Vertex and tracker Si detector hits for MARS/ILCroot simulated beam backgrounds in 1.5 TeV muon collider

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Outline

- The MARS modeling results (particles yield and timing)
- ILCroot vertex and tracker detector hits for MARS background and IP muons/protons (timing)
- Conclusion

The MARS modeling results

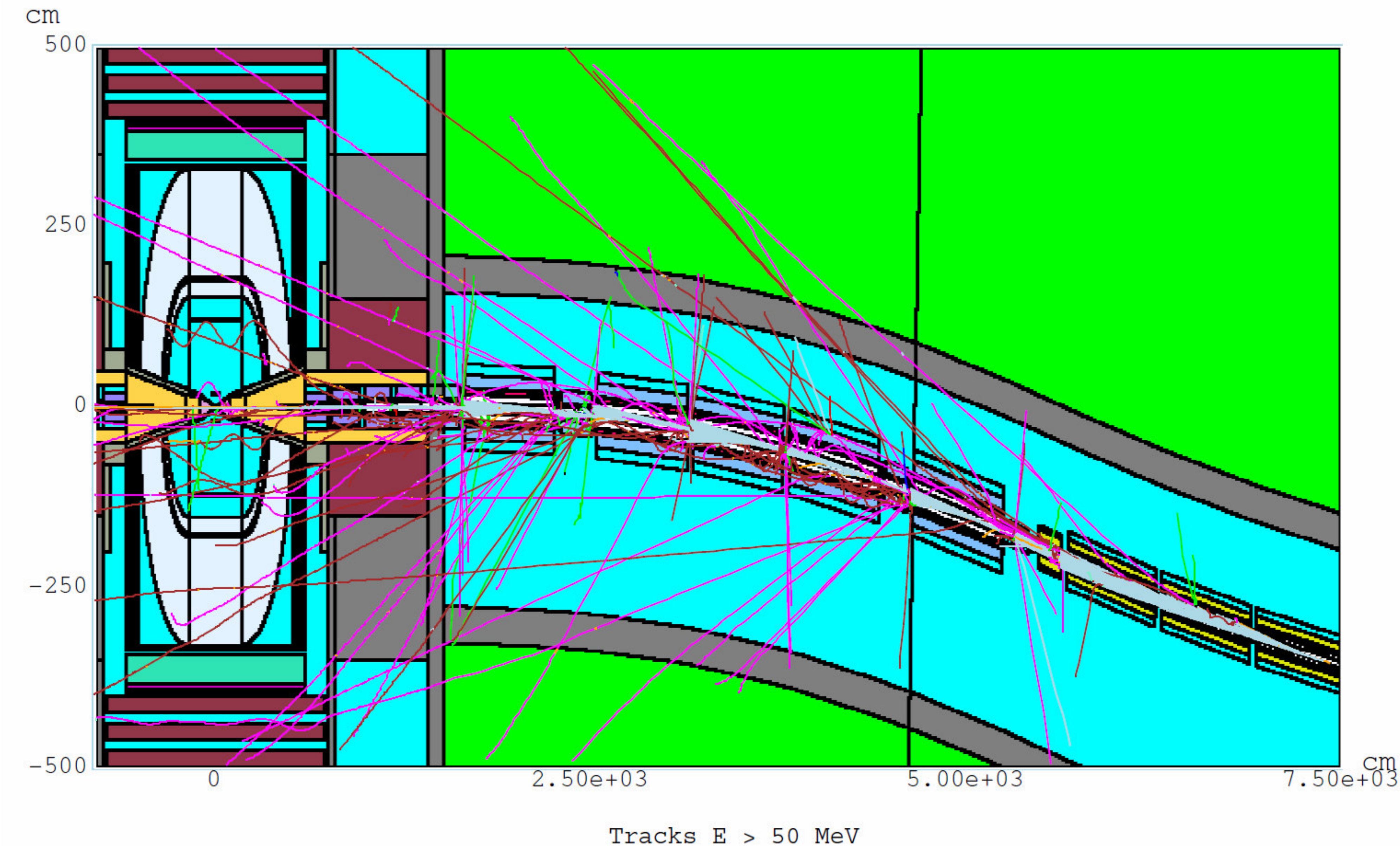
- **MARS – the framework for simulation of particle transport and interactions in accelerator, detector and shielding components**
- **New release of MARS15 available since February 2011 at Fermilab (N. Mokhov, S. Striganov, see www-ap.fnal.gov/MARS)**
- **MARS background simulation results for (750 + 750) GeV $\mu^+ \mu^-$ beams with $2*10^{12}$ muons/bunch each**
  - http://www-ap.fnal.gov/~strigano/mumu/mixture/
  - Background is given at the surface of the 10^o shielding nozzle + walls
- **These data were used as input for ILCroot simulation of the vertex and tracker response (hits).**

The MARS modeling results

- **The major source of background at Muon Collider - muon beam decays producing secondary particle fluxes in the beam line components and accelerator tunnel**
  - For 750 GeV muon beam with $2*10^{12}$ muons/bunch ~ $4.3*10^{5}$ decays/m
- **To suppress background MARS15 muon collider model is using:**
  - 10T dipole magnets in beam line near the detector to sweep decay e^{+-} (the e^{+-} decay angles are small and the e^{+-} stay in the beam pipe for a few meters before exiting)
  - Collimating/shielding nozzle in the detector,
  - Detector magnetic field
- **In MARS15 simulation currently achieved reduction of machine background is ~ 3 orders of magnitude (depends on the nozzle angle)**

