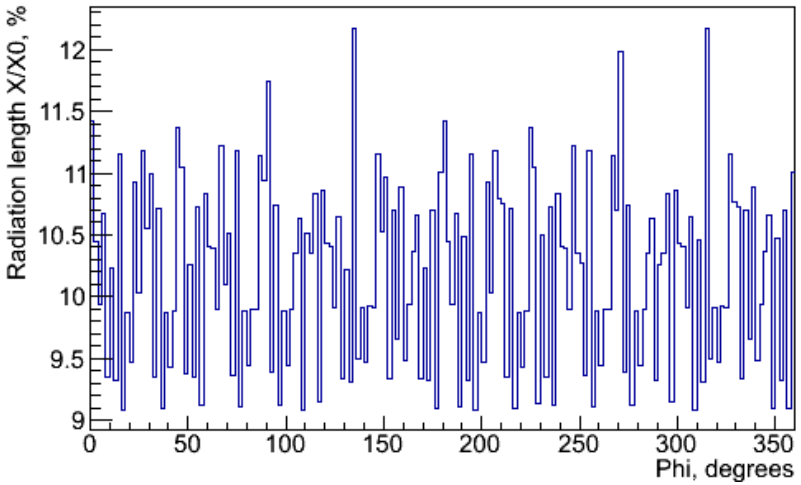
VXD+Tracker Barrels material budget

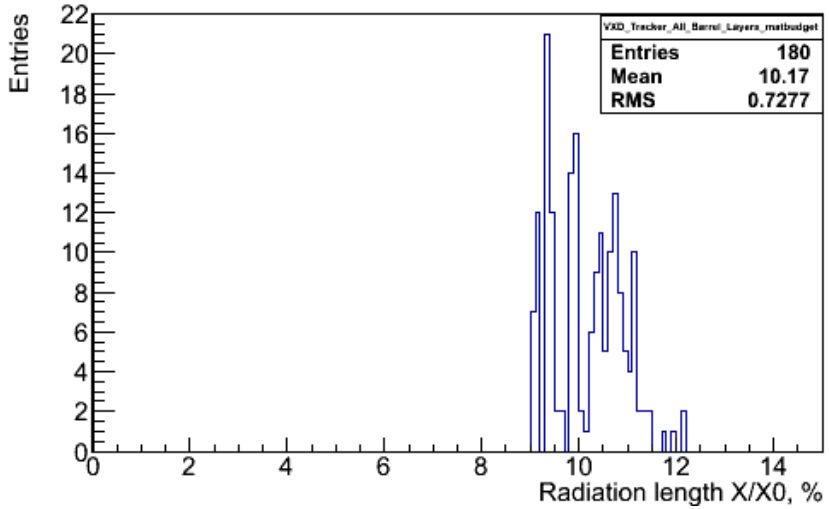
- **The code to calculate radiation and interaction thickness in ILCRoot geometry (ExeScan.C and scanmaterial.C by Vito Di Benedetto)**
  - input is ILCRoot geometry file
  - result is stored as 3D histogram with parameterized binning in R, φ and Z directions
  - user can make 2D and 1D projections
- **Used it for 1D distribution in φ integrated along R and Z**
  - looking at 10 barrel layers of Si VXD and Si Tracker with two 200 microns sub-layers/layer, 1 mm apart, 3.5T magnetic field
  - support material included (carbon fiber, kapton, Si, no cooling)
  - 2 cm < R < 125 cm, 20 microns bin (to be within VXD and Tracker)
    -5 cm < Z < 5 cm, 1 cm bin (all VXD and center of Tracker)
    0^0 < φ < 360^0, 2^0 bin
- **Results are the MEAN of radiation (or interaction) thickness distribution obtained from φ distribution (next slide)**

Radiation X/X0	**10.2%**	Si X0=9.35 cm, Support X0=27.9 cm
Interaction X/X0	3.6% **~7.9%**	Si X0=45.8 cm, Support X0=51 cm Si X0=21 cm, neutrons 20 MeV, S. Striganov

