MDI and detector modeling

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On behalf of
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Muon Accelerator Program Meeting
February 28 - March 4, 2011 Jefferson Lab

Outline

- Recent MARS modeling results
- ILCroot status and development
- ILCroot CLICCT hits (tracker + vertex detectors) for MARS background
- Merging MARS background with muon physics events
- Conclusion

Recent MARS modeling results

- **The most recent MARS modeling results**

  (N. Mokhov. S. Striganov, Fermilab)

  - **MARS15 - Monte Carlo code for simulation of particle transport and interactions in accelerator, detector and shielding components**
    - **New release available since Feb. 24, 2011, see http://www-ap.fnal.gov/MARS/**
  - **New features in muon collider background modeling:**
    - **Refined MDI (Machine-Detector Interface) with a 10^0 nozzle**
    - **Significant reduction of particle statistical weight variation**
    - **Calculated background source term at the interface surface for both beams**

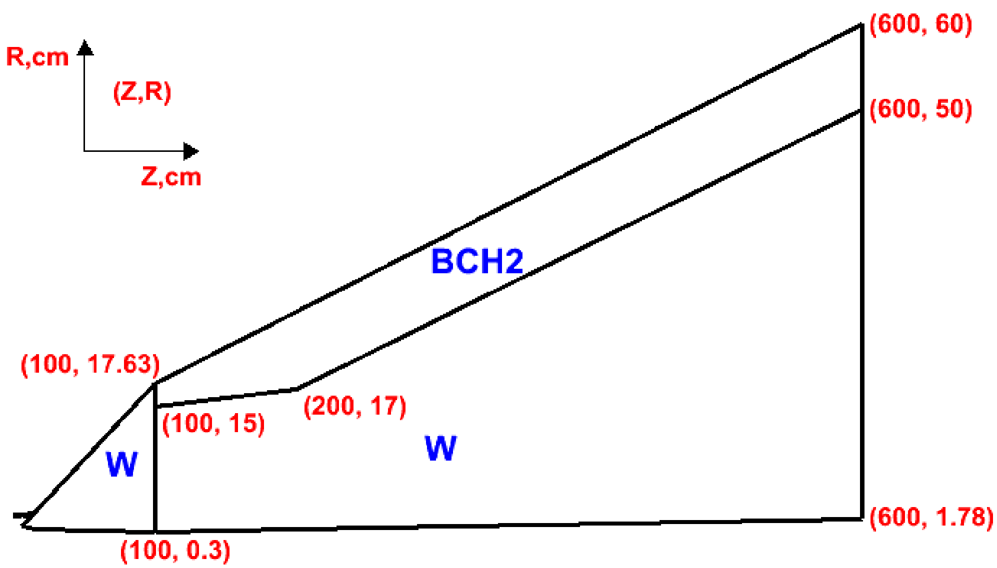
Recent MARS modeling results

- Sources of background at Muon Collider
  - Muon beam decays is the major source: detector irradiation by particle fluxes from beam line components and accelerator tunnel.
    For 750 GeV muon beam of $2*10^{12}$ - $4.3*10^{5}$ decays/m per bunch crossing, or $1.3*10^{10}$ decays/m/s for two beams.
  - IP incoherent e+e- pair production, ~$3*10^{4}$ e+e- pairs per bunch crossing
  - IP $\mu^{+}\mu^{-}$ collisions – negligible
  - At large radii - beam halo, Bethe-Heitler muon flux
- Means to suppress background
  - Collimating nozzle at IP, detector magnetic field
  - ~10T dipole magnets to sweep decay electrons in IR (interaction region), with tungsten masks in between
- Currently achieved reduction of machine background is ~ 3 orders of magnitude (depends on the nozzle angle)