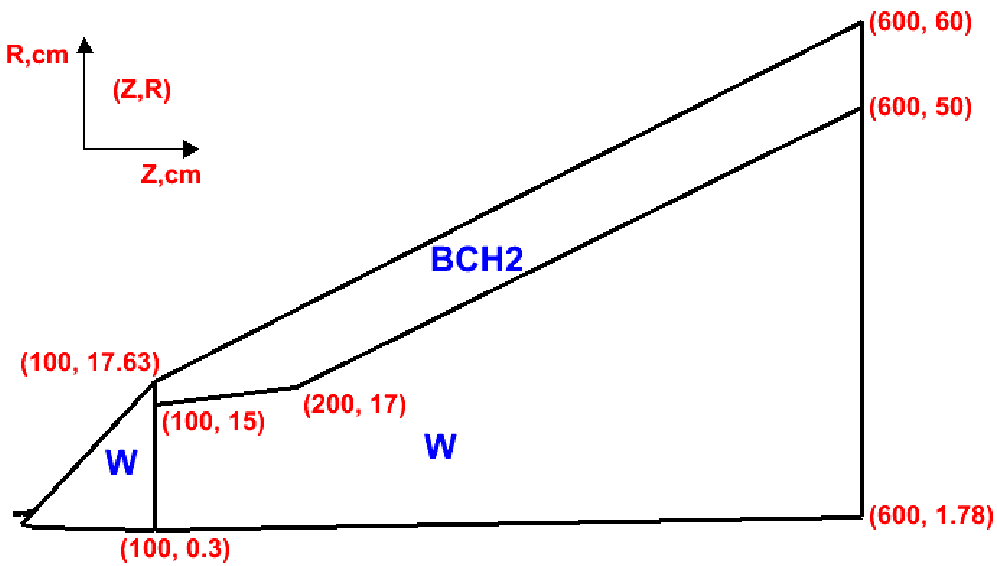
The MARS modeling results

MARS background particle tracks in muon collider near the detector

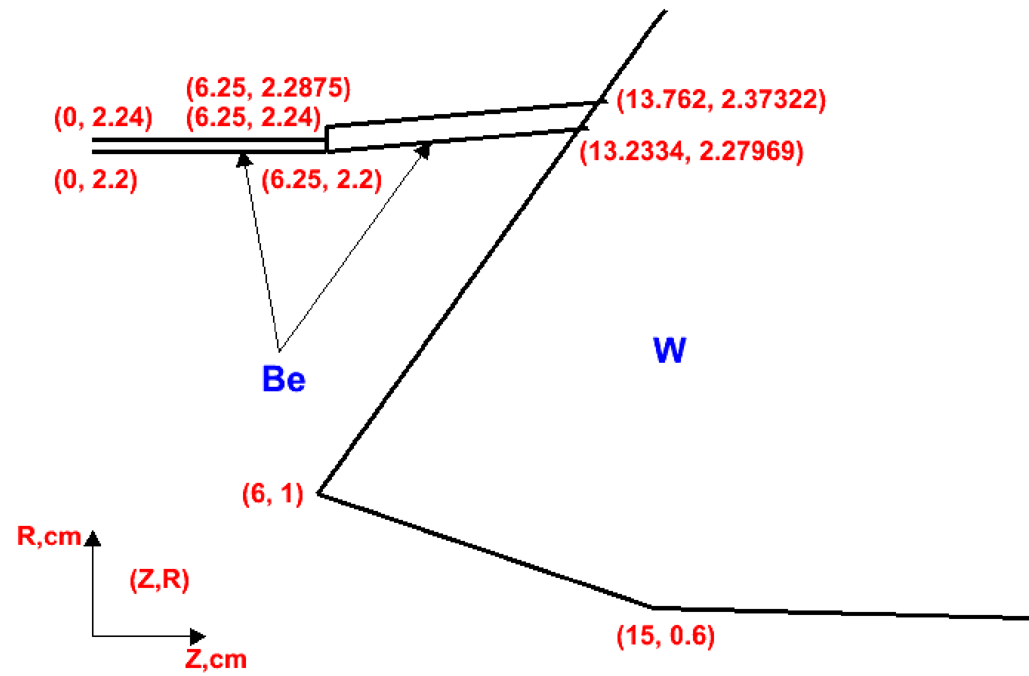


- **10^0 nozzle geometry**

General (1/2 Z view)



Zoom in beam pipe



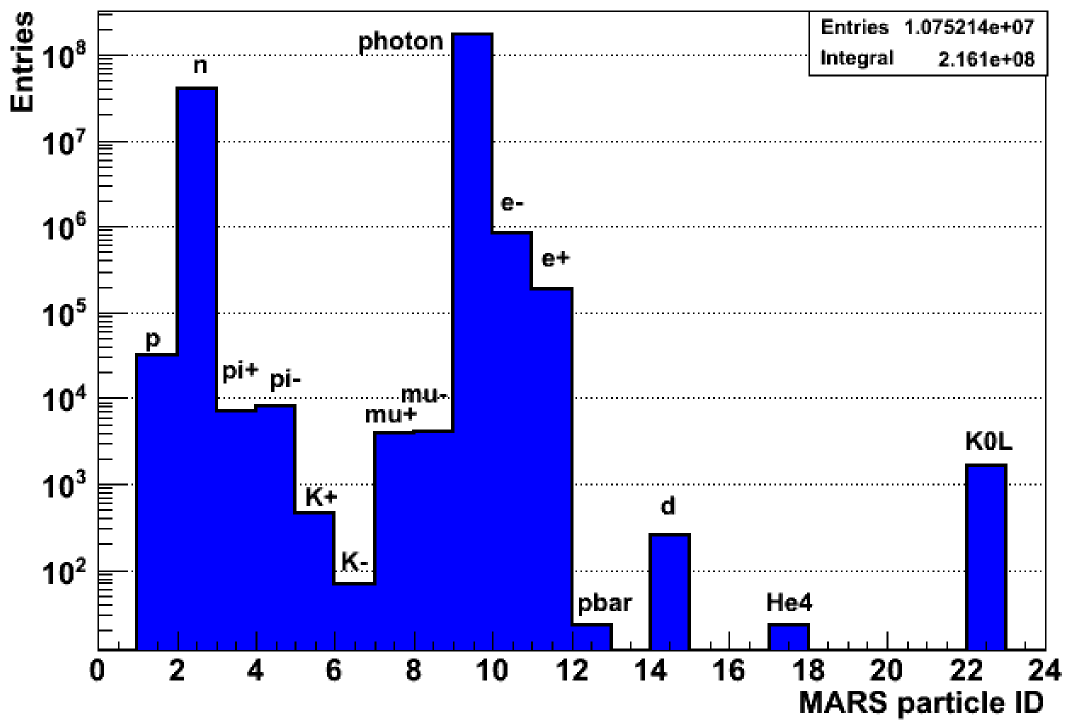
W – tungsten

Be – beryllium

BCH2 – borated polyethylene

The MARS modeling results

- **MARS background particle ID's yields for 750 GeV $2*10^{12}$ muons/bunch**

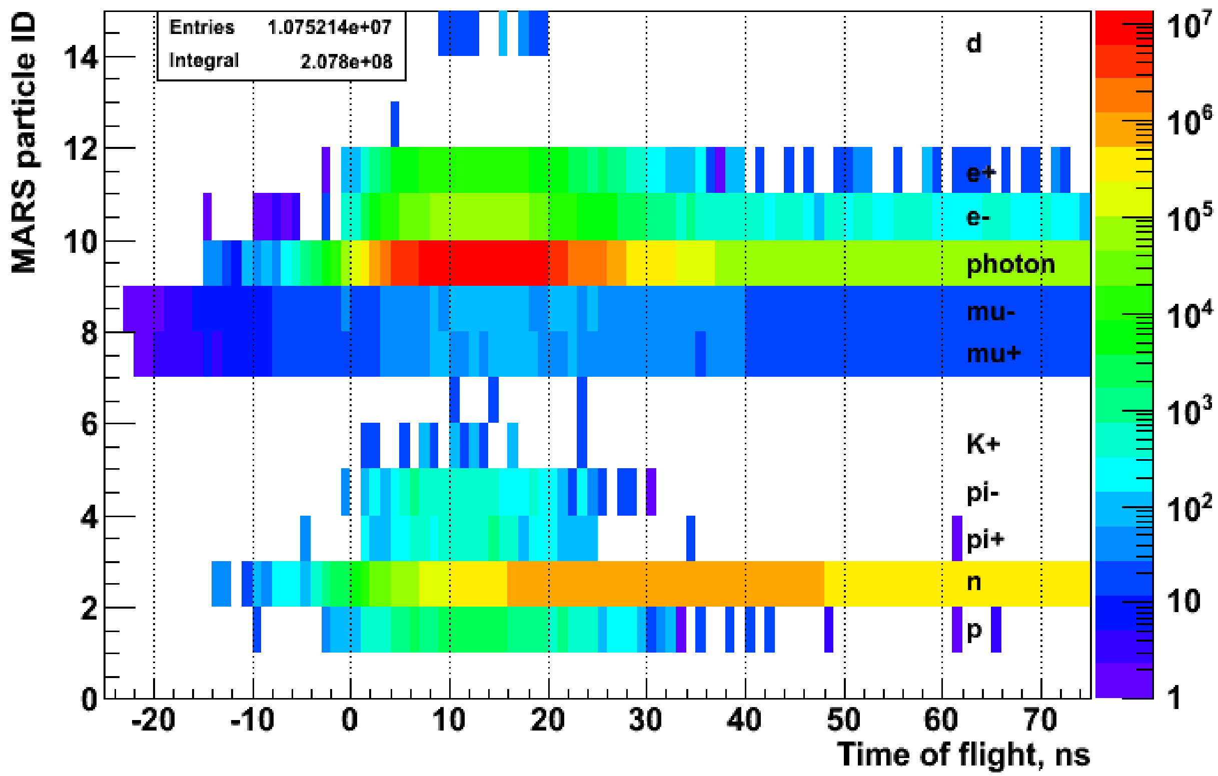


- **Background yields/bunch on 10^0 nozzle surface and MARS thresholds**

	γ	n	e^{+-}	μ^{+-}
Yield	1.77e+08	0.40e+08	1.03e+06	0.80e+04
Ethr, MeV	0.2	0.1	0.2	1.0