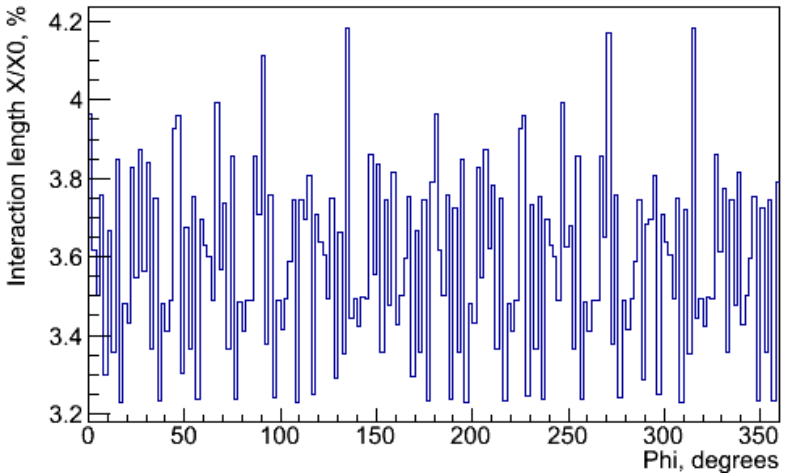
VXD+Tracker Barrels material budget

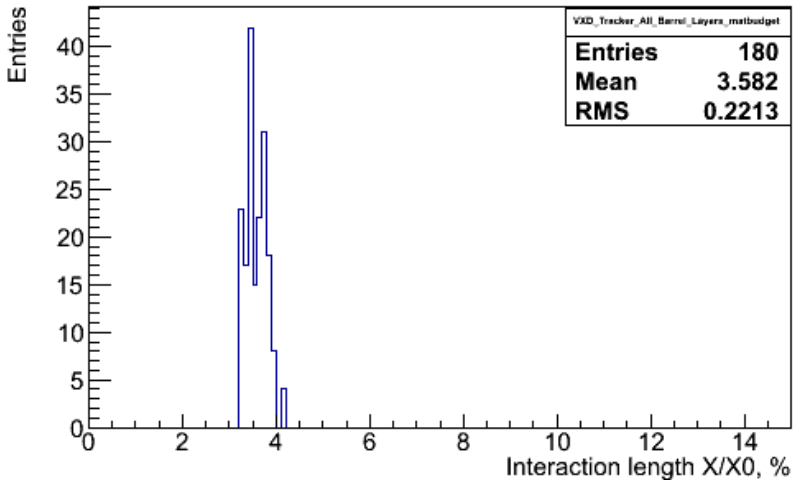
- **Radiation thickness of VXD+Tracker Barrels (the peaks are due to layer dependent Si ladders overlapping in φ) – MEAN=10.2%**





- **Interaction thickness of VXD+Tracker Barrels – MEAN=3.6% (-> 7.9%)**





VXD+Tracker Barrels material budget

- **Material budget and fractions of making hits neutral particles (IP n, g)**
  - simulate **IP n** and **g** in the same geometry (200 μ sub-layers, 1 mm space, 3.5T magnetic field, but only VXD and Tracker, no calorimeters, no shielding cone, no beam pipe etc.)
  - flat distribution of momentum in the region of MARS **n** and **g**
    $0.0137 < P < 0.1$GeV/c for n to have E_{kin} min 0.1MeV, P_{max}=0.1 GeV/c
    $0.0002 < P < 0.01$GeV/c for g to have E_{kin} min 0.2MeV, P_{max}=0.01 GeV/c
    (see backup slides for MARS n and g E_{kin} distributions)
  - limit directions of **n** and **g** momentum to $78^0 < \theta < 102^0$ to be within the acceptance of the outmost Tracker barrel layer
  - using VXD and Tracker hits information identify primary **n** and **g** producing hits thru secondary particles
  - calculate fractions of **n** and **g** as ratio of primaries producing hits to total number of primaries

VXD+Tracker Barrels material budget

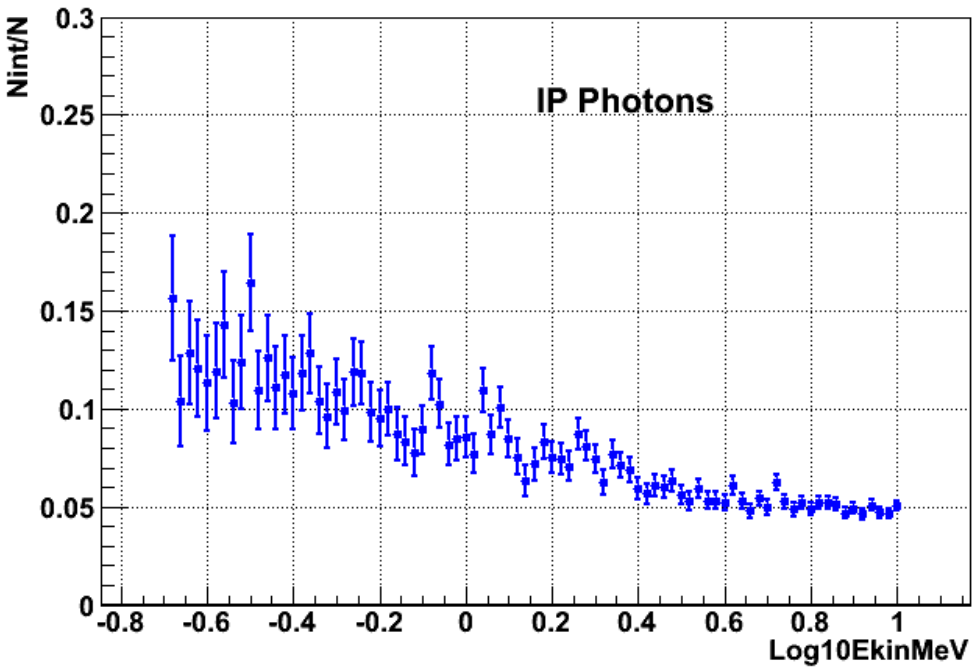
- **Material budget and fractions of making hits neutral particles (IP n, g)**