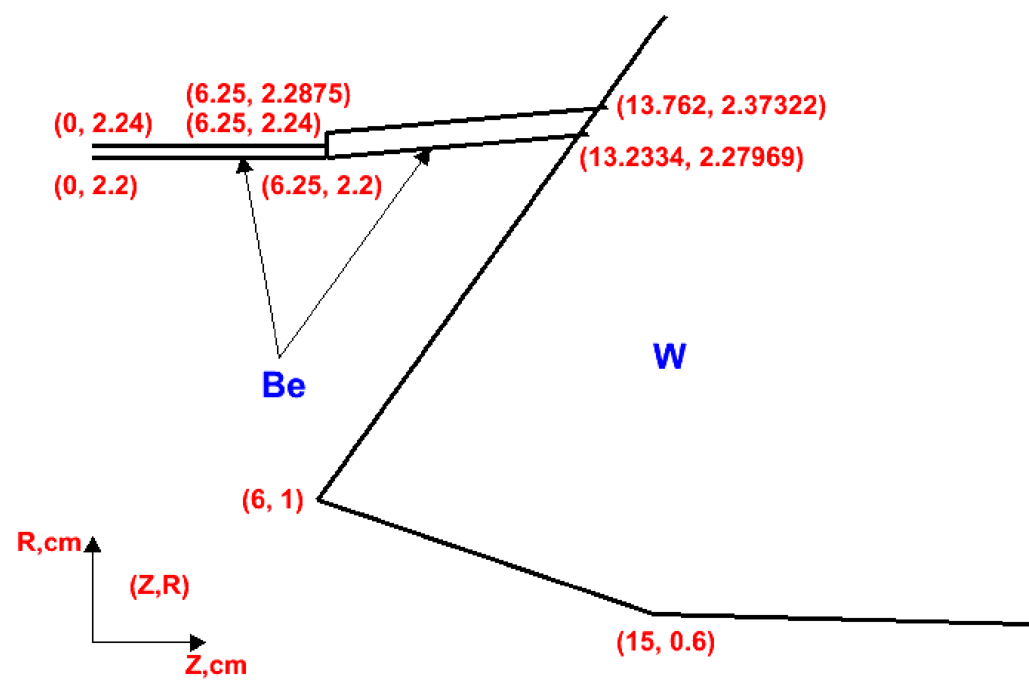
Recent MARS modeling results

- 10^0 nozzle geometry

General view



Zoom in beam pipe

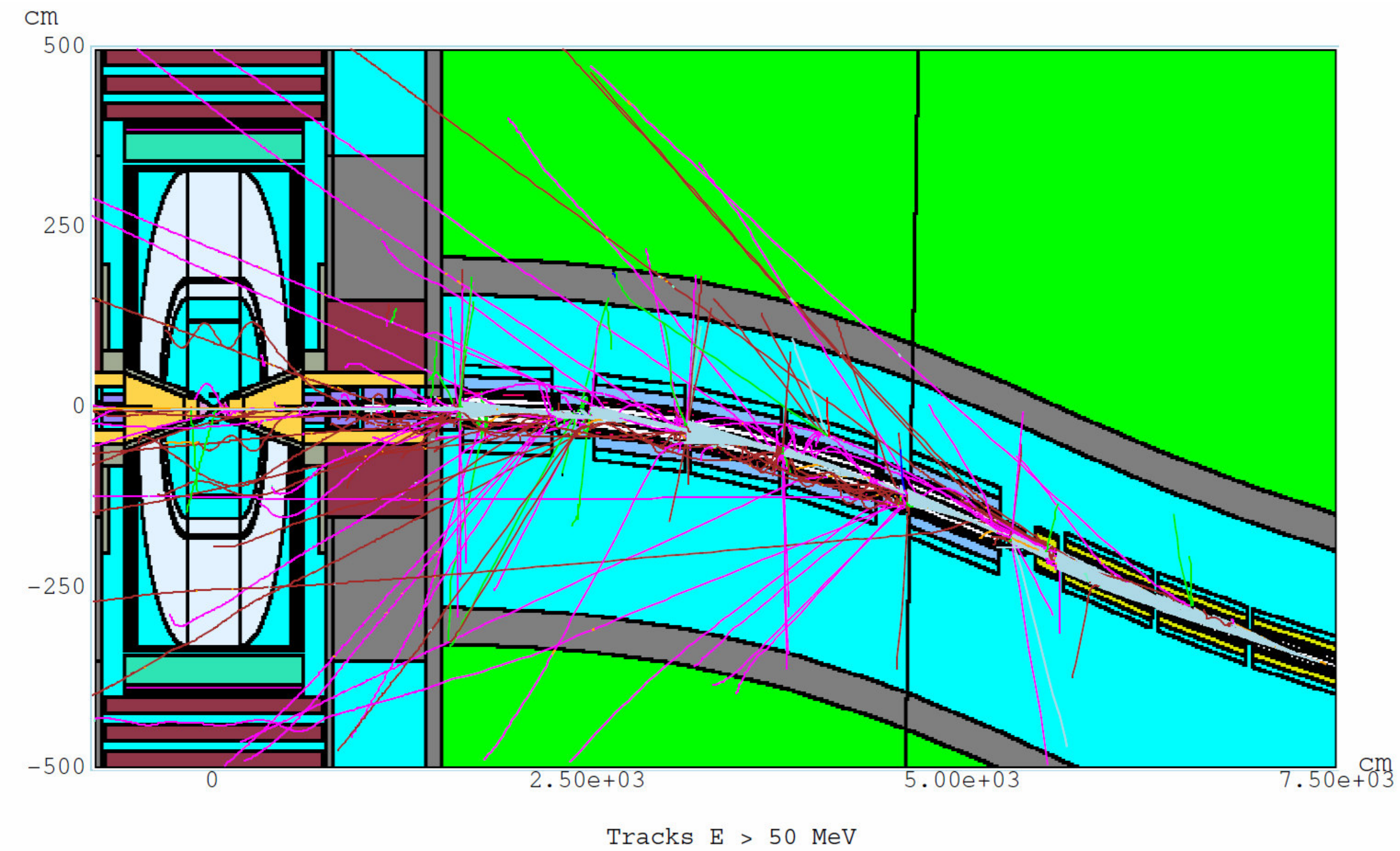


W – tungsten
Be – beryllium
BCH2 – borated polyethylene

Recent MARS modeling results

Physics Carnegie Mellon

- **Particle Tracks in IR**



Recent MARS modeling results

Physics
Carnegie Mellon

- **Reducing Weight Fluctuations - Key for Detector Modeling**

  - Statistical weight W spread has been substantially reduced recently. Internal MARS weight fluctuations came predominantly from modeling of low-energy electromagnetic and hadronic showers as well as from photo- and electro-nuclear hadron and muon production algorithms.
  - These are now user-controlled by material - dependent switches between exclusive, inclusive and hybrid modes.
  - Inclusive approach: multiparticle interaction results are represented by fixed number of particles with weights proportional to partial mean multiplicities.
  - Exclusive simulation: majority of particles with W~1, but much more particles per event and as a result substantial increase of CPU time per event (7 days on 24 CPU for MARS simulation of background from ~ 0.5M decays in one muon beam).

Recent MARS modeling results

- **Available since Nov. 18, 2010**

  (http://www-ap.fnal.gov/~strigano/mumu/mixture/)

  - **750 GeV 2e+12 μ^+ and μ^- beams**
  - **10^0 nozzle geometry**
  - **"Short-range" source term: 4.8e+05 simulated decays for each beam**

    -25m < Z < 1m for μ^+ beam

    -1m < Z < 25m for μ^- beam

    each source term file has about 5M particles
  - **"Long-range" source term: 2.4e+07 simulated decays for each beam**

    -189m < Z < -25 m for μ^+ beam

    25m < Z < 189 m for μ^- beam

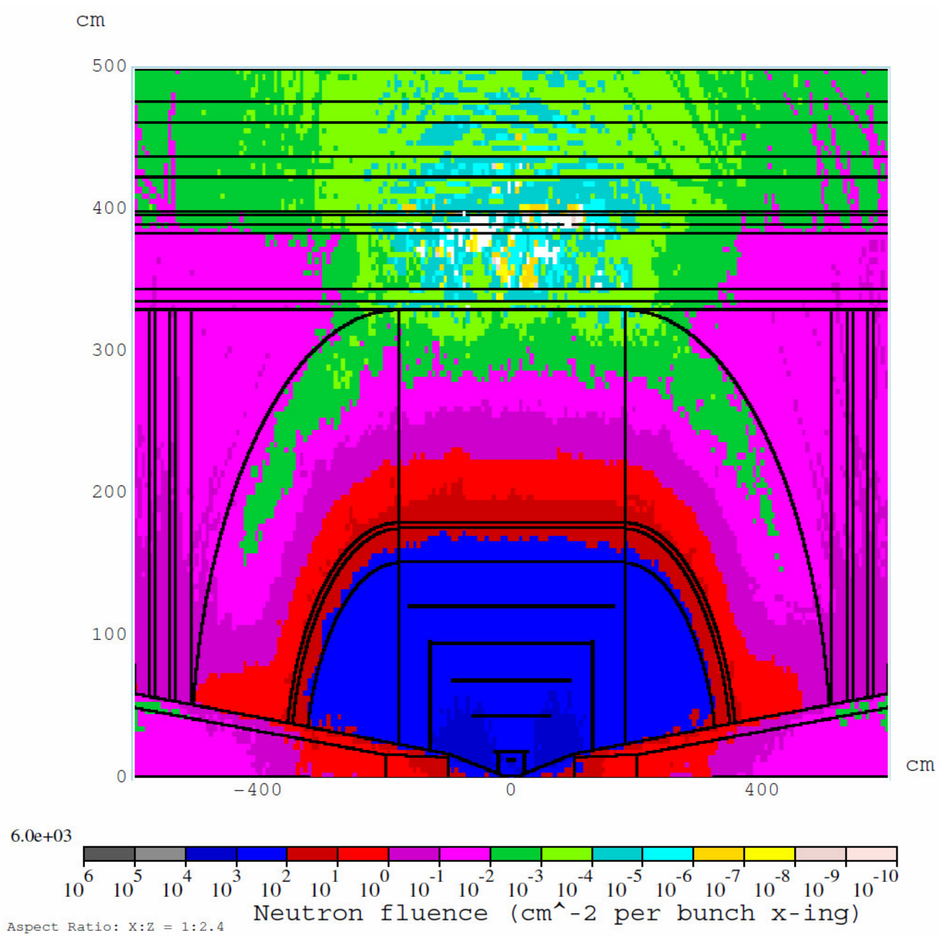
    each file has about 0.44M particles (mostly muons)