The MARS modeling results

- **MARS particle TOF and their ID (see in backup Ekin, Pt and Z)**
  - Time of flight (TOF) wrt. bunch crossing time, on a surface of the 10^0 nozzle
  - In window 0 <= TOF <= 25 ns:
    ~21% of neutrons, ~36% of muons, >94% of other particles
  - TOF < 0 corresponds to the particles making straight path to detector



ILCroot vertex and tracker detector hits

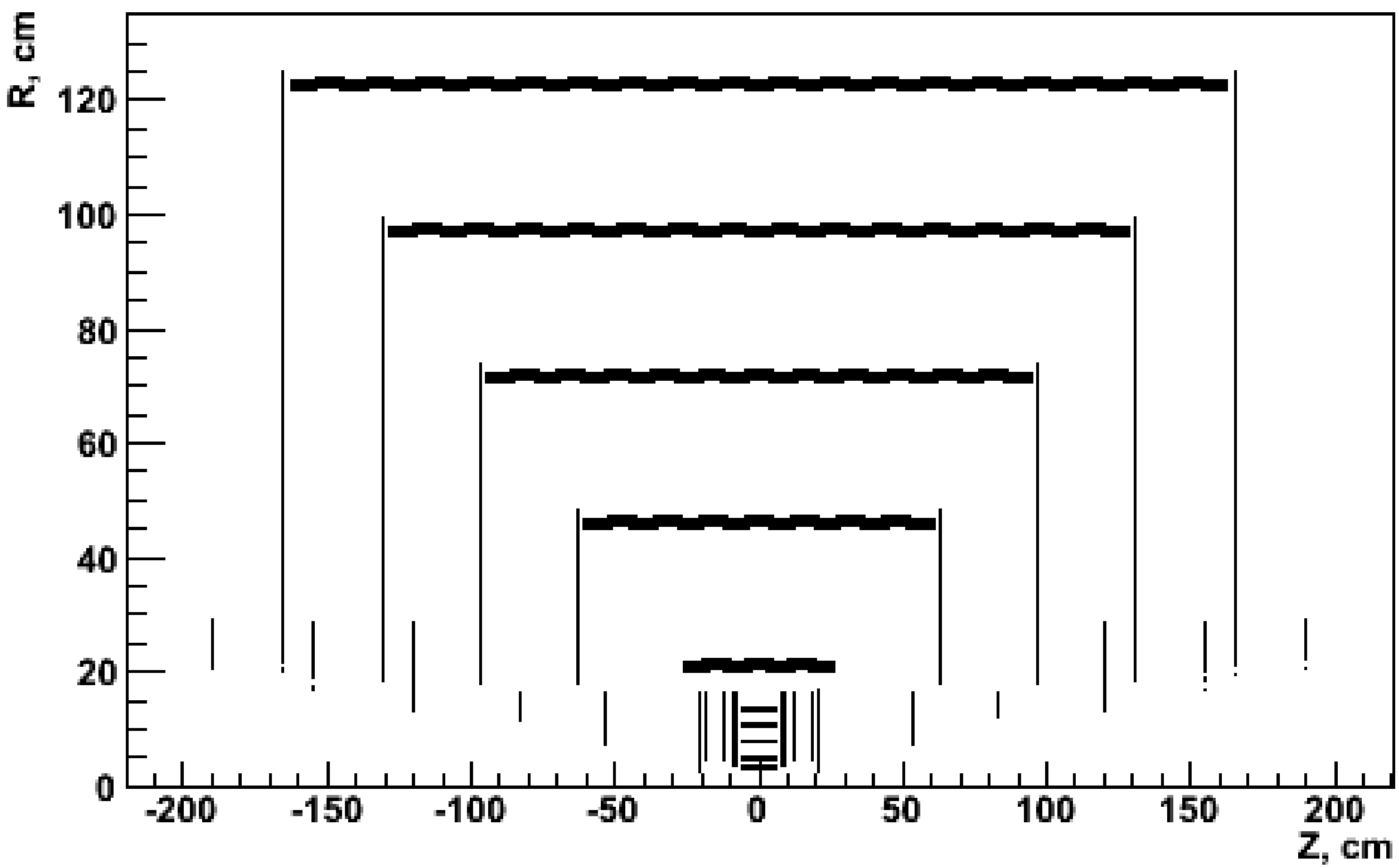
- **The ILCroot - software Infrastructure for Large Colliders based on ROOT and add-ons for Muon Collider studies (more in backup)**
- **ILCroot_2.9.1 (new release) with latest GEANT4 (4.9.4.p01) available at Fermilab**
- **Run ILCroot simulation to look at the hits in vertex and tracker Si detectors**
  - For all statistics MARS data
  - For IP muons and protons
    - Originate in IP (Interaction Point) at X=0, Y=0, Z=0
    - Flat distribution in momentum P, angles Phi and Theta
      0.2 GeV < P < 100 GeV, 10.4^0 < Theta <$(180-10.4)^0$
    - 10 particles per event, total 1000 events or 10,000 muons/protons

ILCroot vertex and tracker detector hits

- **VXD + SiT + FTD detectors (layout details in backup)**
  - Vertex Detector (VXD, mostly ILC SiD layout)
    - 20μ X 20μ Si pixels, 5 barrel layers, 8 endcap disks
  - Silicon Tracker (SiT, mostly ILC SiD layout)
    - 50μ X 50μ Si pixels (or Si strips or double Si strips), 5 barrel layers,14 endcap disks
  - Forward Tracker Detector (FTD)
    - 20μ X 20μ Si pixels, 6 disks
  - Detector magnetic field – 3.5T

ILCroot vertex and tracker detector hits

- **R vs. Z coordinates of the hits from background particles in vertex and tracker detectors**



