# *ILCroot tracker and vertex detector response to MARS simulation of the beam background in the muon collider*

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# Outline

- The MARS modeling results
- ILCroot CLICCT (vertex and tracker detector) hits for MARS background
  - Fractions of MARS background particles making hits in CLICCT
  - Fractions of CLICCT hits vs. time of flight gate
- Conclusion

# The MARS modeling results

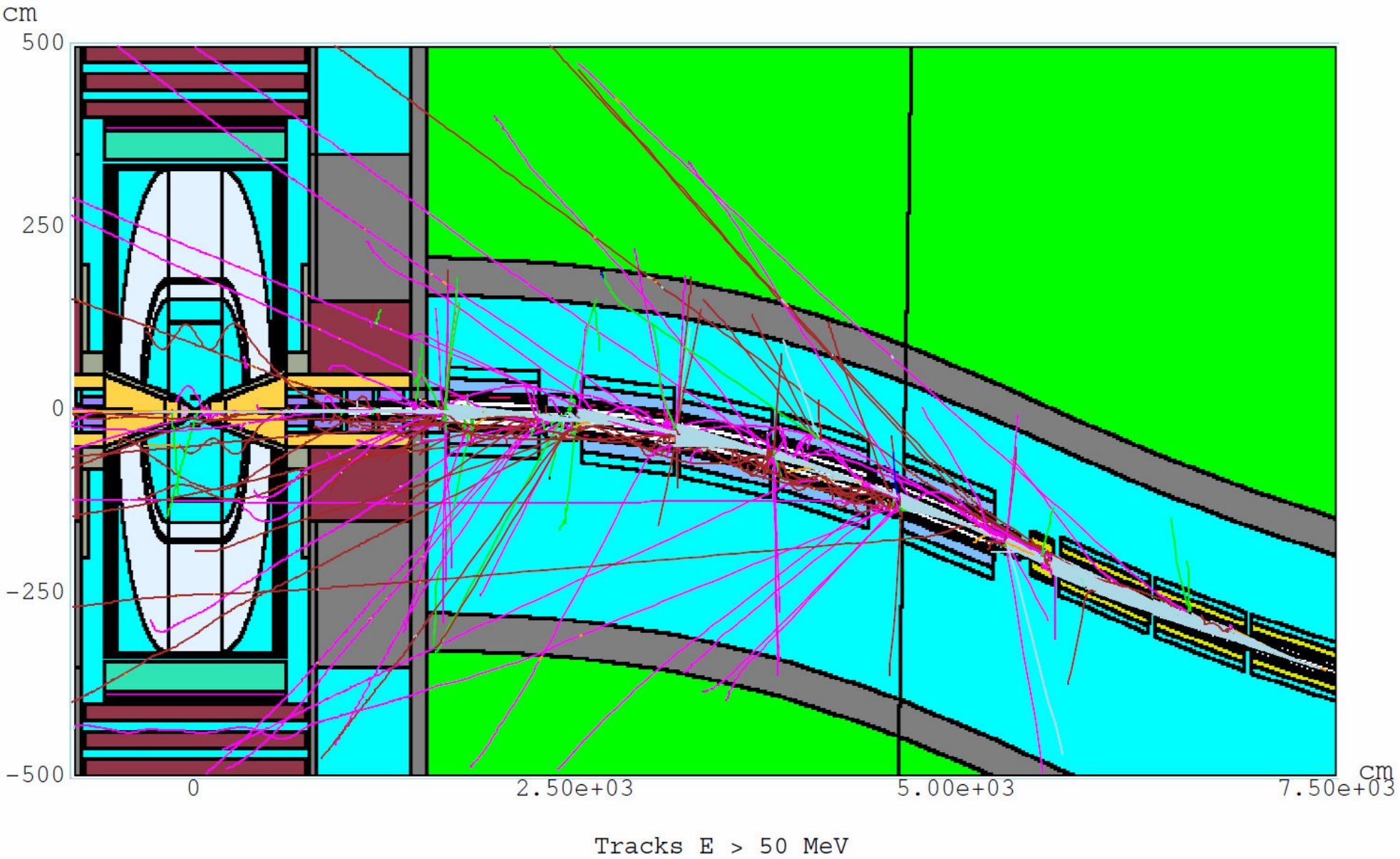
- **MARS – the framework for simulation of particle transport and interactions in accelerator, detector and shielding components**
- **New release of MARS15 available since February 2011 at Fermilab (N. Mokhov, S. Striganov, see www-ap.fnal.gov/MARS)**
- **Among new features:**
  - Refined MDI (Machine Detector Interface) with a $10^{o}$ nozzle
  - Significant reduction of particle statistical weight variation
  - Background is given at the surface of MDI ($10^{o}$ nozzle + walls)
- **Results available for 750 GeV muon beams with $2*10^{12}$ muons/bunch each**

# The MARS modeling results

- **Sources of background at Muon Collider**
  - The major source - 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
  - At large radii – beam halo, Bether-Heitler muon flux
  - At IP (Interaction Point)
    - Incoherent $e^+e^-$ pair production, $3*10^{4}$ pairs/bunch
    - Negligible background from $\mu^+\mu^-$ collisions
- **Means to suppress background**
  - ~ 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 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

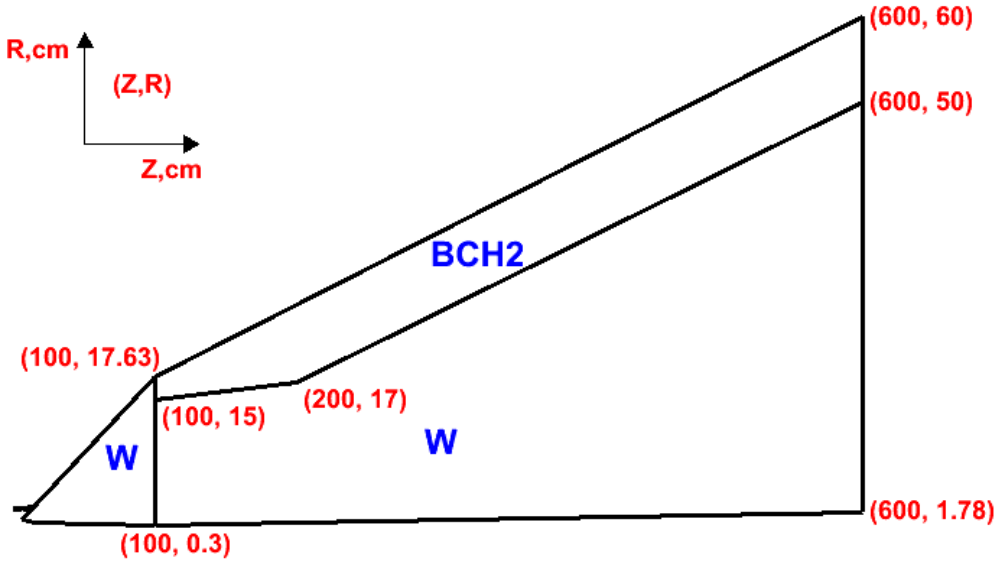
## MARS background particle tracks in muon collider near the detector