Recent MARS modeling results

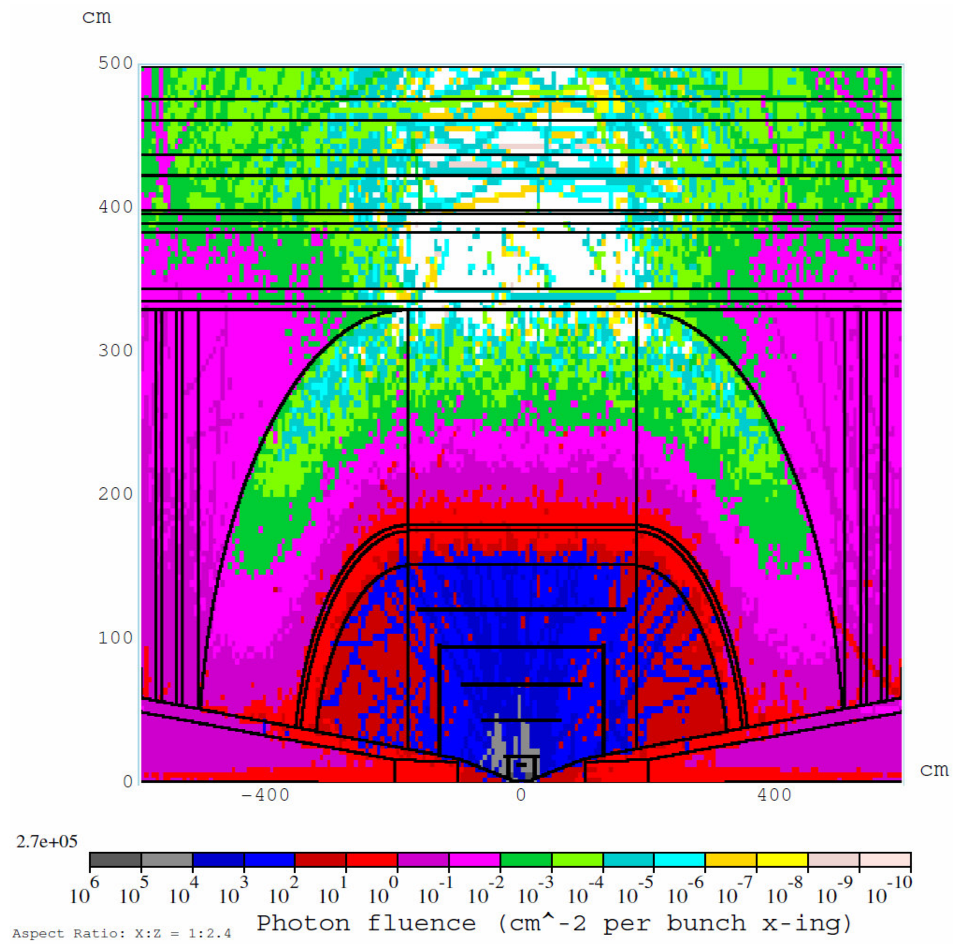
- **Neutron and Photon Fluences**

Neutron peak/yr = 0.1xLHC@10^{34}

Neutrons



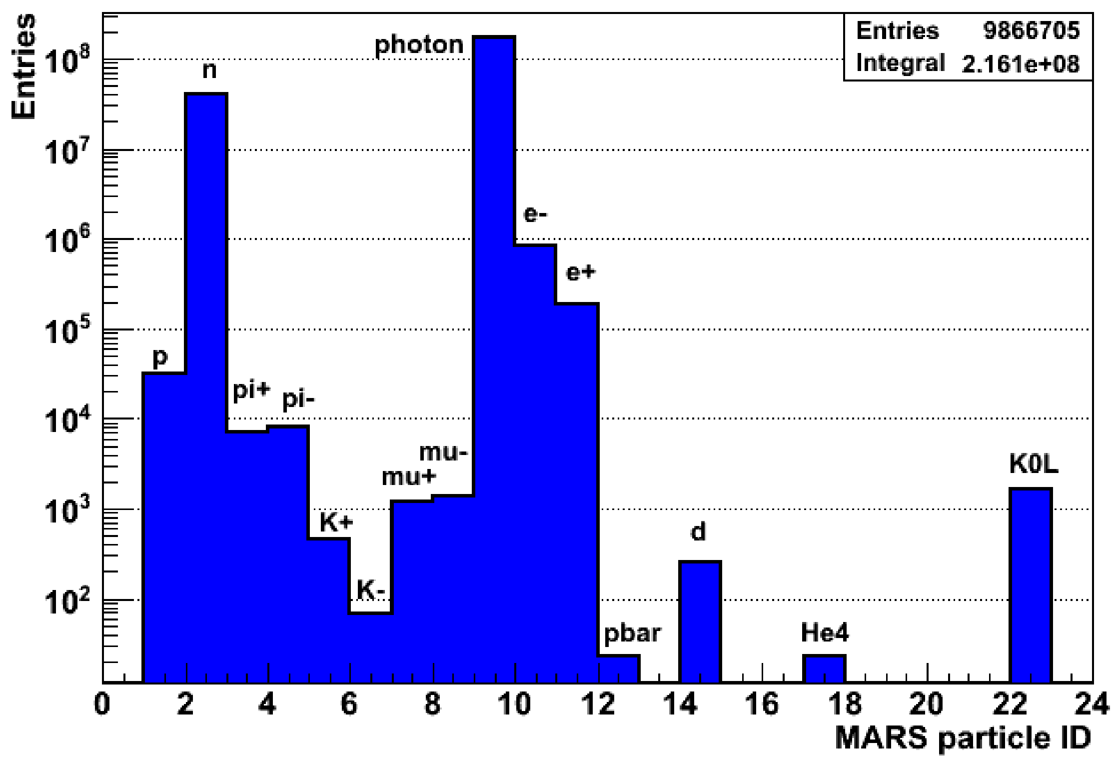
Photons



Recent MARS modeling results

Physics Carnegie Mellon

- MARS particle ID's absolute yields (with weights) on the 10^0 nozzle surface



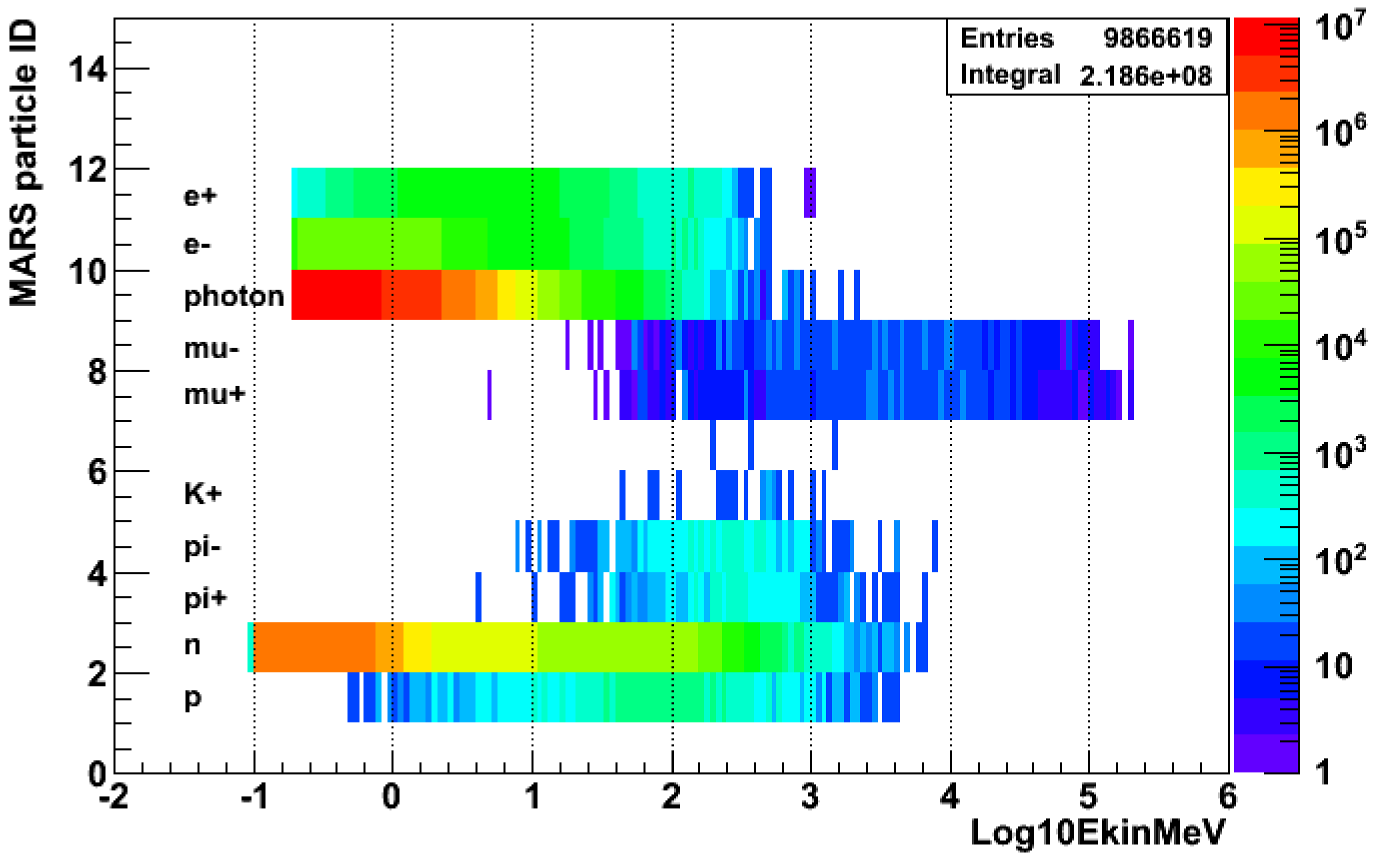
Abs. yields/bunch (E=750 GeV, both beams, 2.0e+12 muons each, L=26 m)

photon	n	e^{+-}	p	π^{+-}	μ^{+-}
1.77e+08	0.40e+08	1.03e+06	3.13e+04	1.54e+04	0.26e+04*