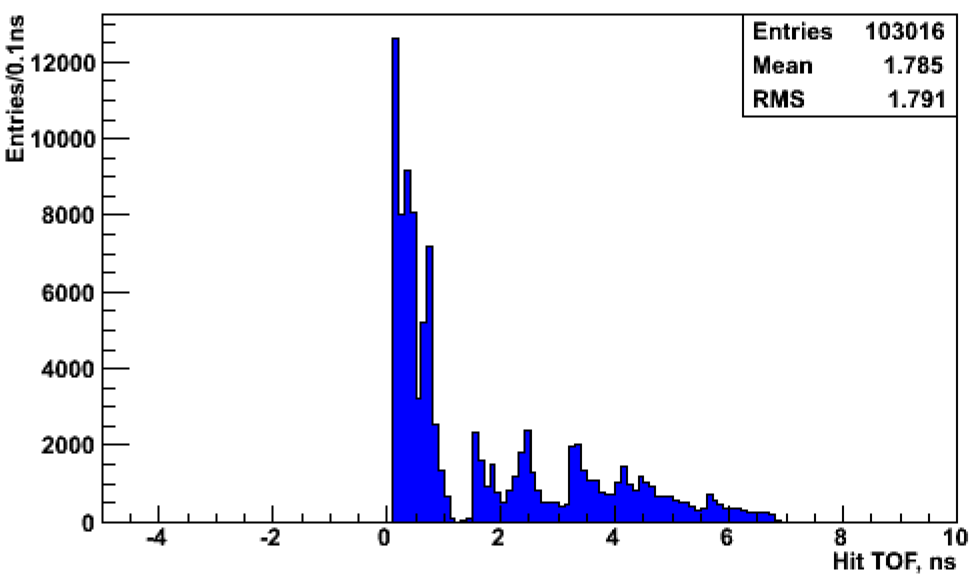
ILCroot vertex and tracker detector hits

- **Vertex and tracker hits timing**
  - Muon collider background time of flight (TOF) has significant spread wrt. the bunch crossing time. Suggests the use of fine time tuning in the front-end for background hits rejection.
  - In ILCroot hits TOF is calculated in GEANT4 (effectively wrt. the bunch crossing time too)
    - For MARS particles – TOF from MARS file + detector propagation time
    - For IP particles – detector propagation time
  - Add to ILCroot a new timing, TOF – T0
    - Define T0 for each hit in each vertex and tracker layer as arrival time of the photon coming from IP to the point with this hit coordinates

      $T0=L/c$, $L=\mathrm{sqrt}(X^2+Y^2+Z^2)$, X,Y,Z – hit coordinates
    - T0 is equivalent to delays in front-end tuned to equalize the hit timing in all Si layers (and within layers with reasonable grouping)

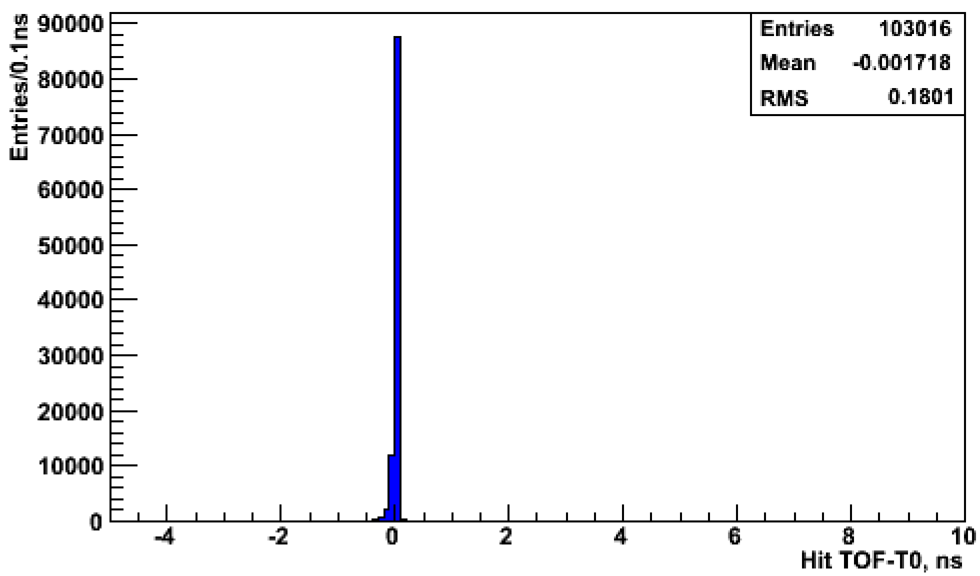
- **Vertex and tracker timing for IP muons**