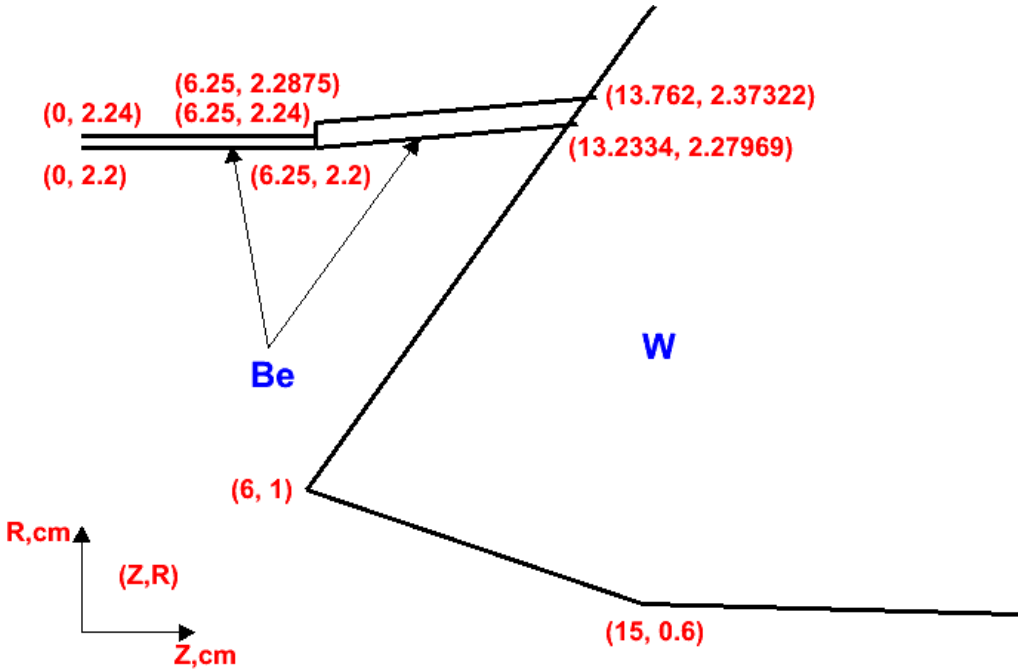
# The MARS modeling results

- **$10^0$ nozzle geometry**

General (1/2 Z view)