* for "short range" source, 0.82e+04 if "long range" source is added

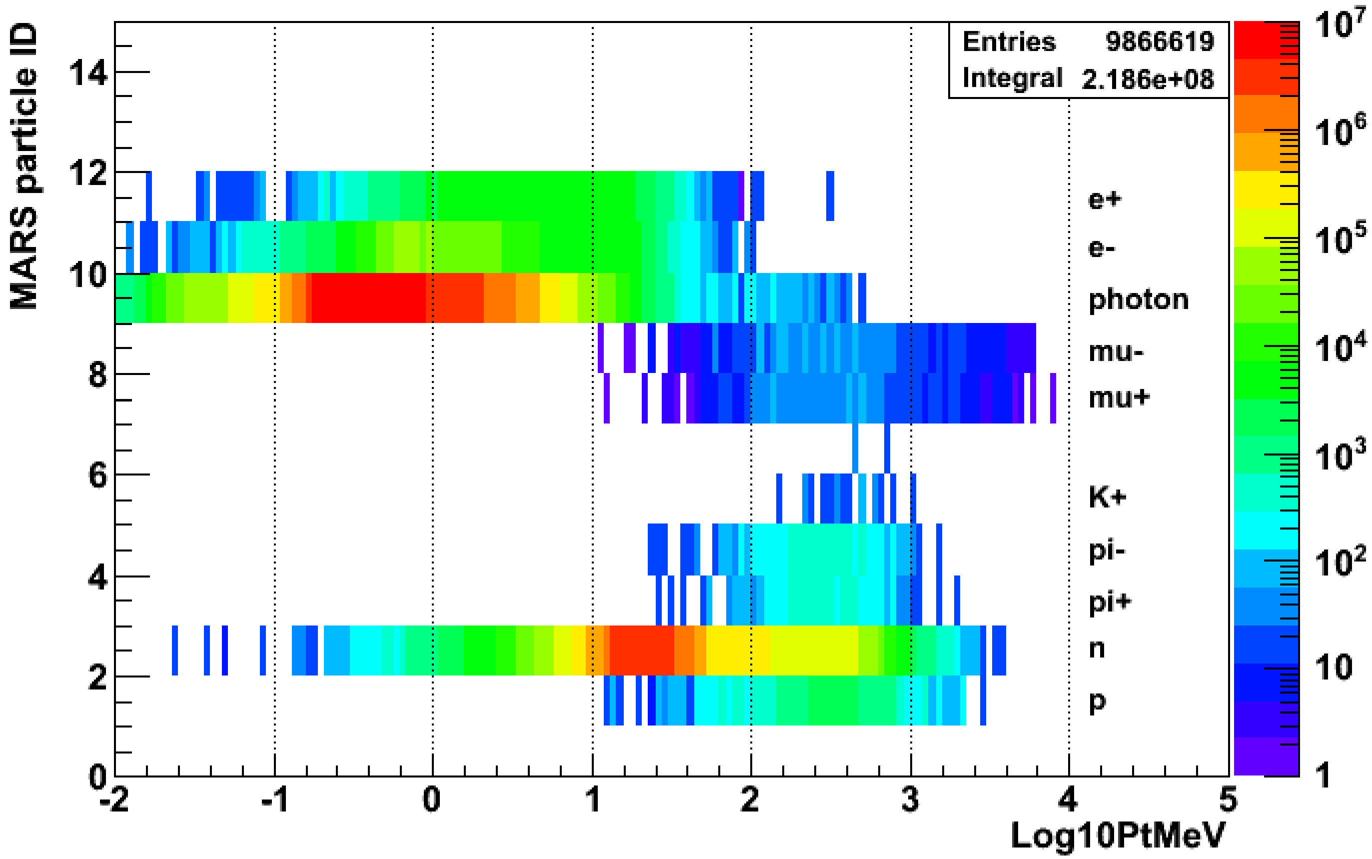
Recent MARS modeling results

- **MARS particle ID and E_{kin} (weights included, 10^0 nozzle, "short range" source)**



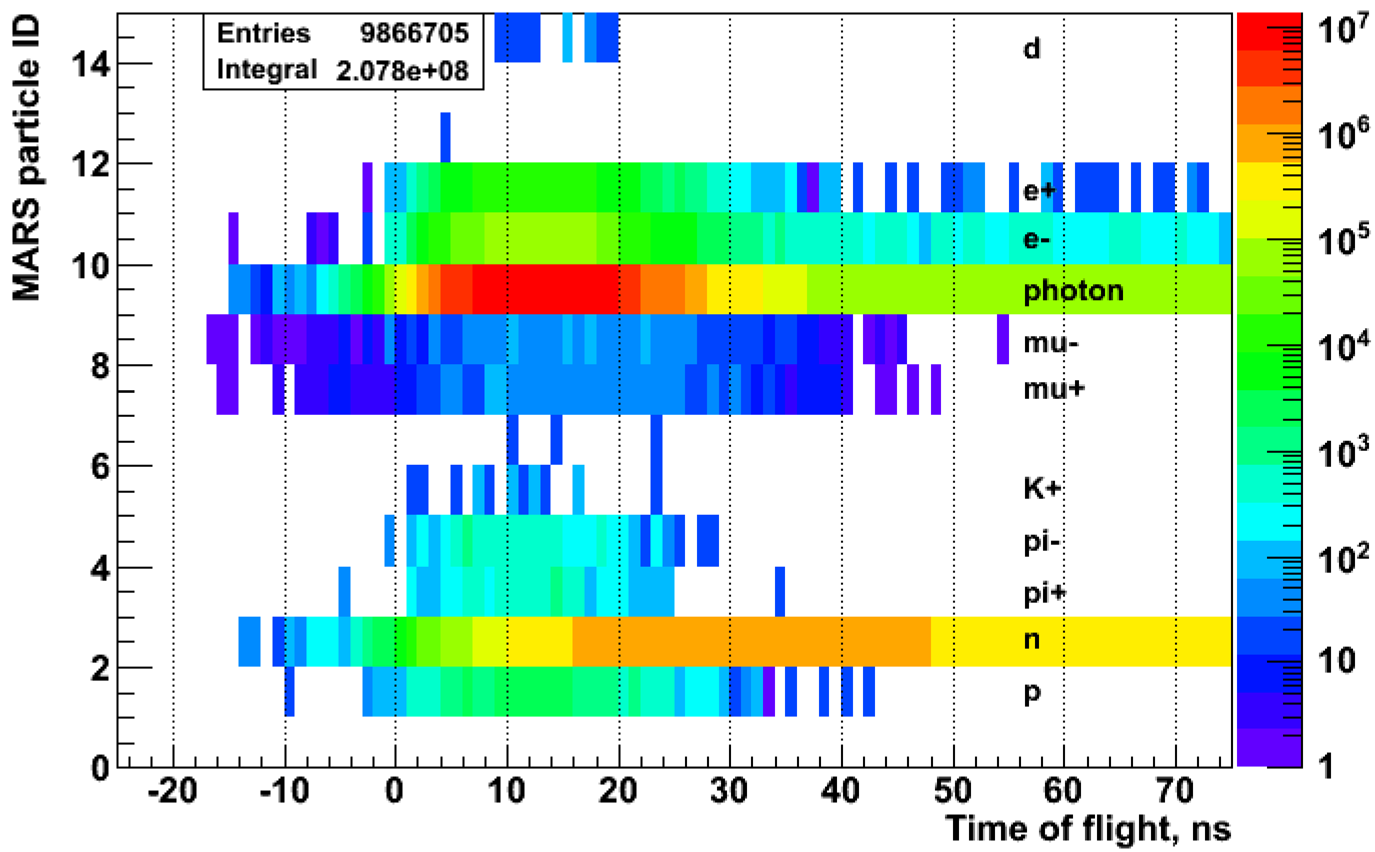
Recent MARS modeling results

- **MARS particle ID and P_t (weights included, 10^0 nozzle, "short range" source)**