TOF



RMS ~ 1.8 ns

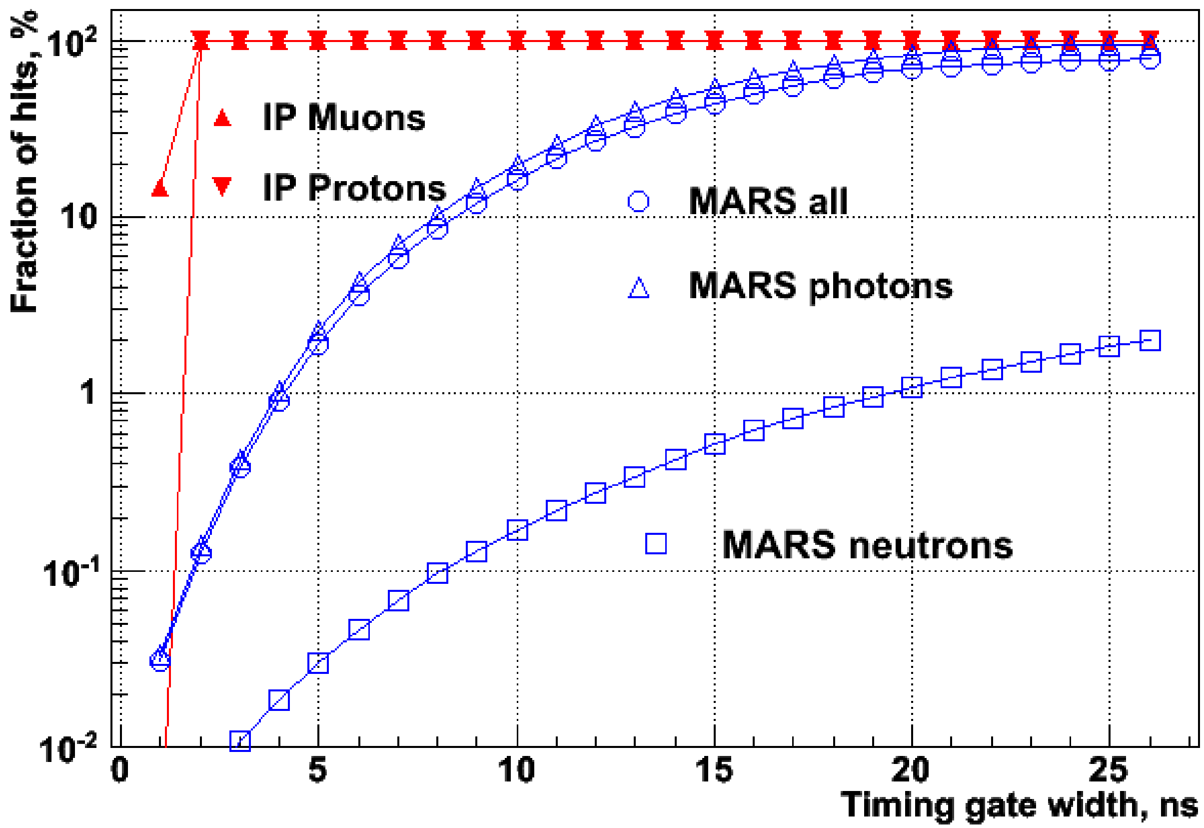
TOF – T0



RMS ~ 0.18 ns

ILCroot vertex and tracker detector hits

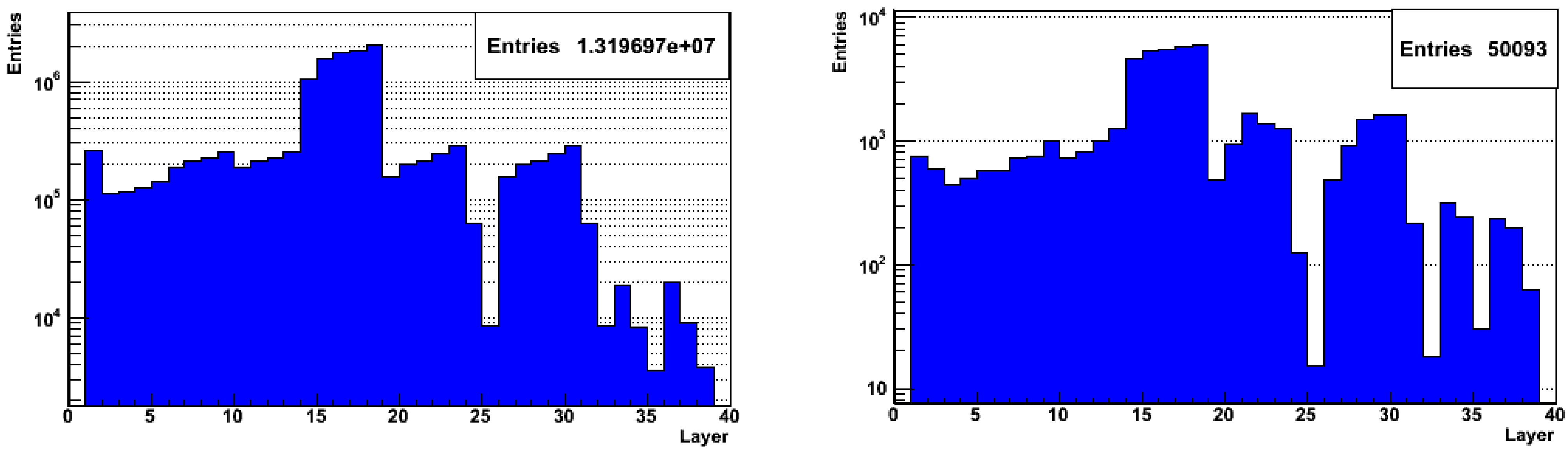
- **Choose TOF – T0 time gate width**
  - To detect hits from IP particles with ~100% efficiency (use muons as the fastest, protons as the slowest particles)
  - Then it will define the rejection of the hits from muon collider background particles
  - For now ignore the Si front-end resolution time
  - The gate starts at TOF-T0 = -1ns
- **2-3 ns time gate width ?**



ILCroot vertex and tracker detector hits

- **Vertex and tracker layers background hits occupancy and time gate**

No cut on TOF-T0   -1ns < TOF-T0 < 2 ns (3 ns gate)



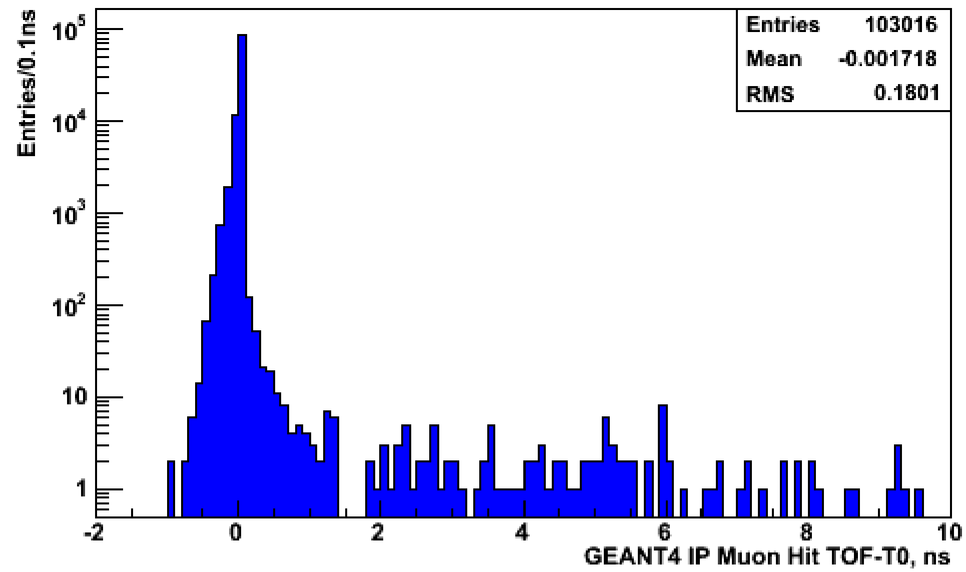
13.2M hits (no gate) reduced to 0.05M (3 ns gate), rejection factor ~260

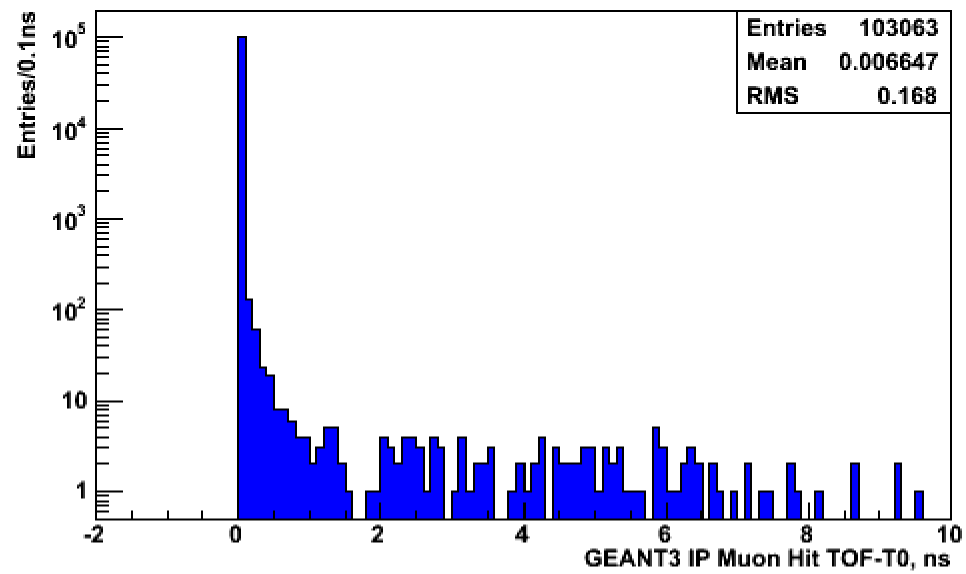
With 3 ns time gate:

Min. occupancy ~ 0.03 hits/(layer*cm^2) in most outer layer of tracker barrel
Max. occupancy ~ 3-4 hits/(layer*cm^2) in most inner layer of vertex barrel

ILCroot vertex and tracker detector hits

- **GEANT4 vs GEANT3 timing**
  - GEANT4: ~15% of hits from IP muons have negative TOF-T0, -1ns < (TOF-T0) < 0ns (top picture)
  - GEANT3: no such hits (bottom), as it should be
  - Needs to be understood