Zoom in beam pipe



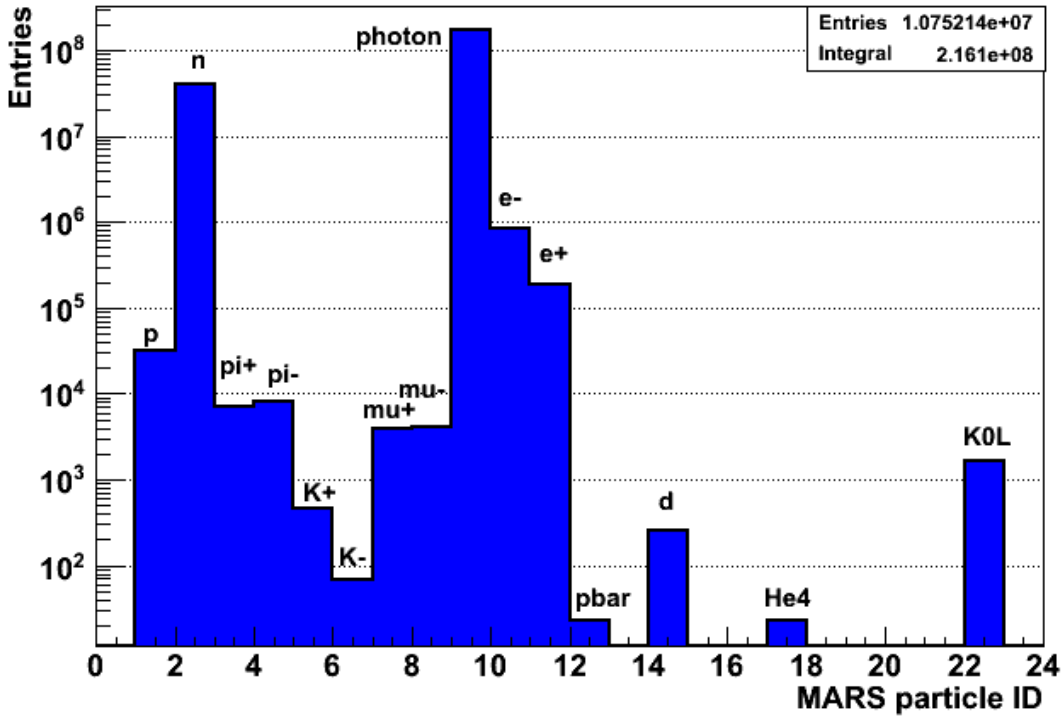

W – tungsten

Be – beryllium

BCH2 – borated polyethylene

# The MARS modeling results

- **MARS background particle ID's yields**

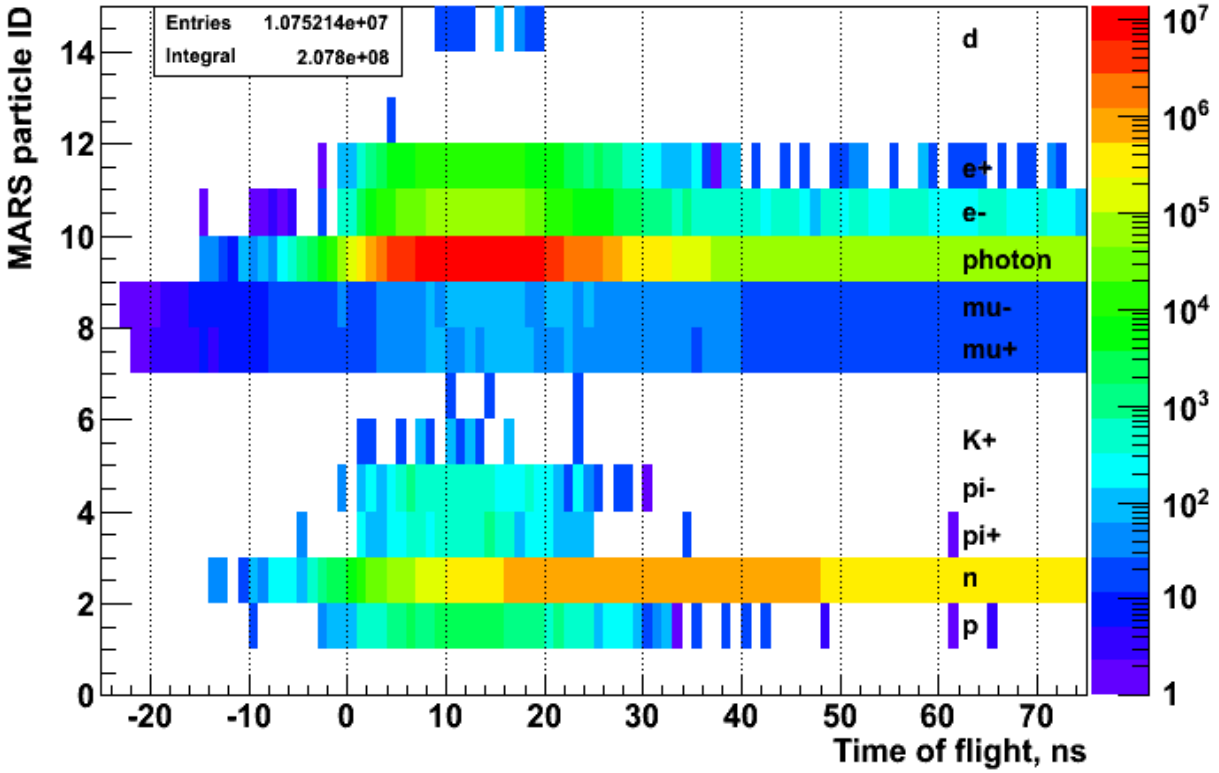



- **Background yields/bunch on $10^0$ nozzle surface and Ethr**

| | $\gamma$ | n | $e^{+-}$ | $\mu^{+-}$ |
|---|---|---|---|---|
| **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



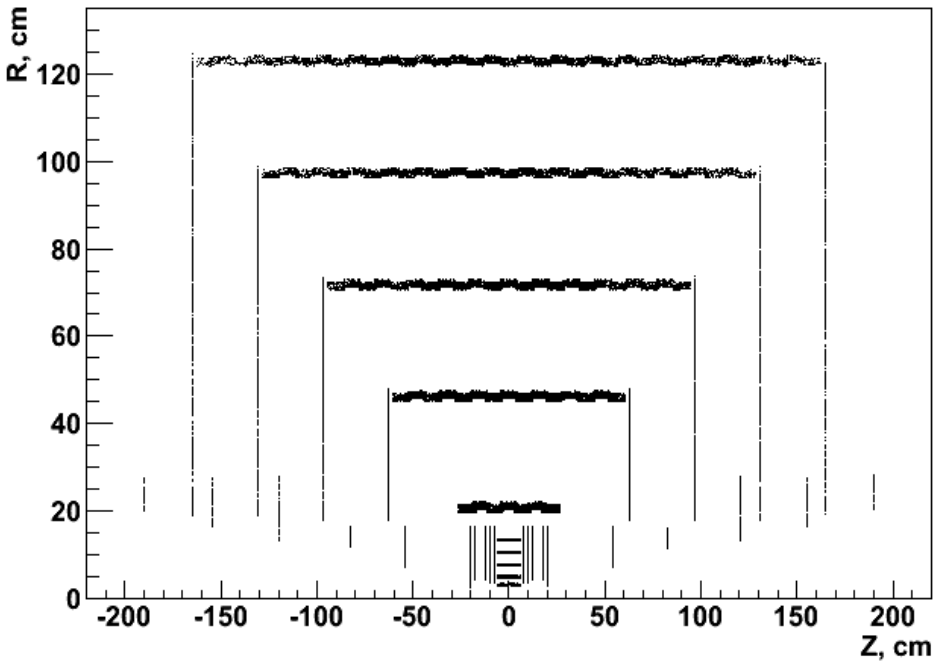
# ILCroot vertex and tracker detector hits

- **The ILCroot - software Infrastructure for Large Colliders based on ROOT and add-ons for Muon Collider studies (more in backup)**
- **Limited MARS background statistics was simulated in ILCroot to look at the hits in CLICCT detectors**
- **CLICCT (CLICCT = VXD + SiT + FTD, 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,12 endcap disks
  - Forward Tracker Detector (FTD)
    - 50μ X 50μ Si pixels, 6 disks

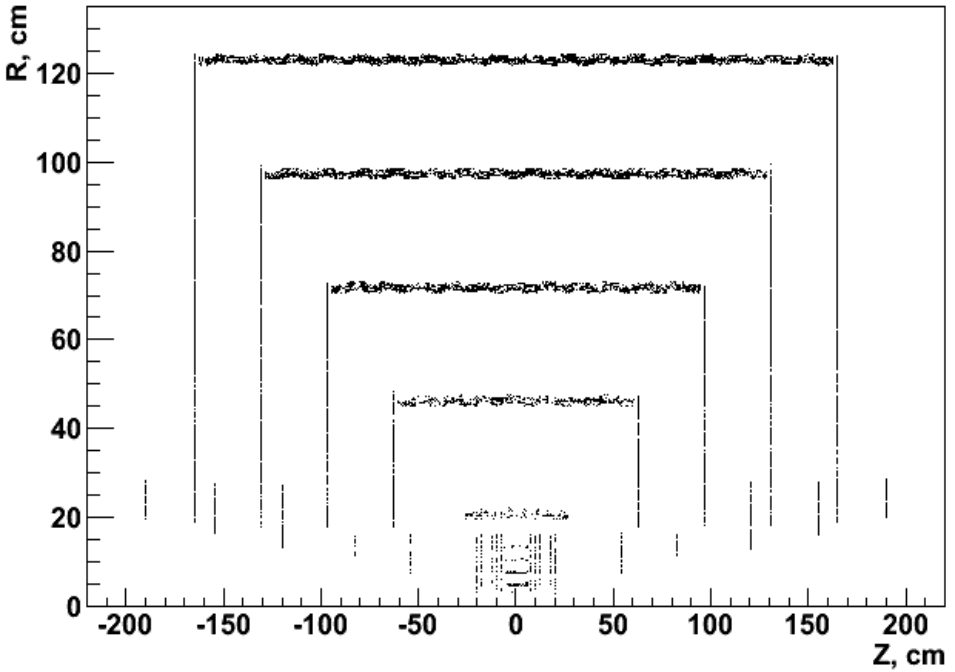
# ILCroot vertex and tracker detector hits

- **Hits from photons and neutrons in sensitive volumes of CLICCT (no time cuts)**