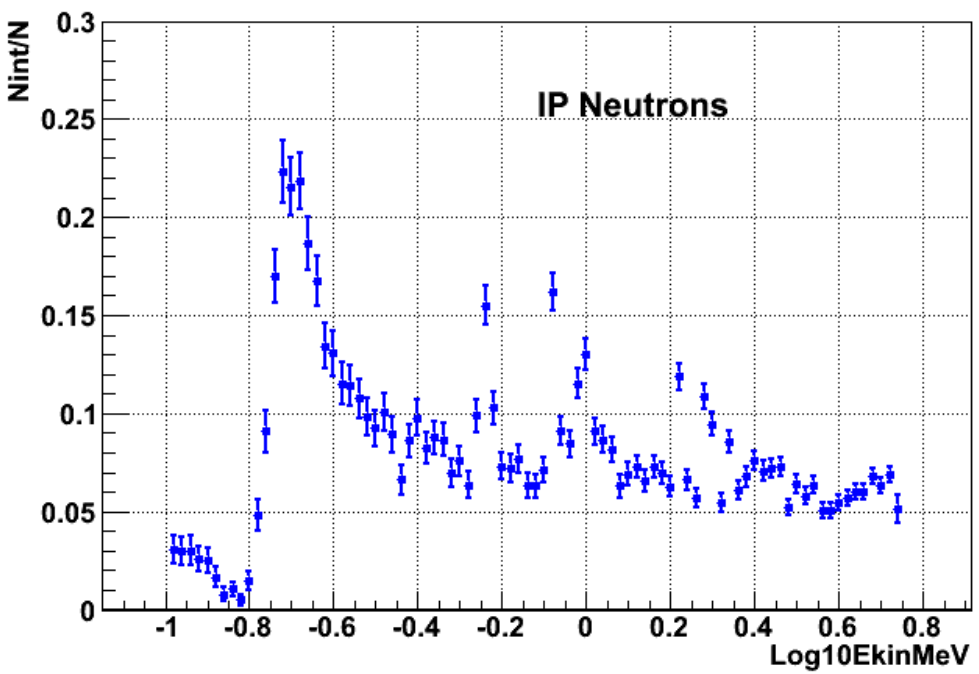
Source	Radiation length X/X0	Interaction length X/X0
Material budget	10.2%	7.9% (using Si X0=21 cm for 20 MeV n)
IP g fraction	6.0%	
IP n fraction		7.7%

- **Comments**
  - fractions of producing hits IP particles are less than fractions of all interacting IP particles (GEANT4 does not keep the history for particles making no hits in detector sensitive volumes)
  - comparison with material budget obtained for -5cm < Z < 5cm is not 100% justified for IP particles (Z=0)
  - qualitative agreement of material budget with fraction of making hits IP particles
- **The fraction of making hits MARS n, g as a measure of VXD+Tracker radiation and interaction lengths X/X0**
  - additional bias due to Z distribution of MARS n, g (see backup slides)

VXD+Tracker Barrels material budget

- **Fractions of making hits neutral particles (IP n, g) vs. Log10(E_{kin})**





Fractions of MARS interacting n and g

- **Fractions of MARS n and g producing hits in two geometries**

  – compare fractions of making hits particles (MARS n and g) in two geometries, **VXD+Tracker only** and **VXD+Tracker + full detector layout** (includes EM and H calorimeters, 10^0 shielding cone, coils, beam pipe etc.)

  – in both geometries VXD and Tracker have 200μ+200μ sub-layers, 1 mm space, 3.5T magnetic field

Geometry	MARS g	MARS n
VXD+Tracker only	7.7%	3.2%
VXD+Tracker in full layout	7.8%	7.7%