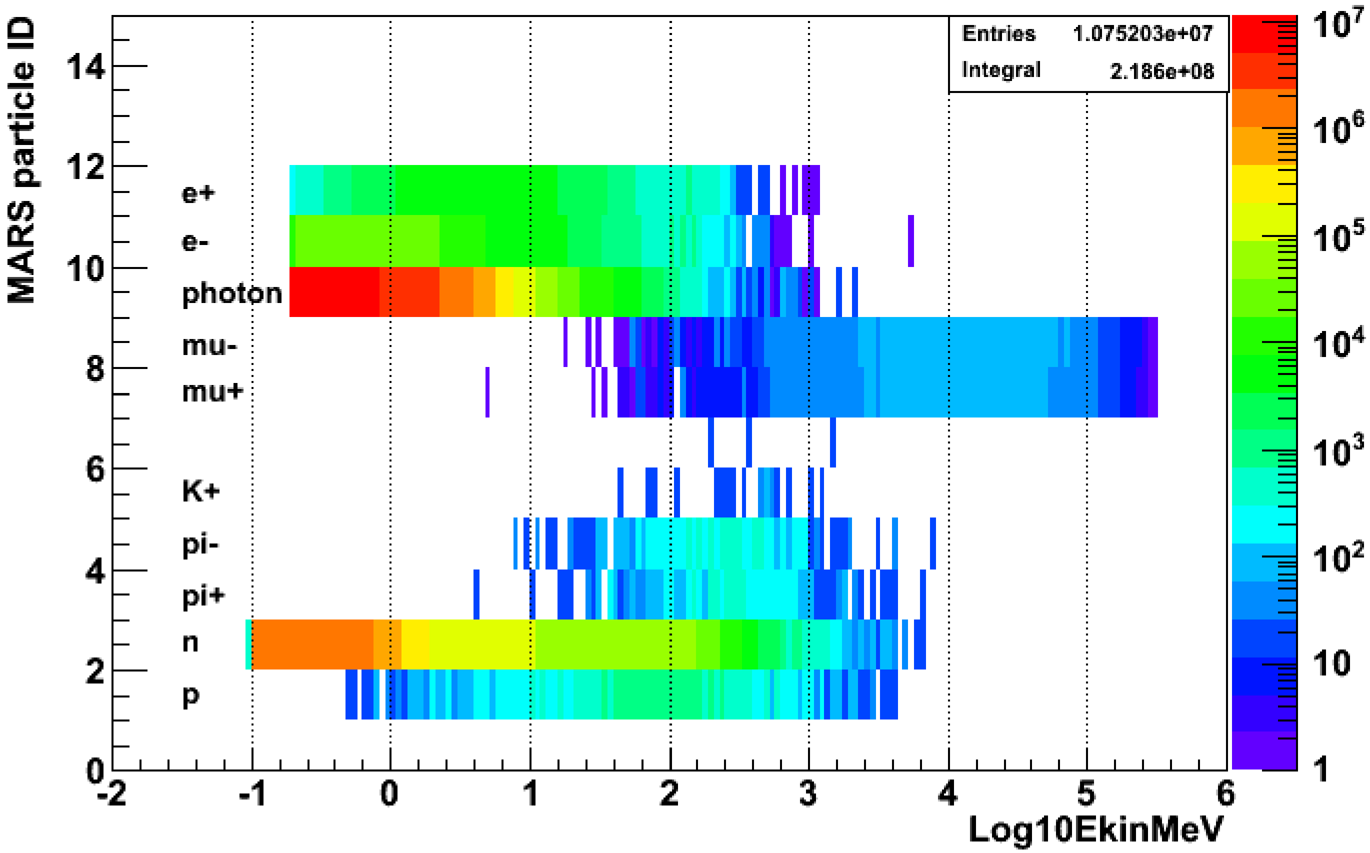




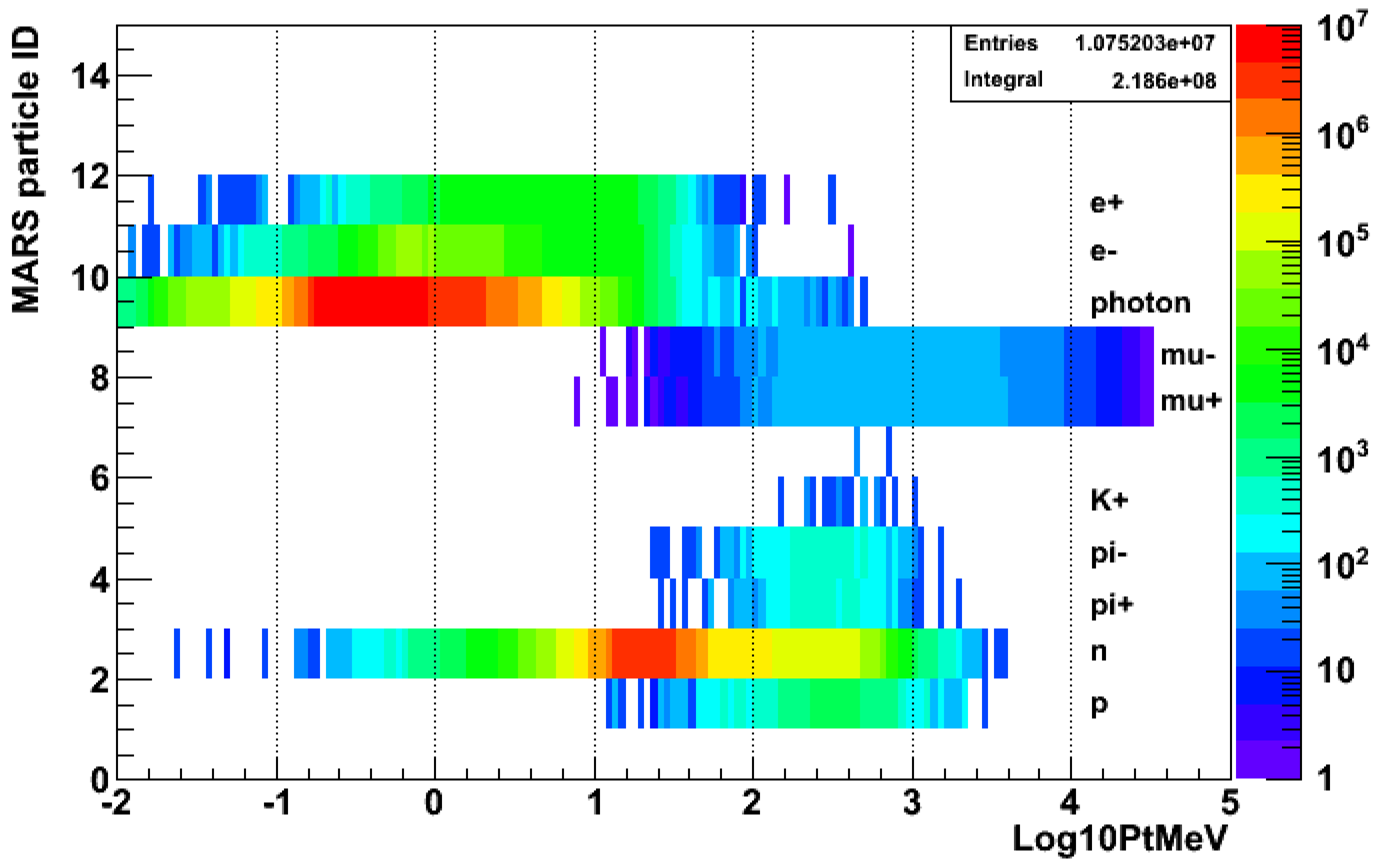
Conclusion

- **Significant progress with MARS – the framework for simulation of particle transport and interactions in accelerator, detector and shielding components**
  - Good results on simulation of 750 GeV beams muon collider detector backgrounds with 10^0 shielding nozzle
- **Results of ILCroot simulation of hits from MARS background and IP particles**
  - Call for fast vertex and tracker Si detectors front-end capable of delivering the precise timing (~100s ps) and narrow time gate (~2-3 ns?)
  - Such parameters can provide ~100% efficiency for physics events and at least two orders of magnitude in reduction of number of hits from muon collider background (at least three orders of magnitude for background neutrons)
  - Remaining hits occupancies are manageable by ILCroot tracking algorithms