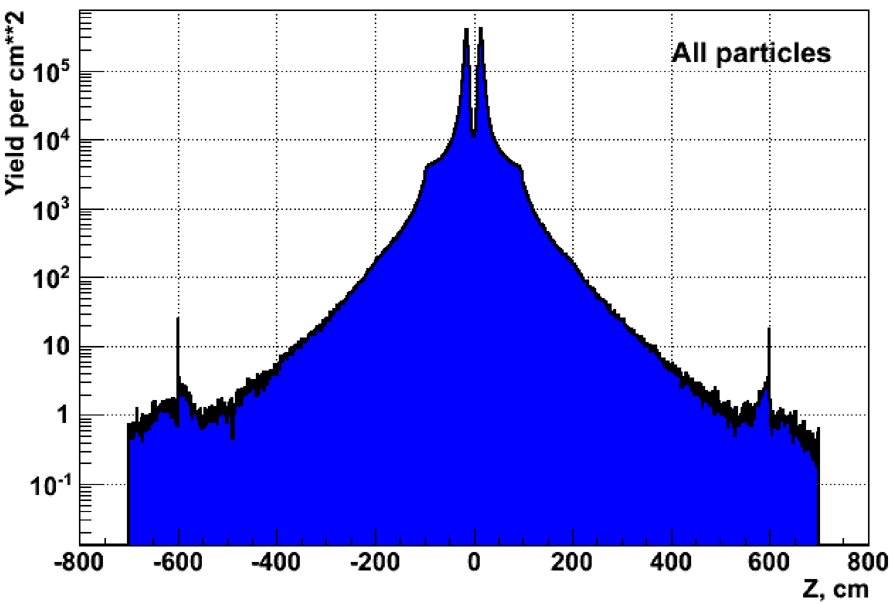
Recent MARS modeling results

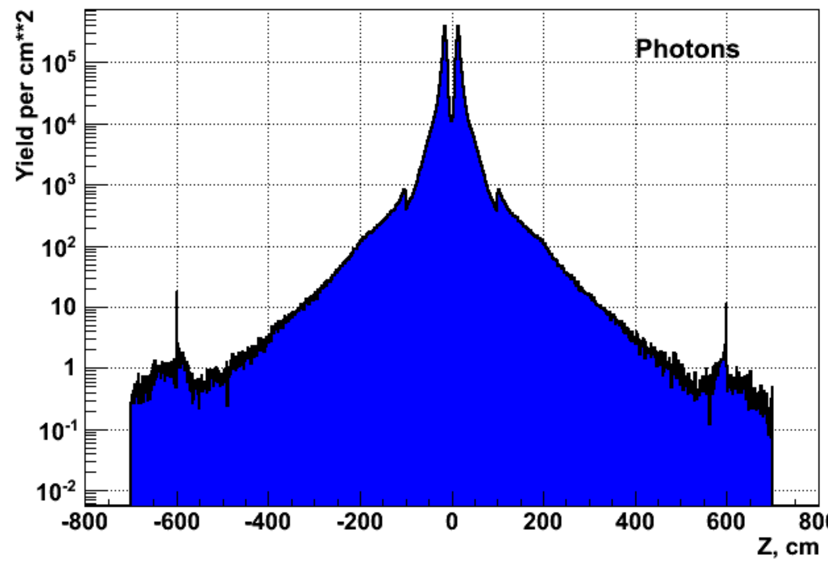
- **MARS particle ID and TOF (weights included, 10^0 nozzle)**
  - Time of flight (TOF) wrt. bunch crossing time
  - 0 <= TOF <= 25 ns for
    ~21% of neutrons (~ 5 times reduction if use timing),
    ~76% of muons (from "short range" source), >94% of other particles

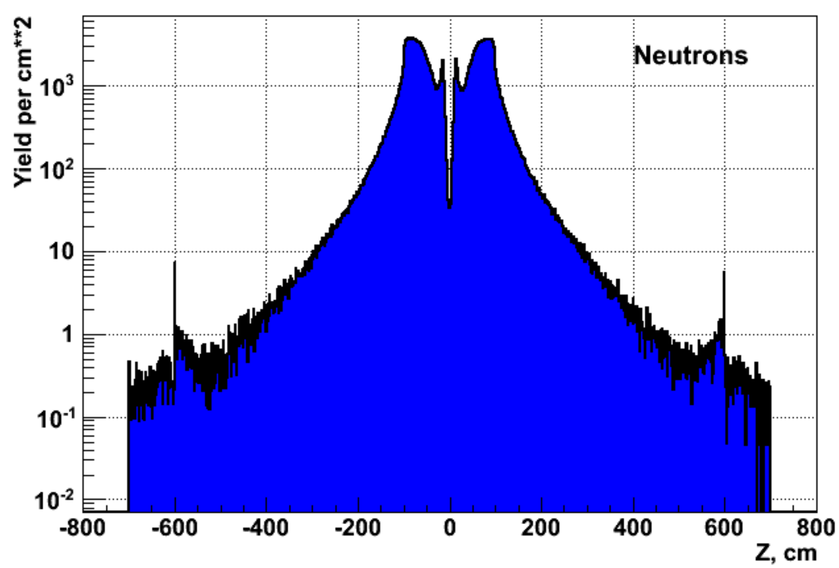


Recent MARS modeling results

- **MARS particles flux per bunch vs. Z (on the 10^0 nozzle surface), weights included, "short range" source**







ILCroot status and development (from C. Gatto, INFN)

ILCroot: root Infrastructure for Large Colliders

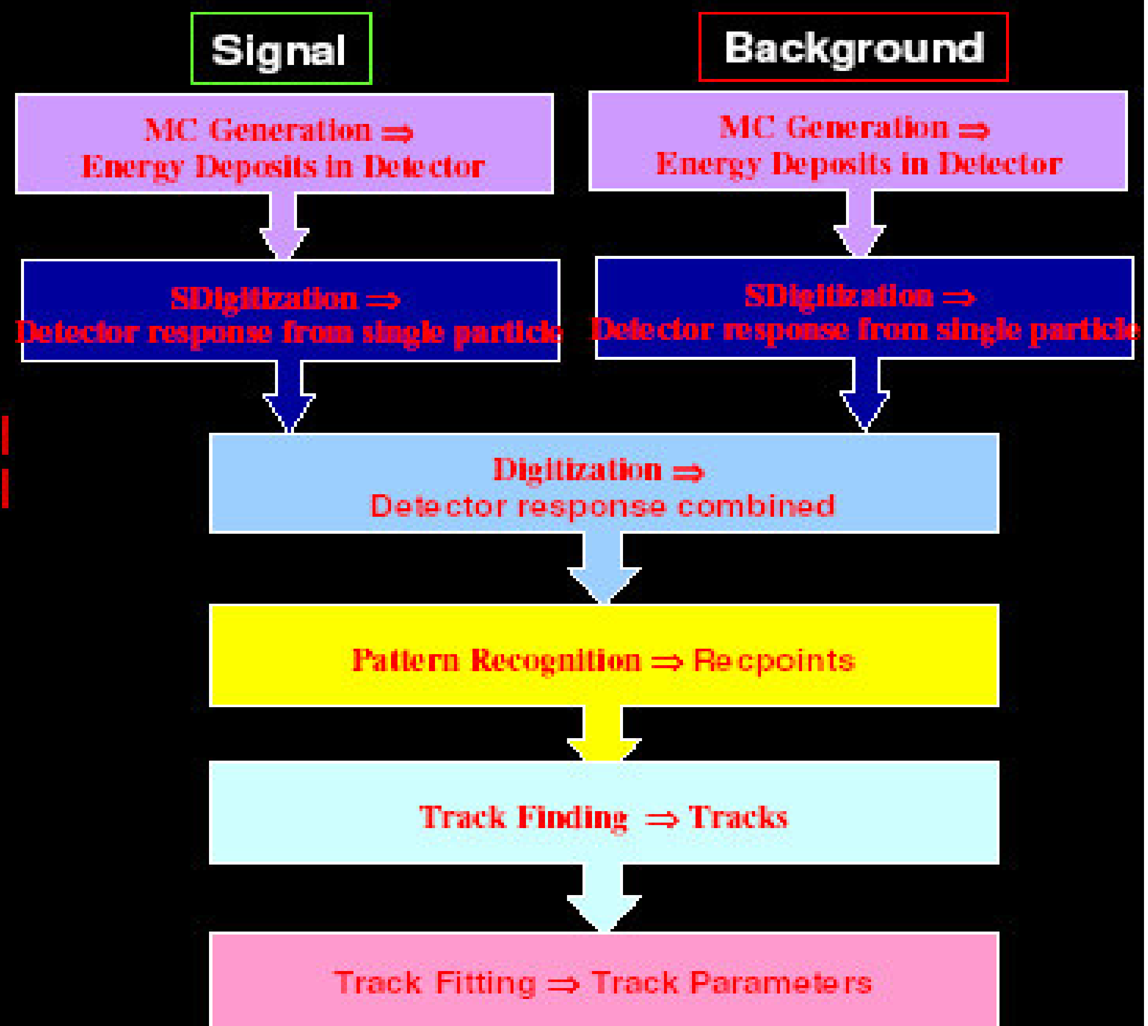
- Software architecture based on root, VMC & Aliroot
  - All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)
  - Extremely large community of users/developers
- Re-allignement with latest Aliroot version every 1-2
- It is a simulation framework <u>and</u> an Offline Systems:
  - 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
- <u>*It is Publicly available at FNAL on ILCSIM since 2006*</u>