Z and R coordinates of the hits from the secondary particles produced by photons

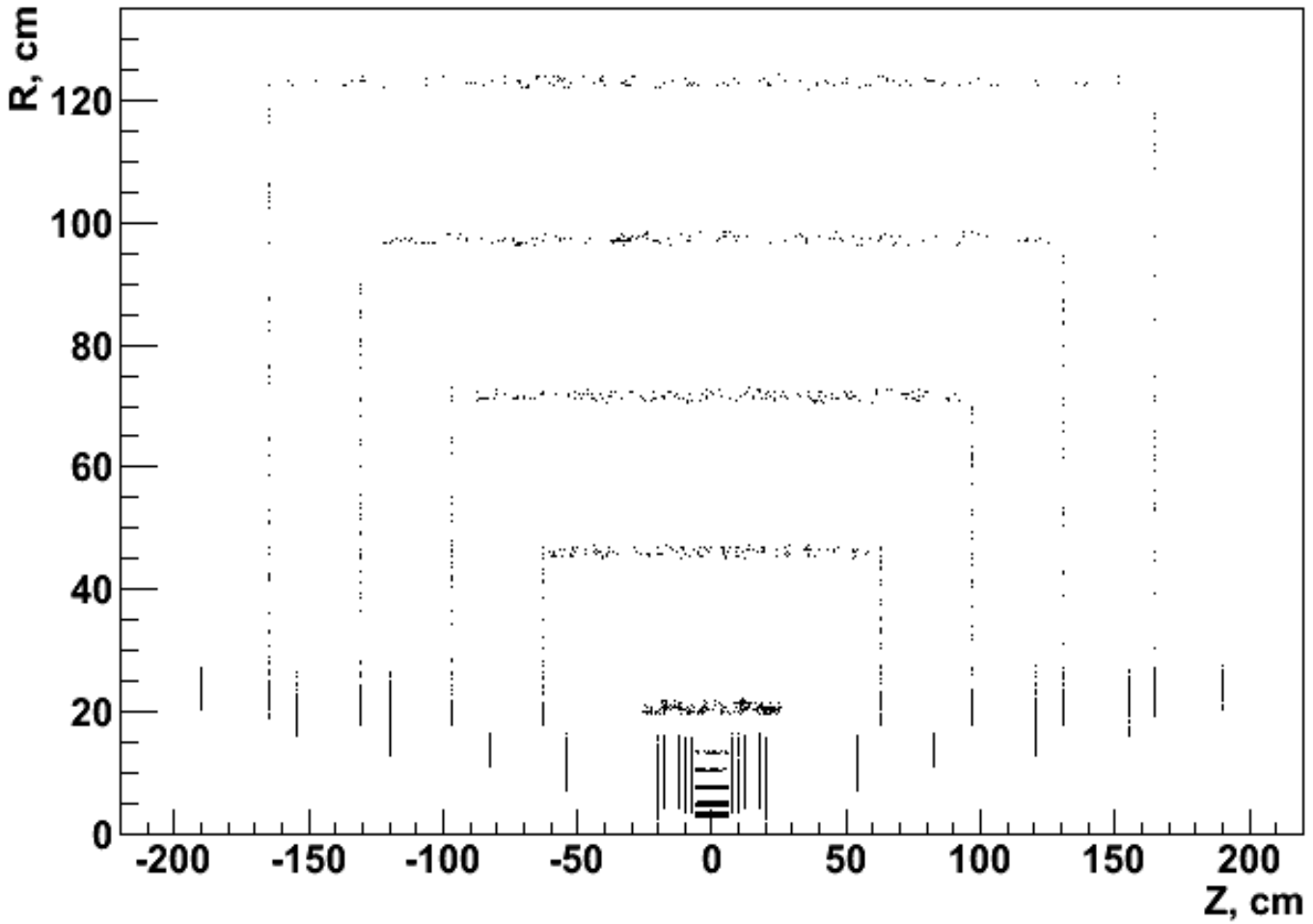



Z and R coordinates of the hits from the secondary particles produced by neutrons



# ILCroot vertex and tracker detector hits

- **Hits from $e^+e^-$ in sensitive volumes of CLICCT (no time cuts)**
  - Most of the hits in the first layers of VXD (magnetic field 3.5T)



# ILCroot vertex and tracker detector hits

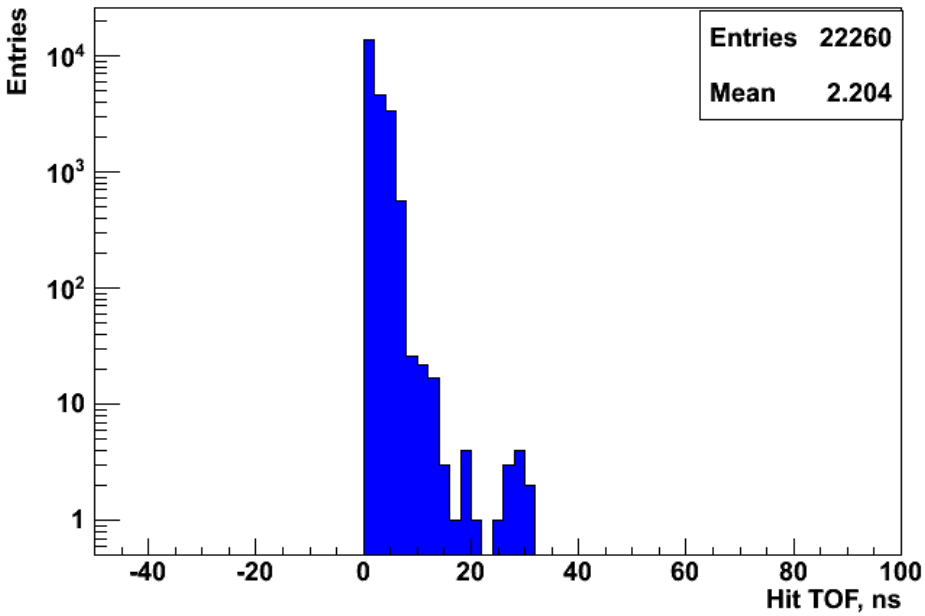
- **Fractions of MARS background particles making hits in CLICCT**