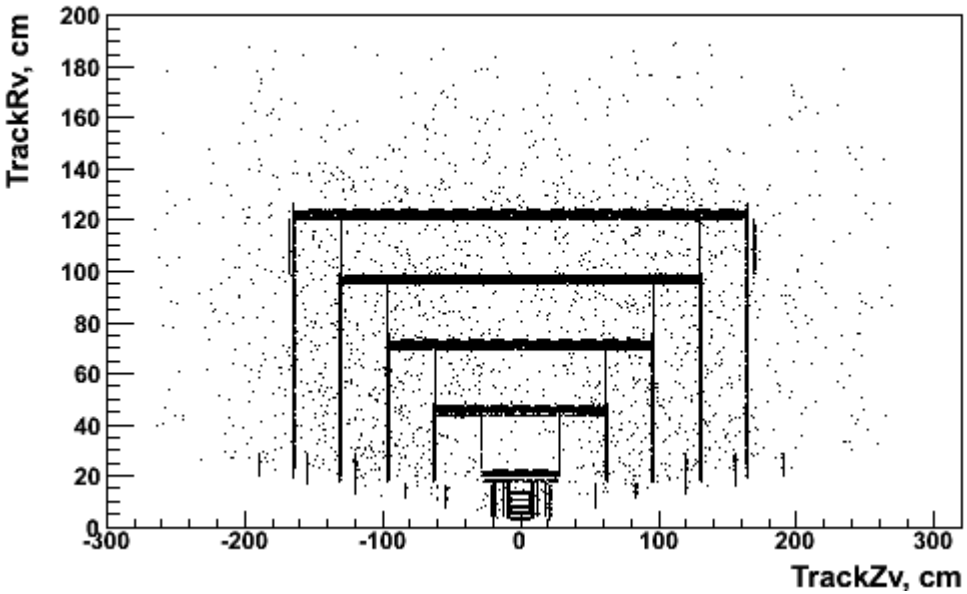
  – no change in fraction of photons

  – increasing number of producing hits neutrons in full layout

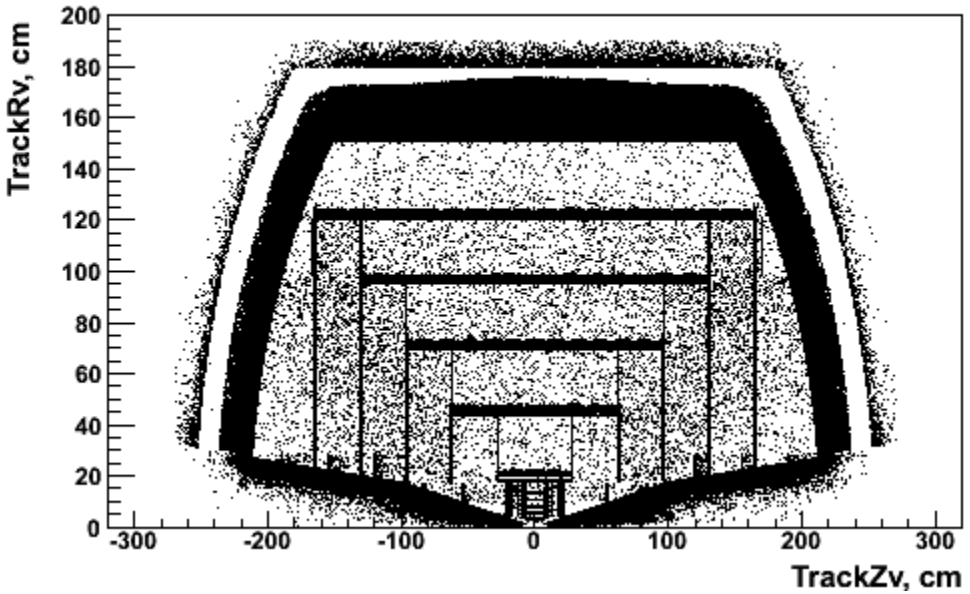
Fractions of MARS interacting n and g

- **For MARS neutrons producing hits in two geometries**
  - secondary (all non primary) tracks vertex radial position Rv vs. Zv position