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

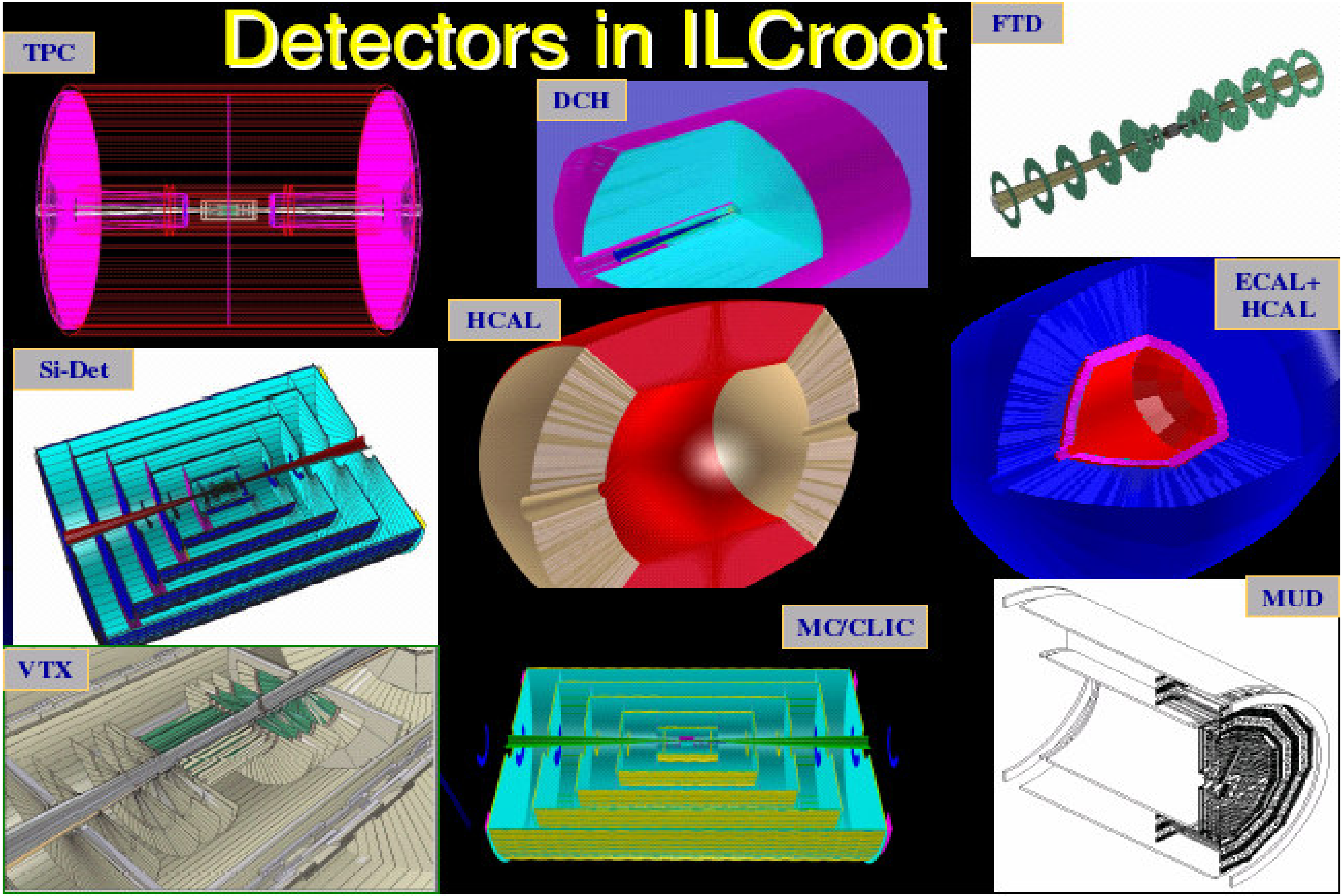
Processing Flow of Full Simulation: detector hits + digitization + reconstruction

- Hits: produced by MC (G3,G4,Fluka)
- SDigits: simulate detector response for each hit
- Digits: merge digit from several files of SDigits (example Signal + Beam Bkgnd)
- Recpoints: Clusterize nearby Digits
- Pattern recognition + track fit through full Parallel Kalman Filter



ILCroot status and development (from C. Gatto, INFN)

Physics Carnegie Mellon



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

ILCroot status and development

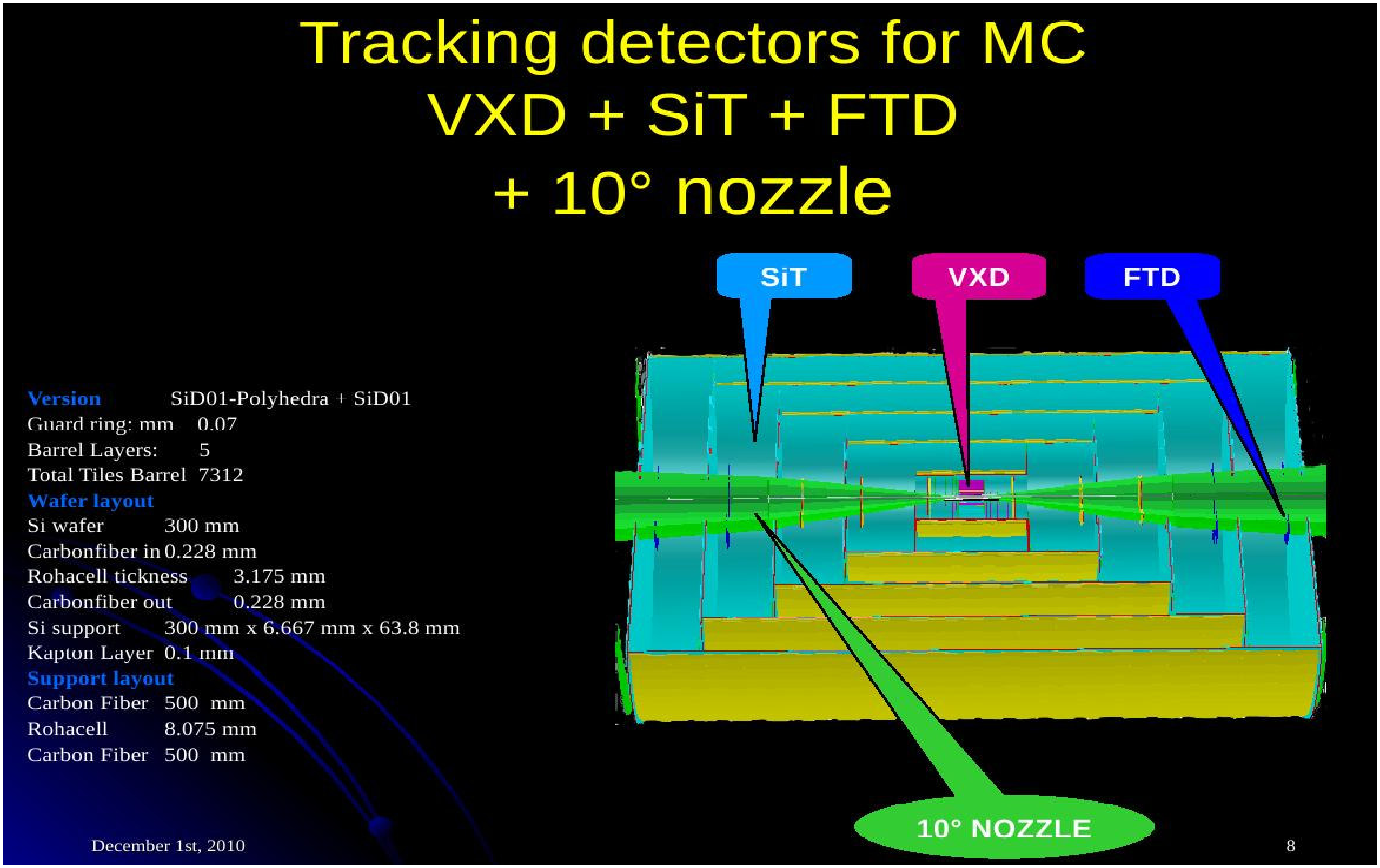
- **Status of ILCroot simulation of physics events and MARS background in detector (INFN/Fermilab/CMU)**
  - **“ILCroot - software infrastructure for Large Colliders based on ROOT and add-ons for Muon Collider studies”, C. Gatto,** (http://indico.fnal.gov/conferenceDisplay.py?confId=3634)
  - **"Preliminary studies of the production of a single Z0 in a fusion process using ILCroot", V. Di Benedetto,** (http://indico.fnal.gov/conferenceDisplay.py?confId=3727 http://indico.fnal.gov/conferenceDisplay.py?confId=3887)
  - **"Tracking in ILCroot with different nozzles", A. Mazzacane,** (http://indico.fnal.gov/conferenceDisplay.py?confId=3750)
  - **"ILCroot CLICCT Tracker Hits for Latest MARS Simulations", N. Terentiev,** (http://indico.fnal.gov/conferenceDisplay.py?confId=3996)