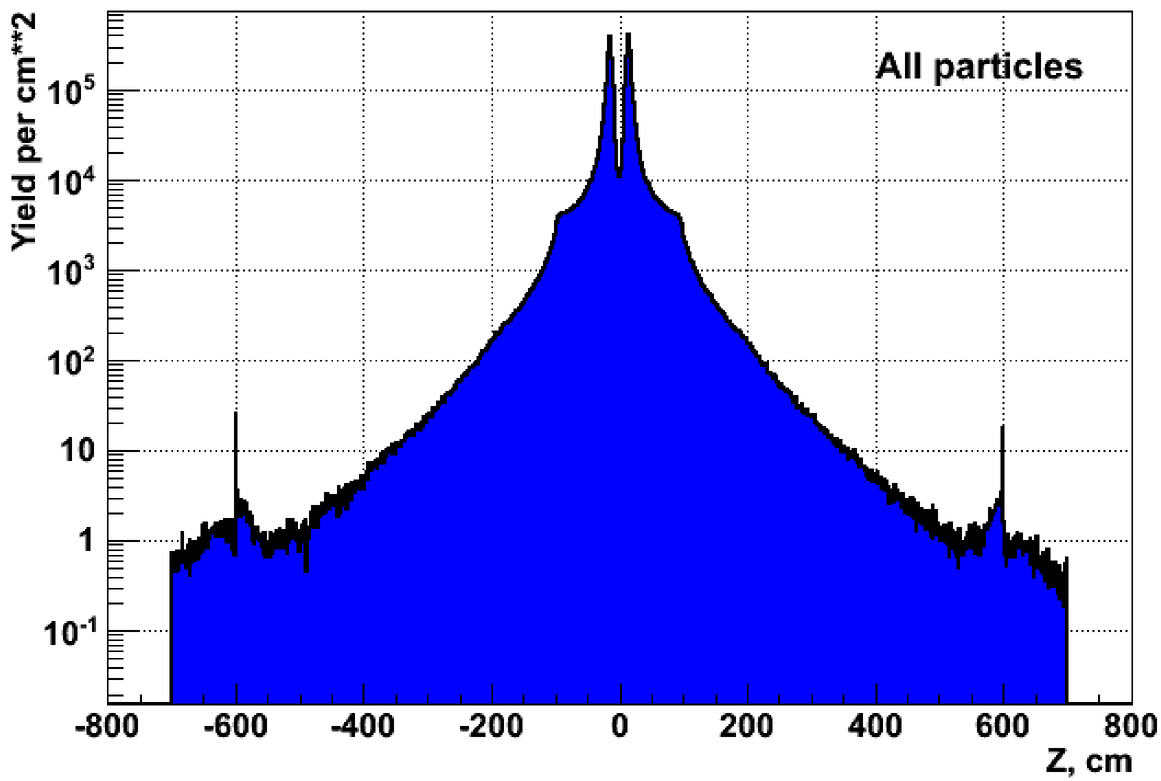
- **MARS particles Ekin and their ID**



- **MARS particles Pt and their ID**



- **MARS particles yield per cm^2 vs. Z (on the 10^0 nozzle surface)**



Backup

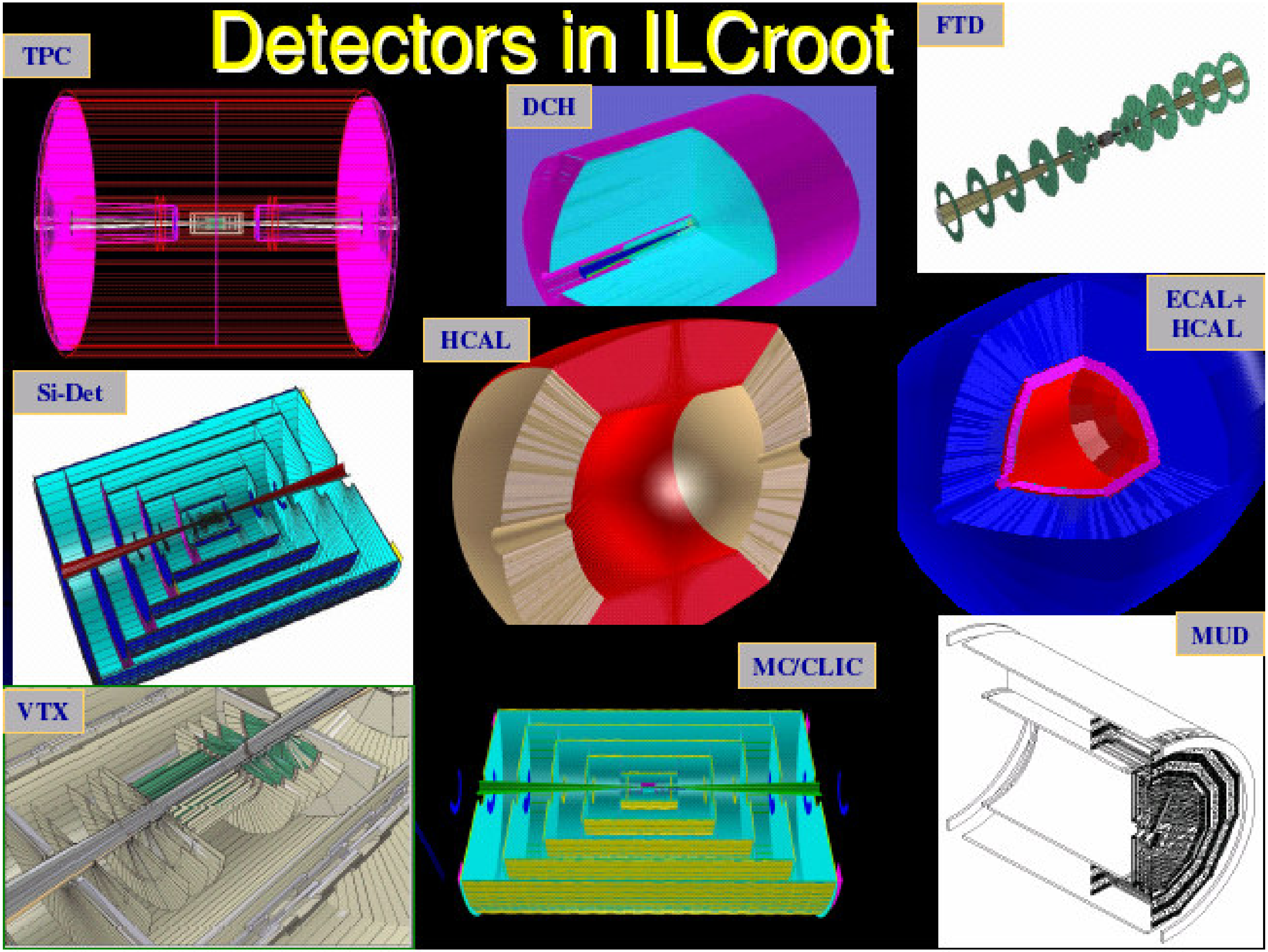
ILCroot: root Infrastructure for Large Colliders