VXD+Tracker only



VXD+Tracker+Full layout

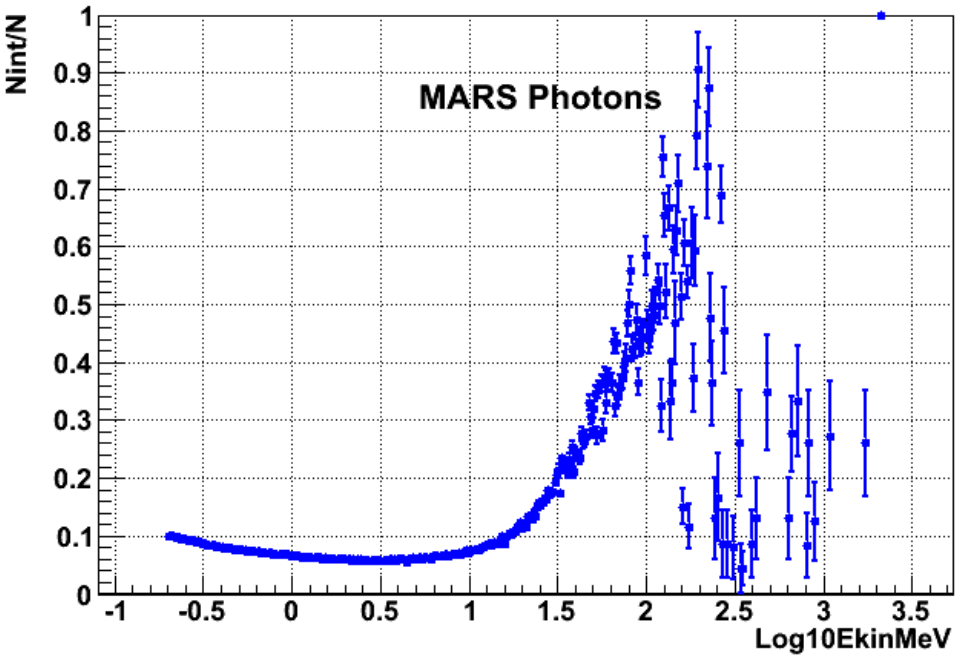


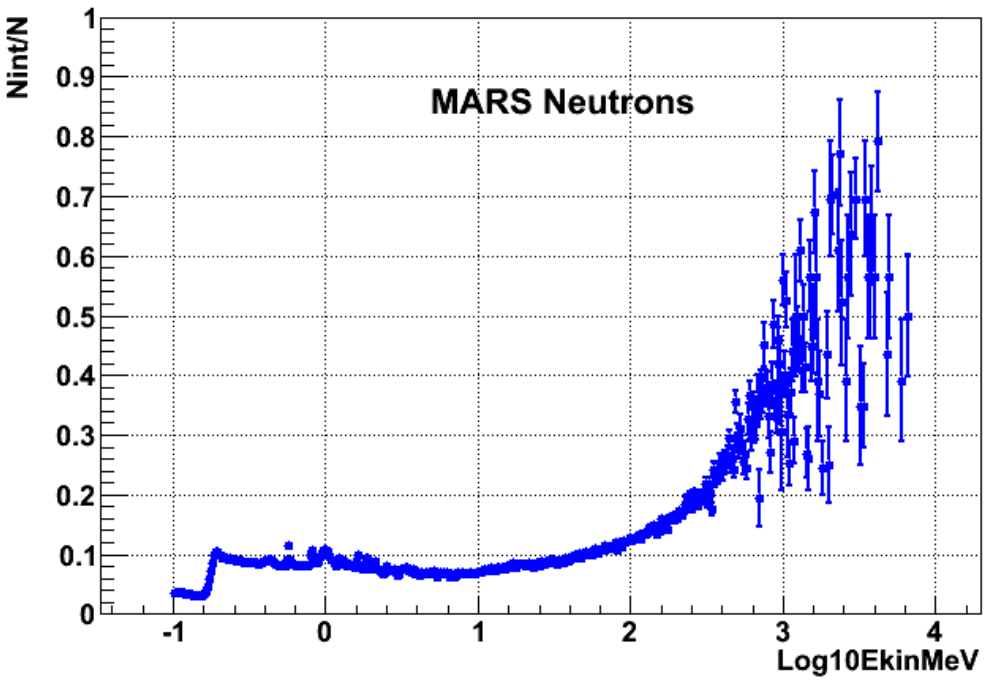
- **ID of particles producing hits from MARS neutrons interactions**

Geometry/Particle IDs	e-	e+	p	Si ions	# of hits
VXD+Tracker only hits	2.4%	0.2%	6.5%	91%	1.52e+06
VXD+Tracker in full layout hits	31%	1.3%	1.7%	65.8%	4.50e+06

Fractions of MARS interacting n and g

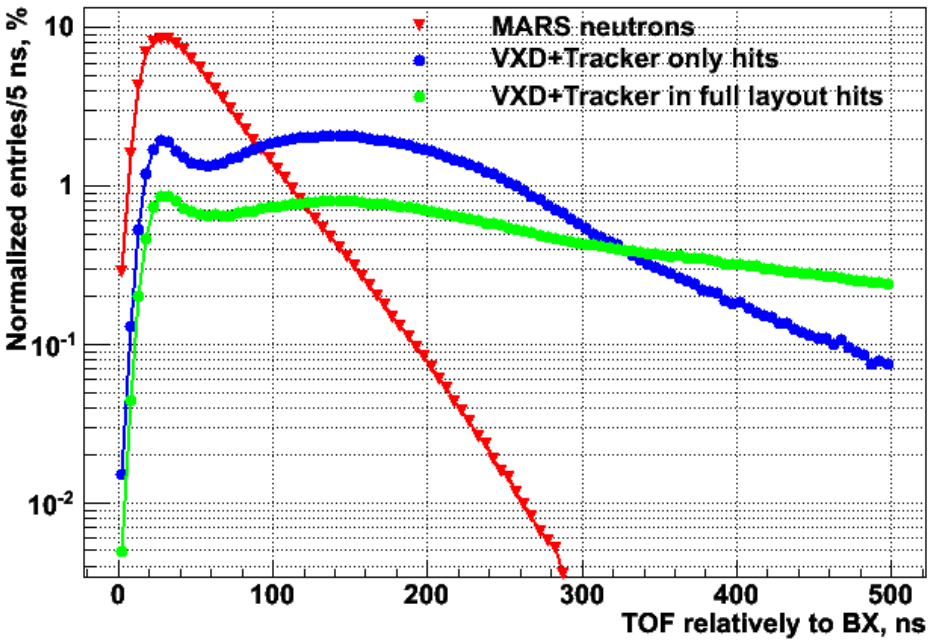
- **Fractions of making hits MARS neutral particles (n, g) vs. Log10(E_{kin})**