ILCroot CLICCT hits for MARS background

- Looking at CLICCT (CLICCT = VXD + SiT + FTD) response to ID specific particles:
  - Goals
    - What fractions of photons, neutrons and e^+e^- make hits in sensitive volumes of CLICCT?
    - Their P_{tot} and P_t dependence?
  - Limited statistics MARS ROOT files were prepared having only ID specific background particles from both muon beams
    - Photons - 1M (~0.5% of MARS photons full statistics)
    - Neutrons - 1M (~2.5%)
    - e^+e^- - 0.046M (~5%)
  - Run ILCroot simulation on grid for these samples (use no weights)
    - Use official layout of CLICCT
    - Ignore the fact that MARS simulation is made for 10^0 nozzle while official ILCroot version is using 6^0 nozzle (impact of CLICCT/nozzle overlap is minor)

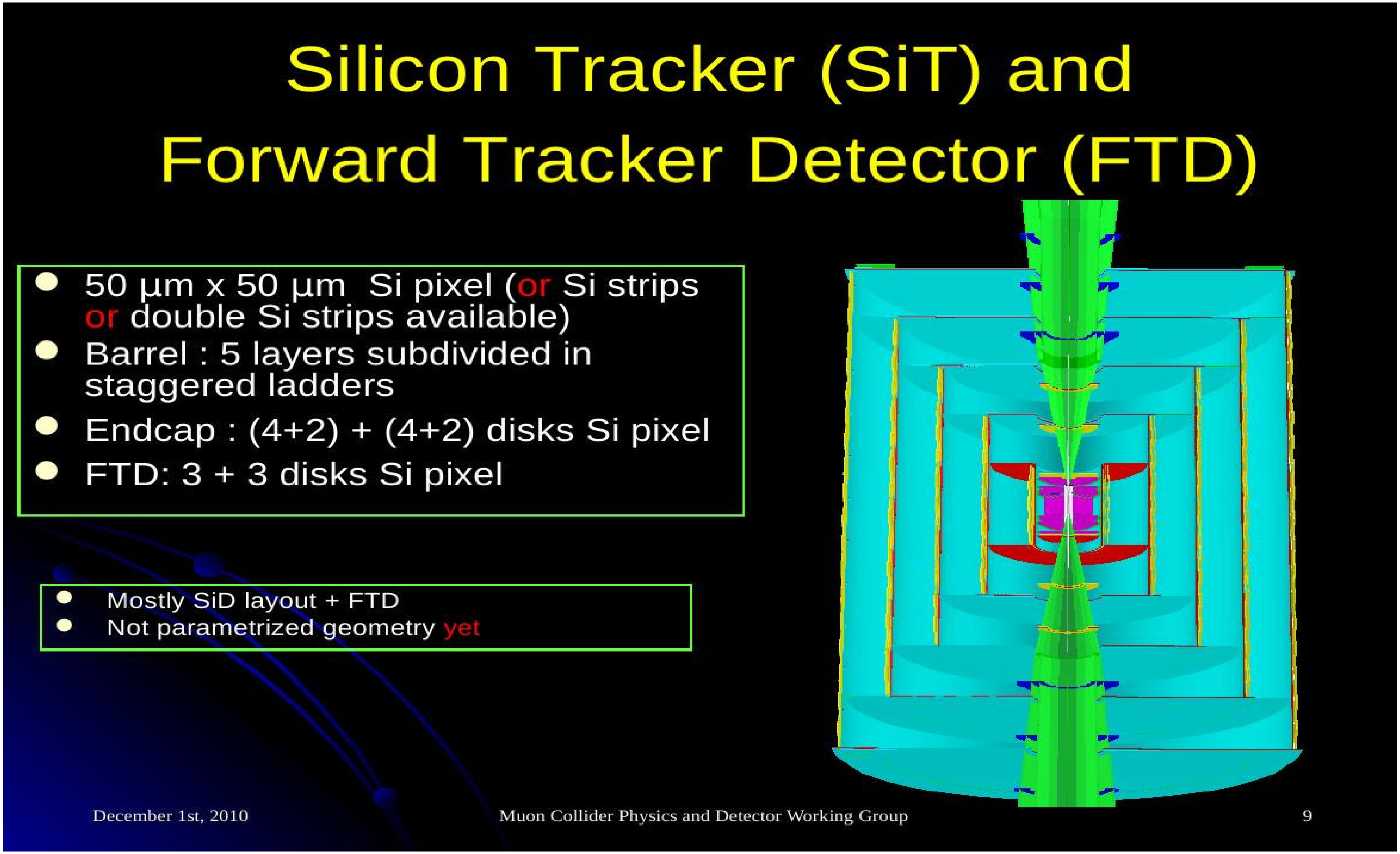
ILCroot CLICCT hits for MARS background

- **Tracking detectors layout (CLICCT = VXD + SiT + FTD) + 10° nozzle (from A. Mazzacane)**