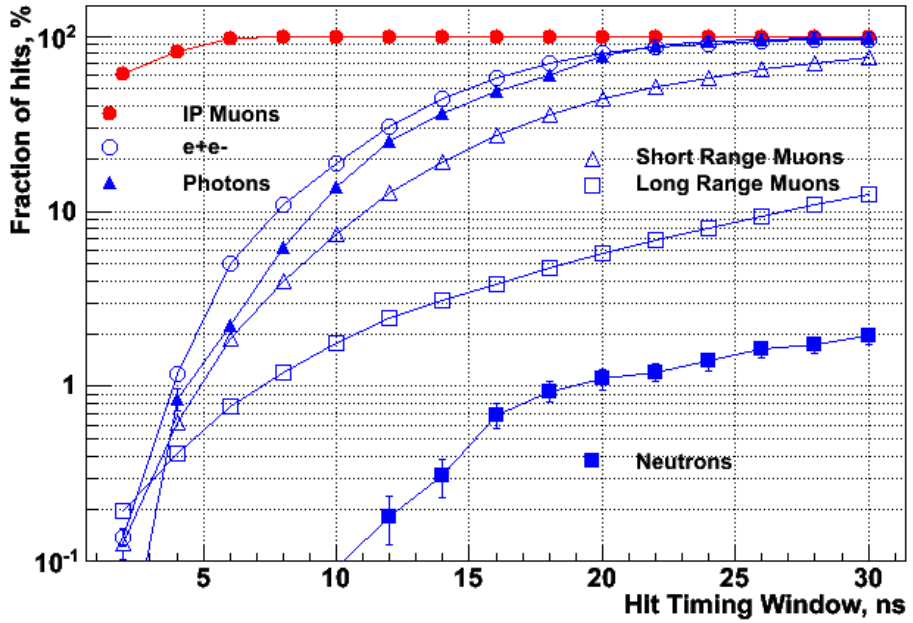
| | $\gamma$ | n | $e^+e^-$ |
|---|---|---|---|
| **MARS yields, # of particles** | **~1.77e+08** | **~0.40e+08** | **~1.03e+06** |
| **Fraction of particles producing hits in CLICCT sensitive volumes** | **~2.8%** | **~4.2%*** | **~43%** |
| **# of MARS particles "seen" by CLICCT** | **~5.0e+06** | **~1.68e+06*** | **~0.44e+06** |

- Limited MARS statistics study (0.5% for $\gamma$, 2.5% for n and 5% for $e^+e^-$)
- No cooling elements in CLICCT geometry
- * for GEANT4 neutron transport model QGSP_BERT_HP
- No time cuts

# ILCroot vertex and tracker detector hits

- **Fractions of CLICCT hits vs. TOF (time of flight) gate**
  - Muon collider background TOF has significant spread wrt. the bunch crossing time suggesting the use of the fine time tuning for background rejection
  - TOF gate begins at 0 ns (bunch crossing time)
  - Ignore MARS particle statistical weight, smearing in the CLICCT collection and resolution time, neutron contribution from beams in previous bunches…
  - IP muons are simulated to represent physics events (a picture on the left)
  - Expect better background rejection if the hit TOF calculated wrt. the time of IP photon hit with the same coordinates