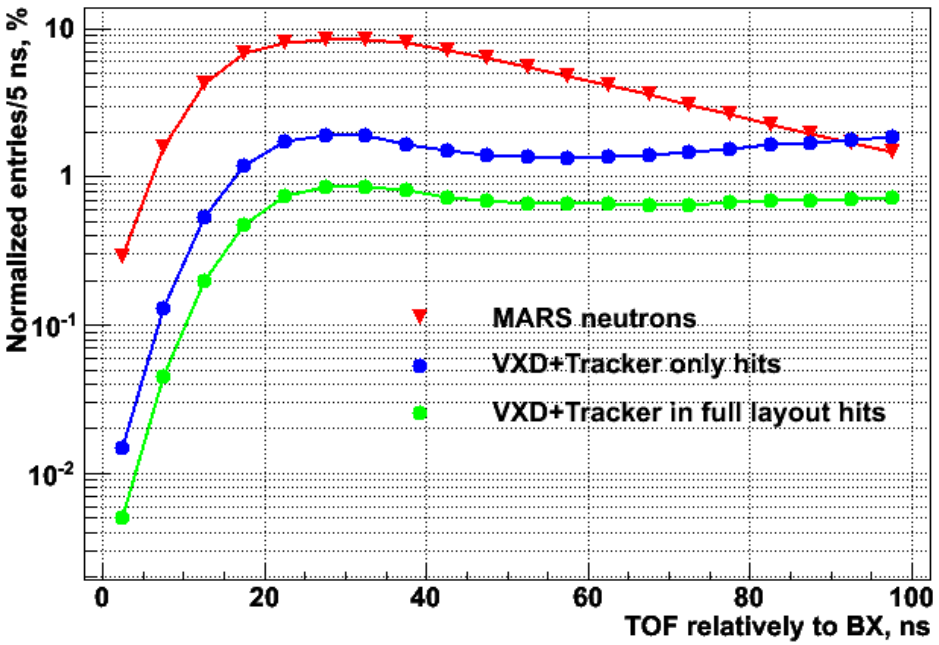




Fractions of MARS interacting n and g

- **Timing for MARS neutrons producing hits in two geometries**
  - compare normalized distributions of TOF of MARS neutrons and hits in two geometries, VXD+Tracker only and VXD+Tracker in full layout (both geometries have 200μ+200μ sub-layers, 1 mm space, 3.5T magnetic field)
  - neutrons interact with material in and outside of VXD and Tracker (including elastic scattering, "neutron gas") producing more hits with larger TOF





MARS yields, interacting particles and hits

- **MARS background yields/bunch on 10^0 nozzle surface, weights included, (750 + 750)GeV $\mu^+ \mu^-$ beams with $2*10^{12}$ muons/bunch each**

	Total	g	n	e+-	Other
Particles, in 1e+06	219	177	40.9	1.03	0.052
Fractions	100%	80.8%	18.7%	0.5%	0.024%

- **MARS particles producing hits in Si VXD + Si Tracker in full detector layout (200μ+200μ sub-layers, 1 mm space, 3.5T magnetic field)**

	Total	g	n	e+-	Other
Particles, in 1e+06	17.0	13.7	3.13	0.137	0.034
Fractions	100%	80.6%	18.4%	0.8%	0.2%

- **Hits from MARS particles in Si VXD + Si Tracker in full detector layout (200μ+200μ sub-layers, 1 mm space, 3.5T magnetic field)**

	Total	g	n	e+-	Other
Hits, in 1e+06	33.8	28.3	4.50	0.648	0.341
Fractions	100%	83.7%	13.3%	1.9%	1.0%

Conclusions

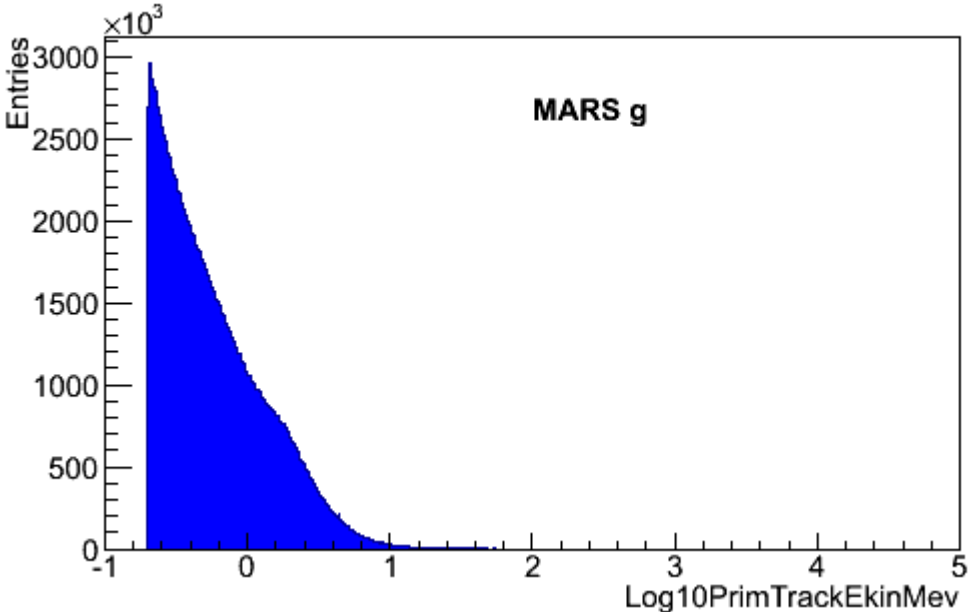
- **ILCRoot simulation data sets with VXD+Tracker hits completed**
- **Fractions of making hits IP n and g particles (in VXD+Tracker only geometry) are in reasonable agreement with VXD+Tracker Barrels material budget**
  - 6% vs. 10% for radiation X/X0
  - ~8% for interaction X/X0 (extrapolating for Si X0=21 cm, n at E_{kin} = 20 MeV)
- **MARS neutrons interactions in material outside VXD and Tracker**
  - increase # of hits in VXD and Tracker (~3 times if compare with VXD+Tracker only layout)
  - additional hits have larger timing