- **Software architecture based on root, VMC & Aliroot**
  - All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)
  - Extremely large community of users/developers
- **Re-allignement with latest Aliroot version every 1-2**
- **It is a simulation framework and an Offline Systems:**
  - **Single framework, from generation to reconstruction and analysis!!**
  - It naturally evolves into the offline systems of your experiment
  - Six MDC have proven robustness, reliability and portability
- ***It is Publicly available at FNAL on ILCSIM since 2006***

The Virtual Montecarlo (VMC) Concept

- **Virtual MC provides a virtual interface to Monte Carlo**
- **It allows to run the same user application with all supported Montecarlo's**
- **The real Monte Carlo (Geant3, Geant4, Fluka) is selected and loaded at run time**

Backup


Detectors in ILCroot
TPC
DCH
FTD
ECAL+
HCAL
HCAL
Si-Det
VTX
MC/CLIC
MUD

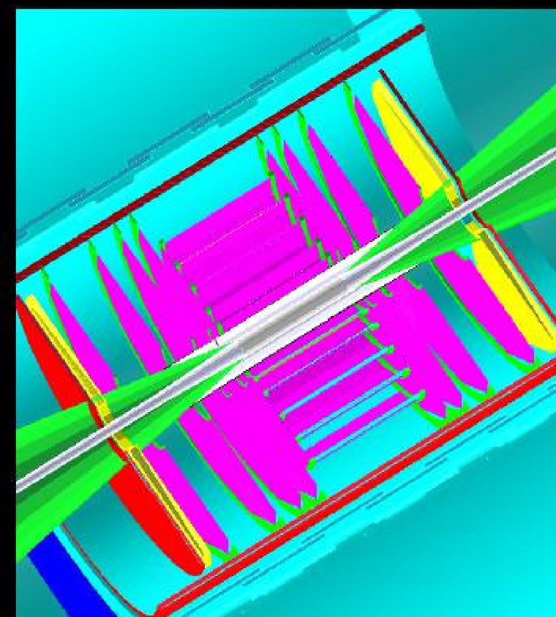
MARS + ILCroot (Oct. 2009)
Dedicated ILCroot framework for MUX Physics and background studies

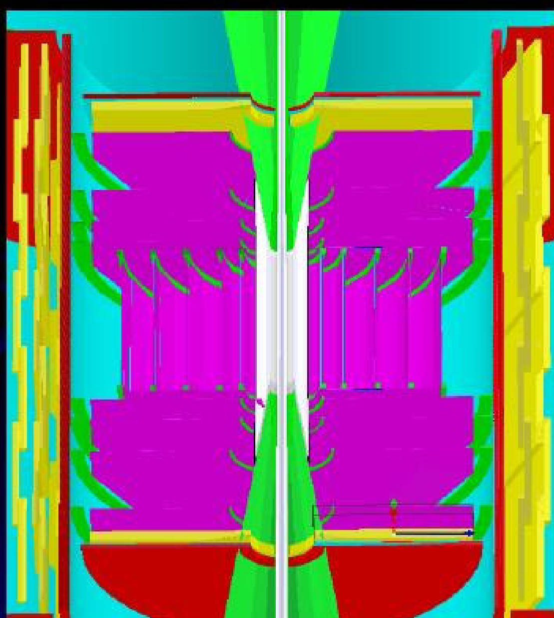
(in collaboration with N. Mokhov group)

- **The ingredients:**
  - Final Focus descripted in MARS & ILCroot
  - Detector description in ILCroot
  - MARS-to-ILCroot interface (Vito Di Benedetto)
- **How it works**
  - The interface (ILCGenReaderMARS) is a *TGenerator* in ILCroot
  - MARS output is used as a config file
  - ILCGenReaderMARS creates a STDHEP file with a list of particles entering the detector area at z = 7.5m
  - MARS weights are used to generate the particle multiplicity for G4
  - Threshold cuts are specified in Config.C to limit the particle list fed to G4
  - Geant4 takes over at 7.5m
  - Events are finally passed through the usual simulation (G4)-> digitization->reconstruction

Vertex Detector (VXD) Nozzle and Beam Pipe

- 20 µm x 20 µm Si pixel
- Barrel : 5 layers subdivided in 12- 30 ladders
- Endcap : 4 + 4 disks subdivided in 12 ladders





- Mostly SiD layout
- Different dimensions (different B field = 3.5 T)
- Full parametrized geometry

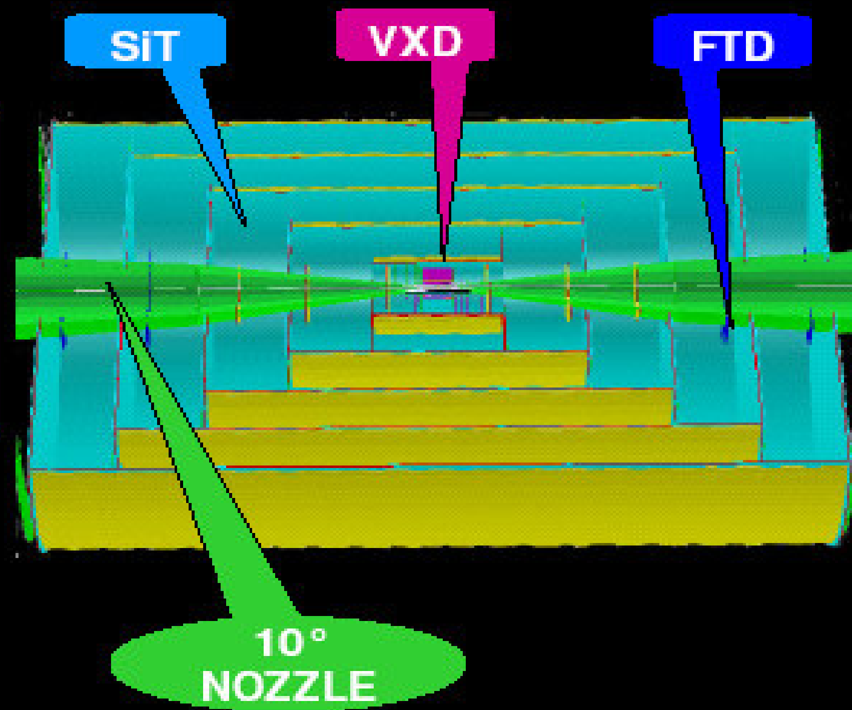
December 1st, 2010 Muon Collider Physics and Detector Working Group 10

Backup

Silicon Tracker (SiT) and Forward Tracker Detector (FTD)

SiT

- 100 µm thick Si layers
- 50 µm x 50 µm Si pixel (or Si strips or double Si strips available)
- Barrel : 5 layers subdivided in staggered ladders
- Endcap : (4+3) + (4+3) disks subdivided in ladders
- R_{min}~20 cm R_{max}~120 cm L~330 cm



FTD

- 20 µm x 20 µm Si pixel
- Endcap : 3 + 3 disks
- Distance of last disk from IP = 190 cm

- Silicon pixel for precision tracking amid up to 10^5 hits
- Tungsten nozzle to suppress the background

A. Mazzacane (Fermilab)

1