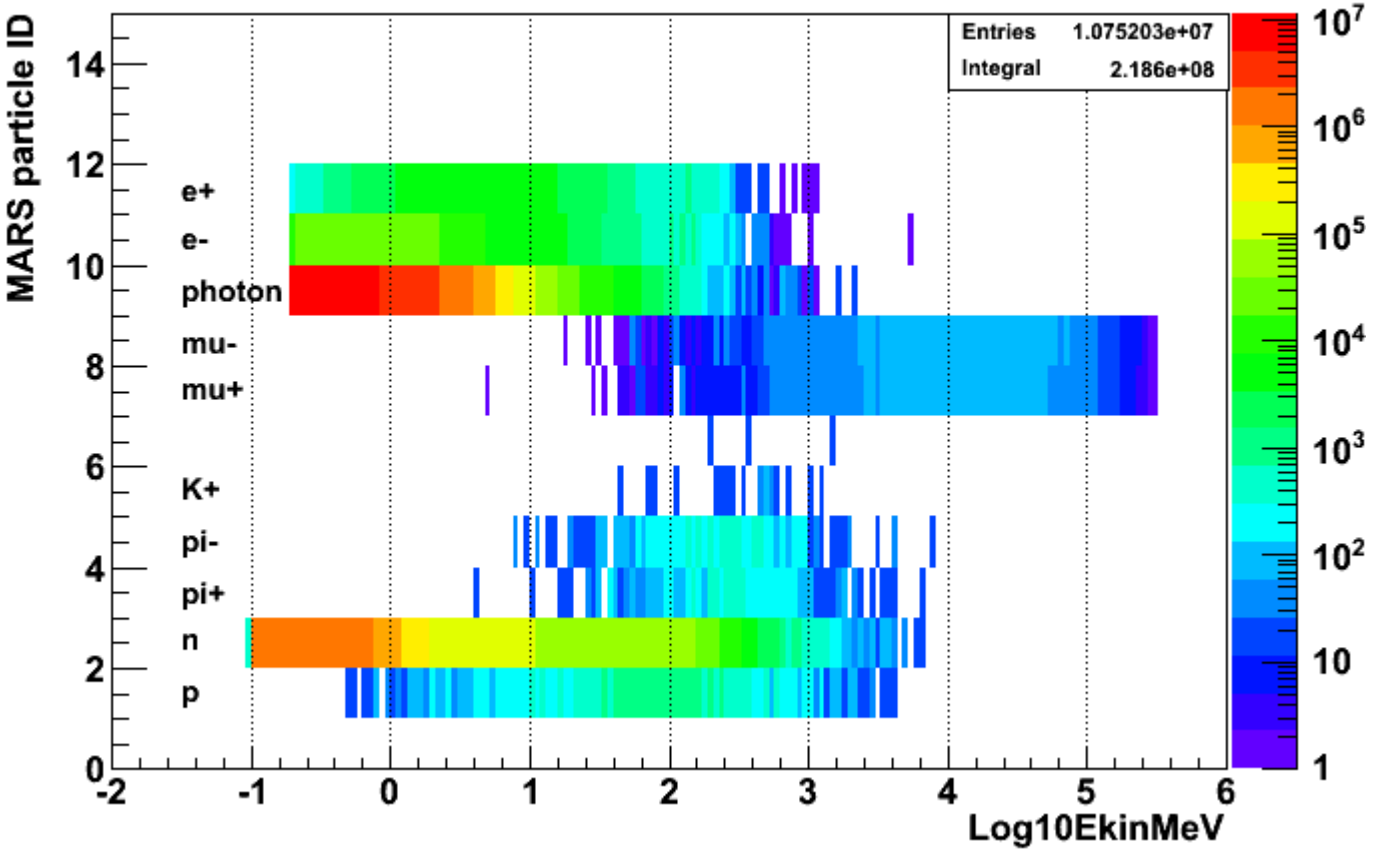



# Conclusion

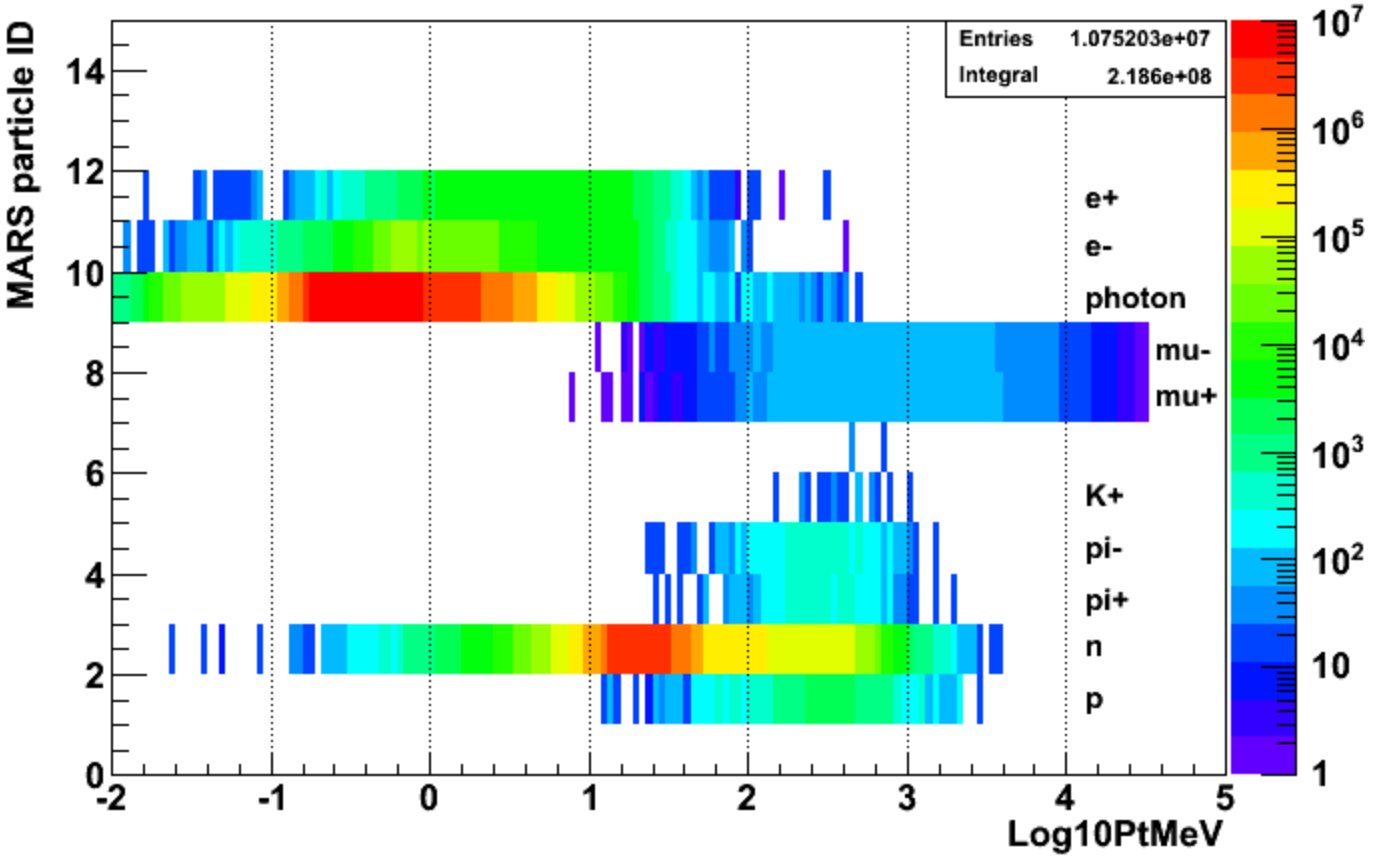
- **Significant progress with MARS – the framework for simulation of particle transport and interactions in accelerator, detector and shielding components**
  - New release of MARS15 available since February 2011 at Fermilab
  - Encouraging results on simulation of 750 GeV beams muon collider detector backgrounds with $10^0$ shielding nozzle
- **The ILCroot CLICCT (vertex and tracker) hits for IP muons and small samples of the MARS background data were analyzed**
  - The fractions of background particles producing hits in sensitive volumes of CLICCT are:

    ~2.8% for $\gamma$, ~4.2% for n and ~43% for $e^+e^-$
  - Use of time correlation of hits from IP particles can significantly reduce the contribution of hits produced by random background from muon beams
- **Plans:**
  - Run ILCroot simulation for total statistics of MARS background
  - Introduce the space correlation of the IP particles hits and combine it with their time correlation to estimate the total reduction of the random background hits in CLICCT