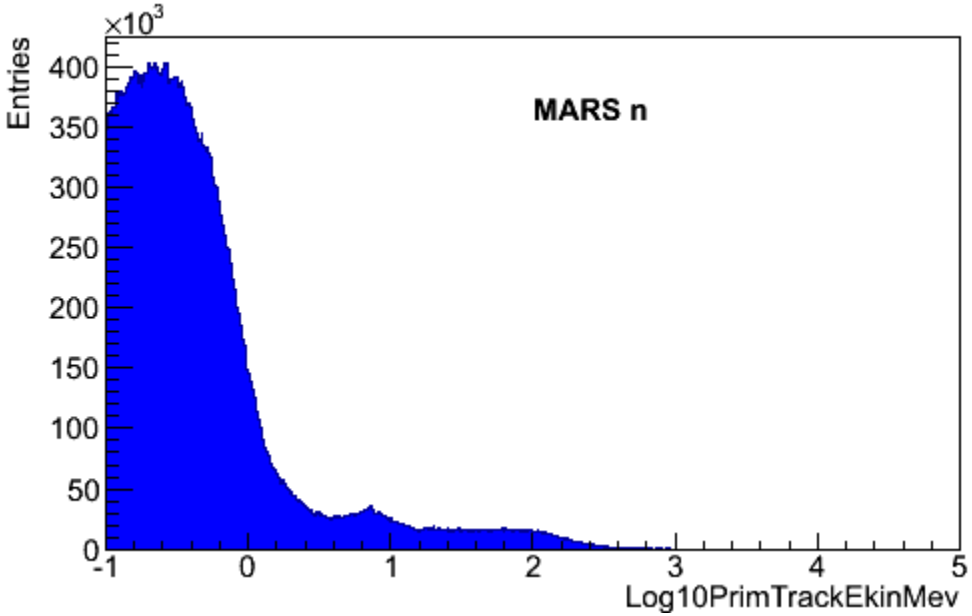
Plans

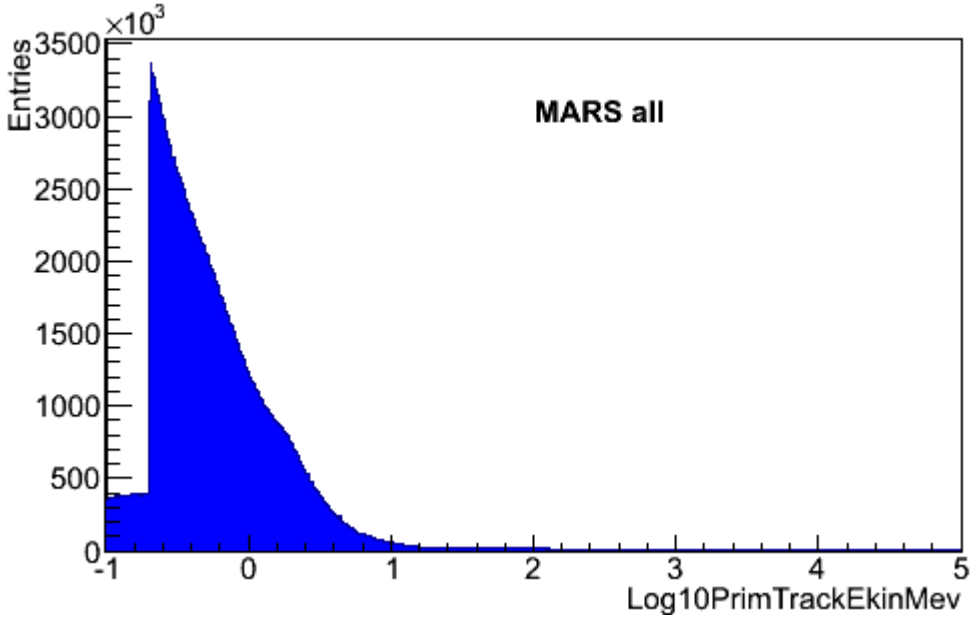
- **Analysis of ILCRoot VXD and Tracker hits made by MARS background in progress**
  - the goals are to estimate timing and double layer criteria rejection for the MARS background (in different geometry sets, including geometry for SiPM)
- **Start to use LCSIM simulation for current MARS background (750 + 750 GeV $\mu^+ \mu^-$ beams with $2*10^{12}$ muons/bunch each)**
  - try the same geometry for VXD and Tracker (with double layer if possible or move back to single layer geometry)
  - compare results for hits with ILCRoot
- **While waiting the new MARS background data for 125 GeV Higgs muon factory --> for now we can try to merge LCSIM simulation results (hits) for current MARS background (for 750 + 750 GeV $\mu^+ \mu^-$ beams) with 125 GeV Higgs production in 125 GeV CM $\mu^+ \mu^-$ beams**

Backup

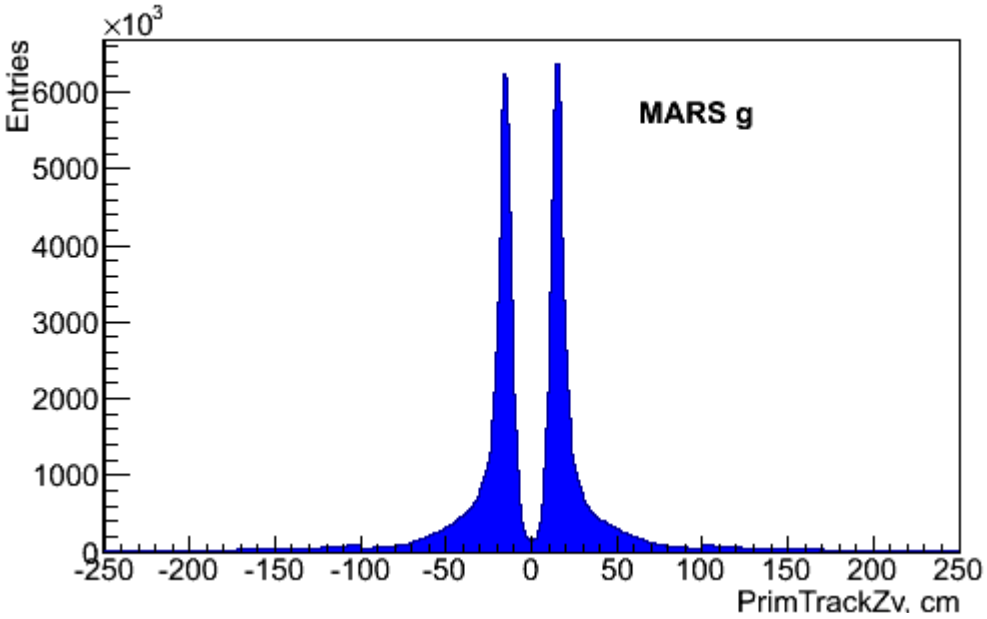
- **Log10(E_{kin} MeV) distributions of MARS particles (g, n and all)**

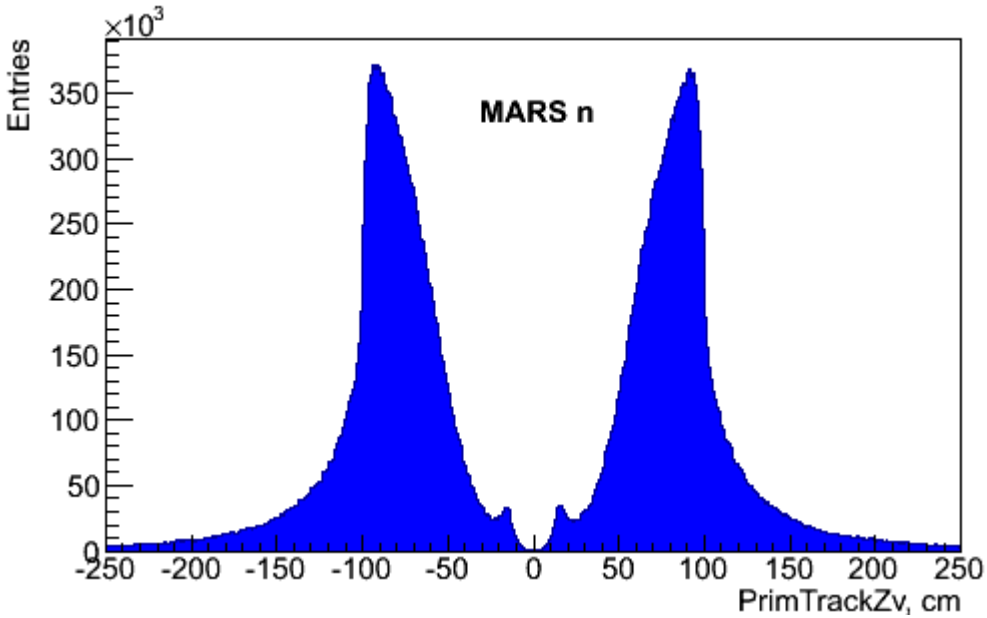


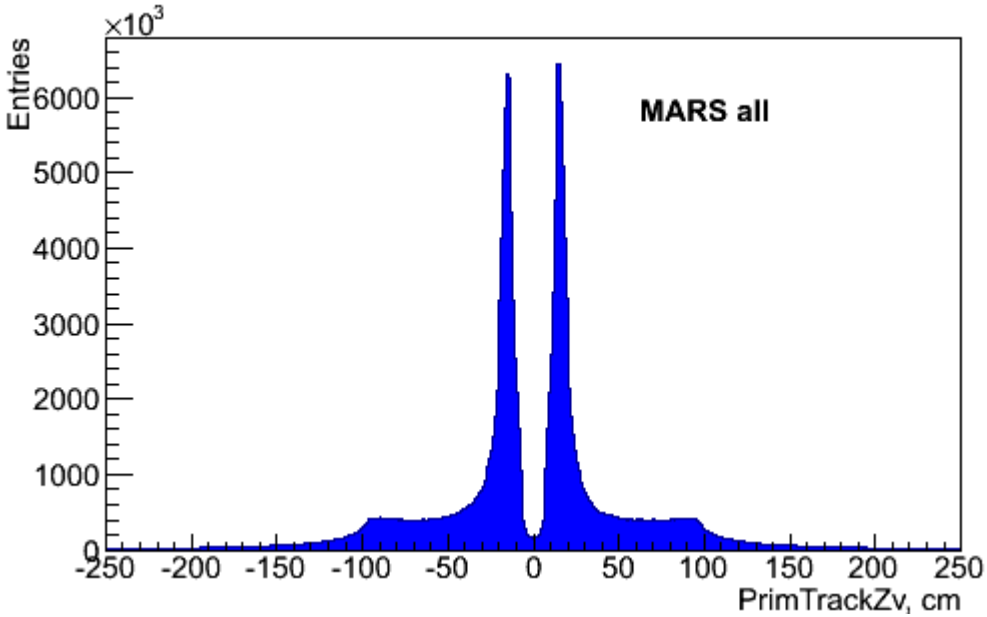




- **Zv distributions of MARS particles (g, n and all)**







- **VXD and Tracker Hits R vs. Z distribution for MARS particles**