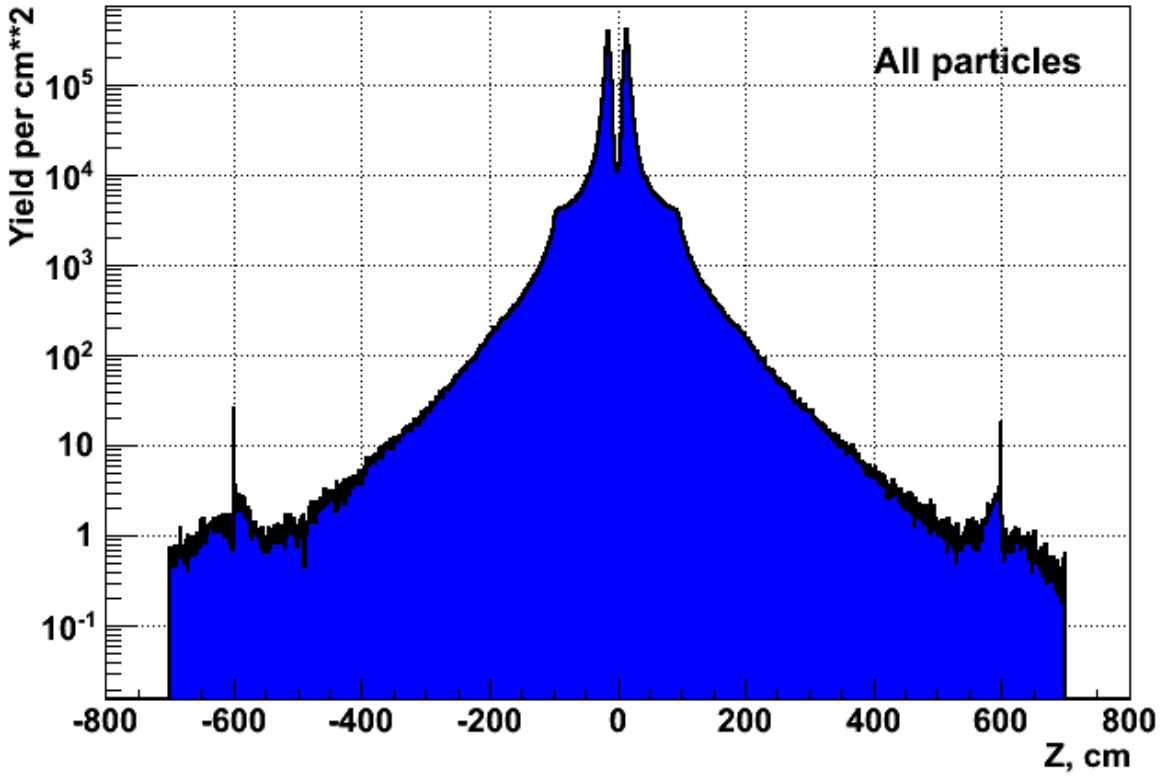
- **MARS particles Ekin and their ID**

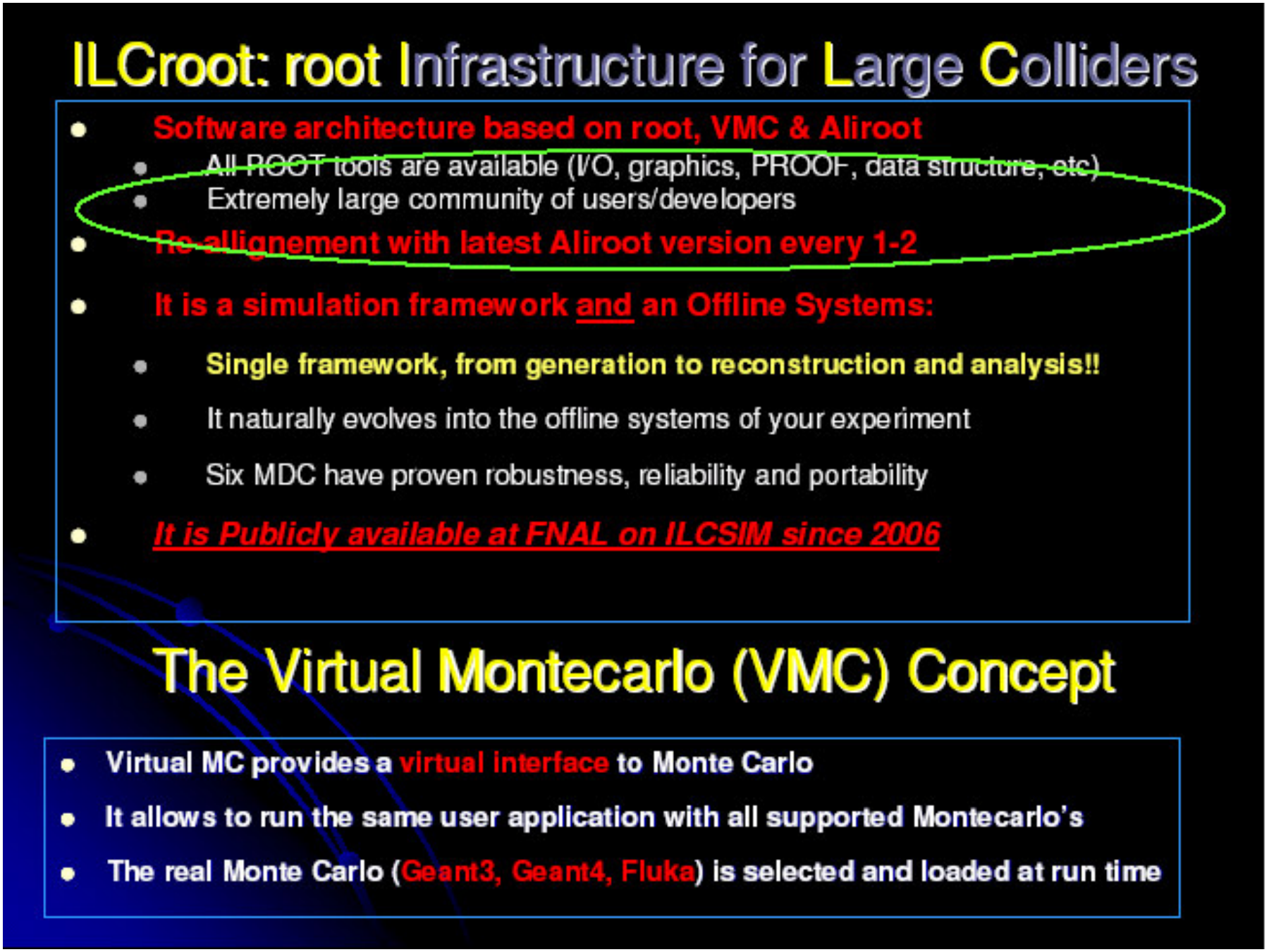


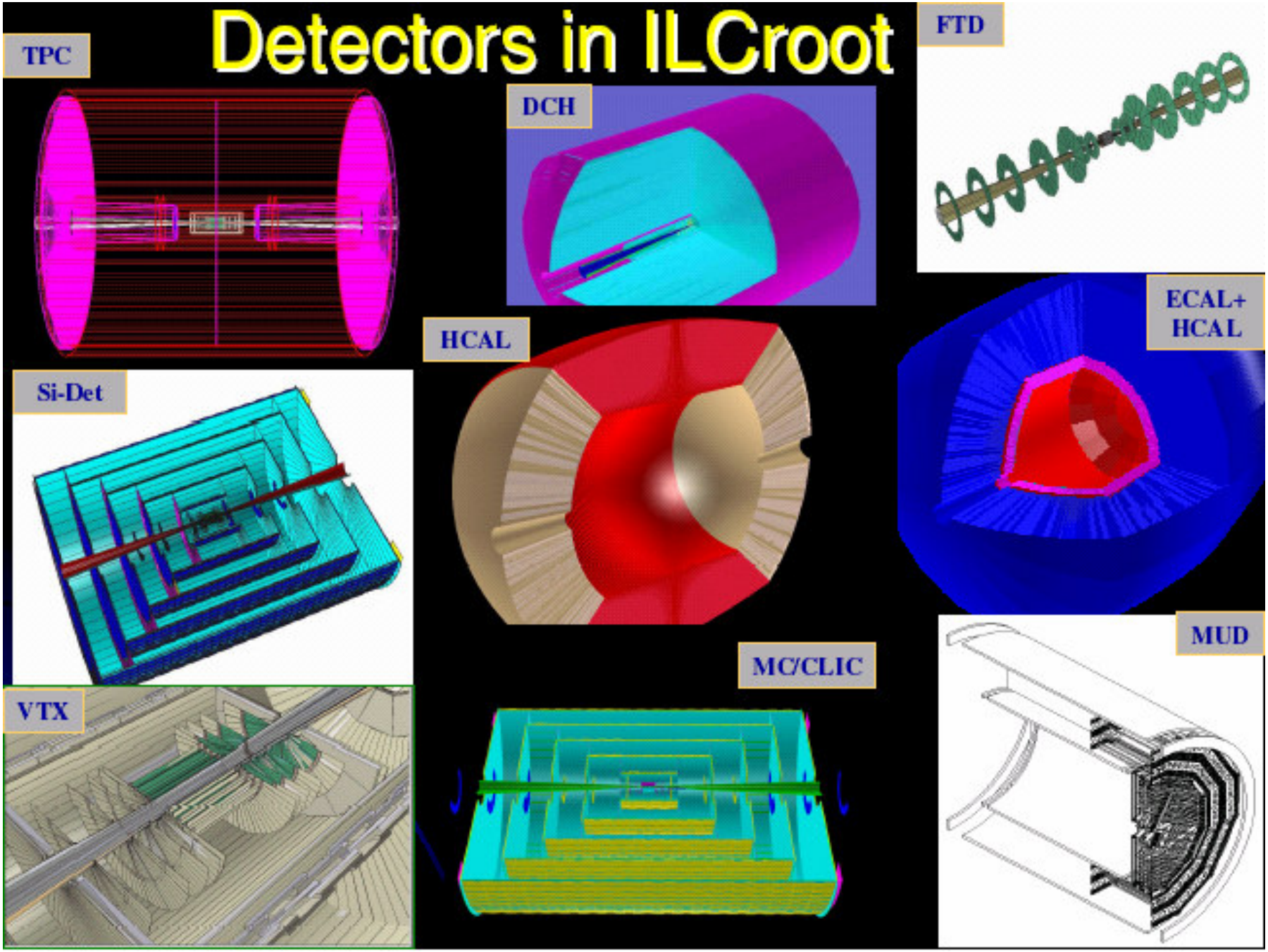
- **MARS particles Pt and their ID**



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




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

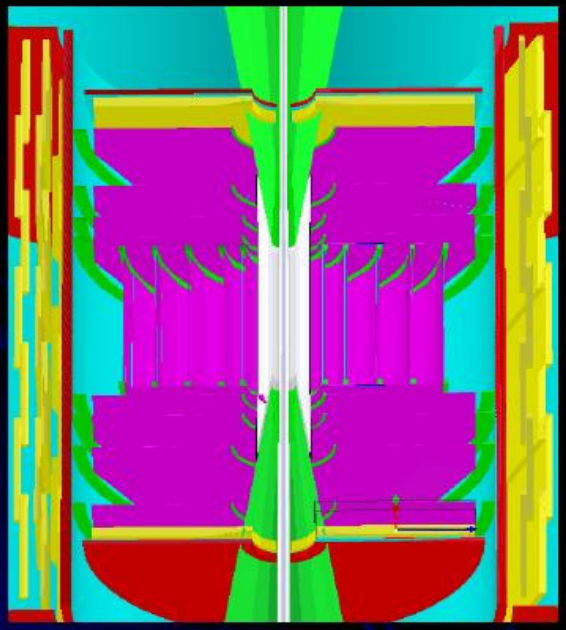

Detectors in ILCroot
TPC
DCH
FTD
HCAL
ECAL+
HCAL
Si-Det
MC/CLIC
MUD
VTX

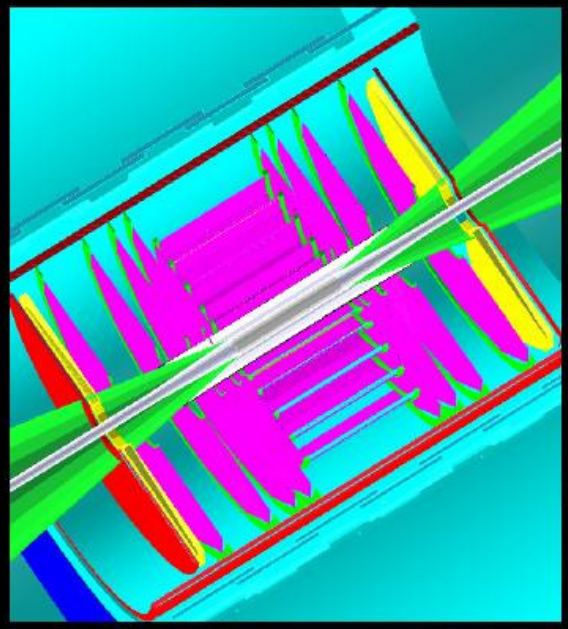
## MARS + ILCroot (Oct. 2009)
## Dedicated ILCroot framework for MUX Physics and background studies
(in collaboration with N. Mokhov group)

- **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

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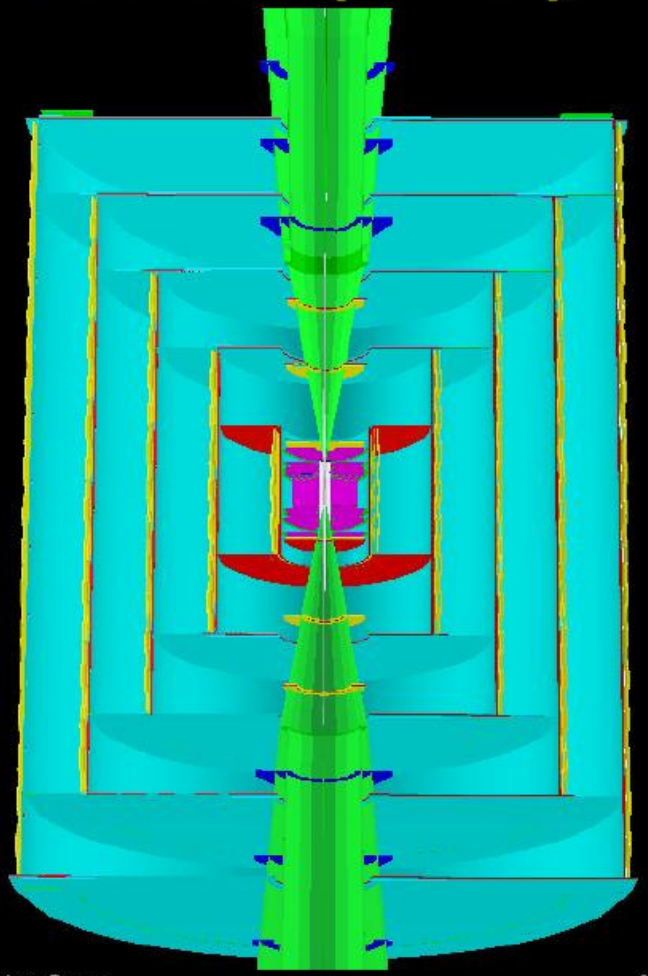
# Silicon Tracker (SiT) and Forward Tracker Detector (FTD)

- 50 µm x 50 µm Si pixel (or Si strips or double Si strips available)
- Barrel : 5 layers subdivided in staggered ladders
- Endcap : (4+2) + (4+2) disks Si pixel
- FTD: 3 + 3 disks Si pixel



- Mostly SiD layout + FTD
- Not parametrized geometry yet

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