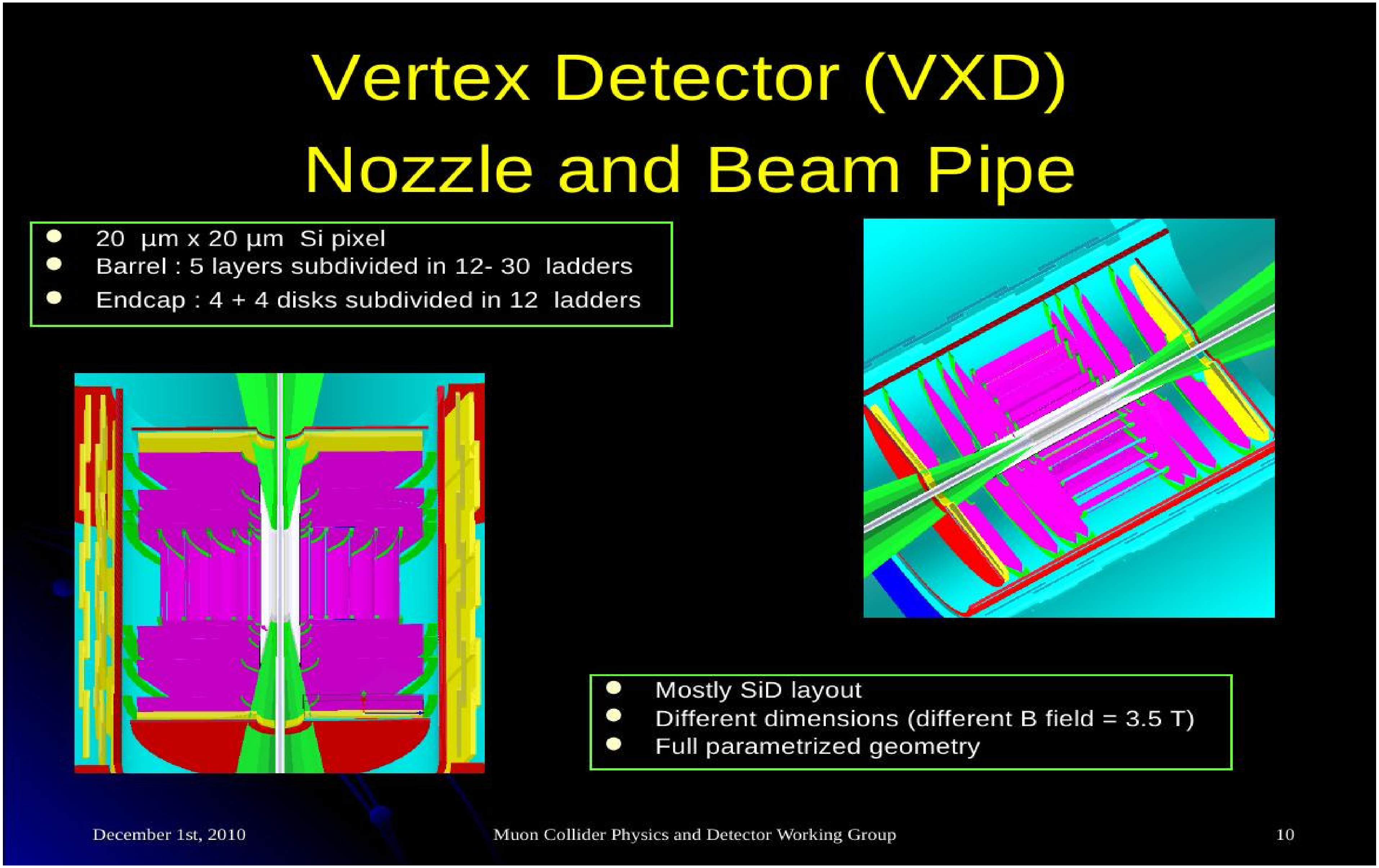
ILCroot CLICCT hits for MARS background

- **Silicon Tracker (SiT) and Forward Tracker Detector (FTD) (from A. Mazzacane)**



ILCroot CLICCT hits for MARS background

- **Vertex Detector (VXD), Nozzle and Beam Pipe (from A. Mazacanne)**

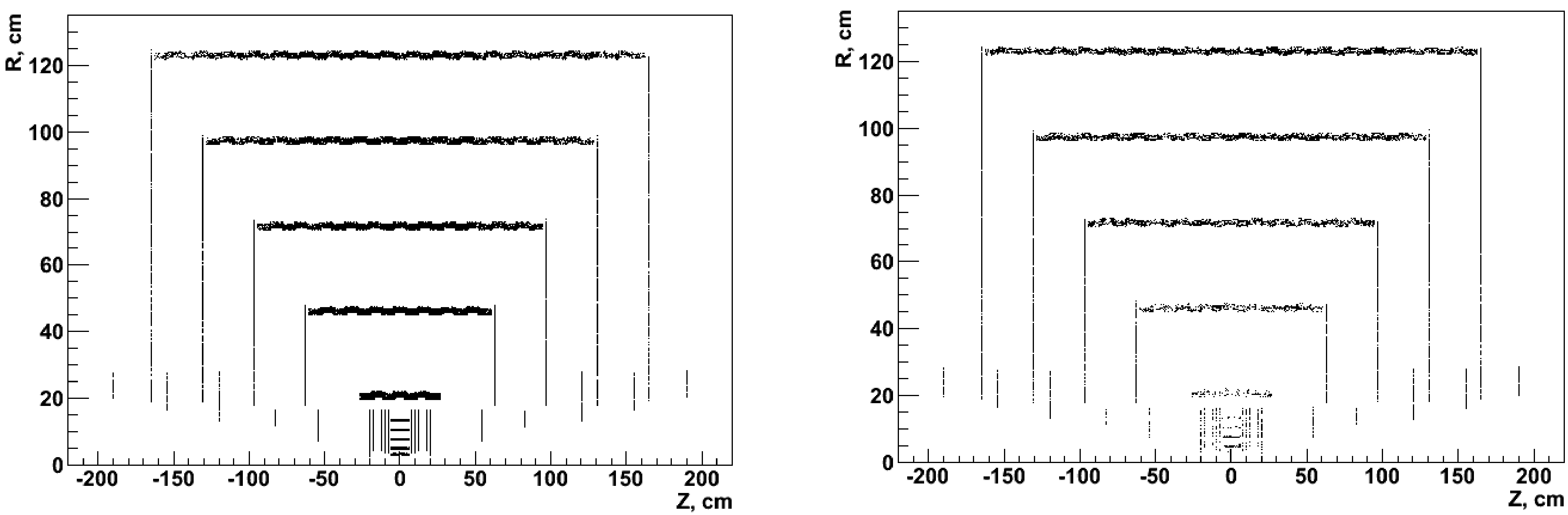


ILCroot CLICCT hits for MARS background

- **Hits from photons and neutrons in sensitive volumes of CLICCT**

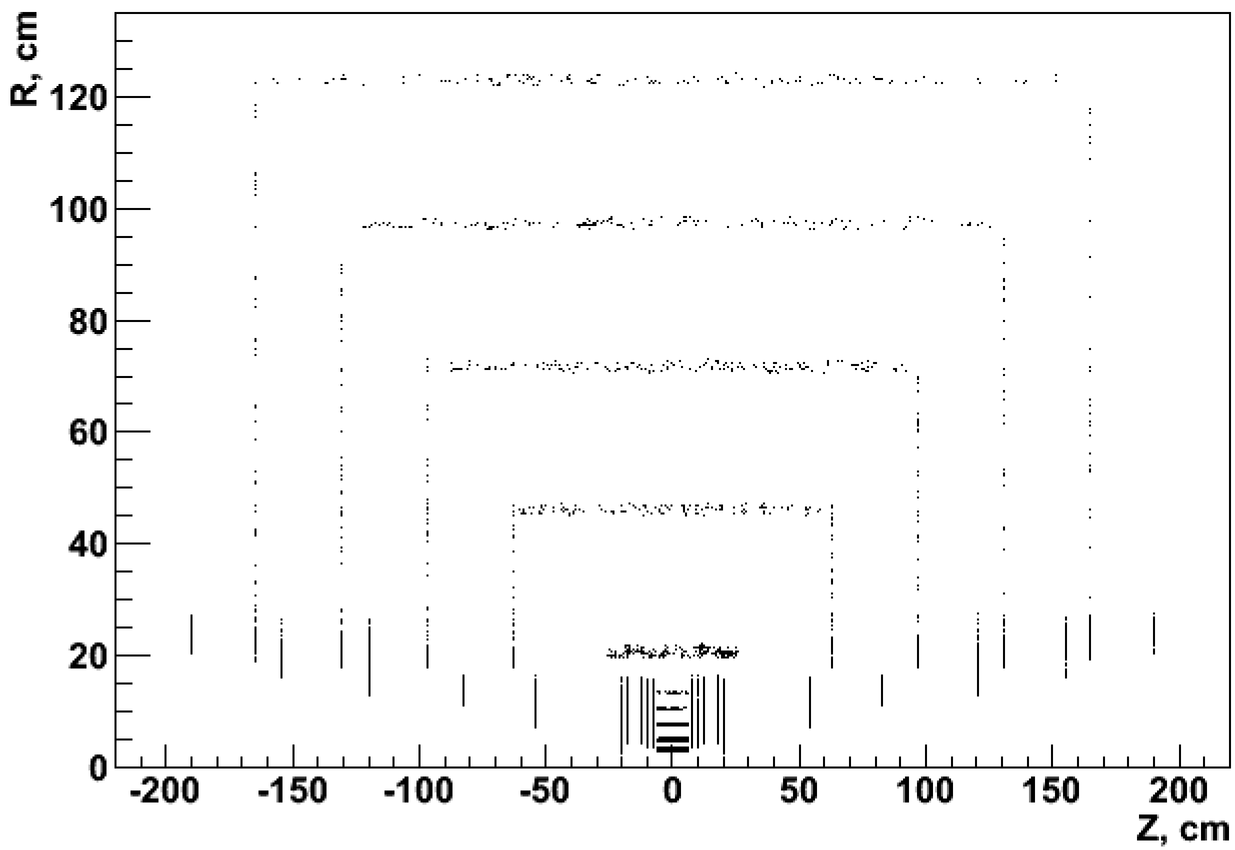
Z and R coordinates of the hits from the secondary particles produced by photons

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



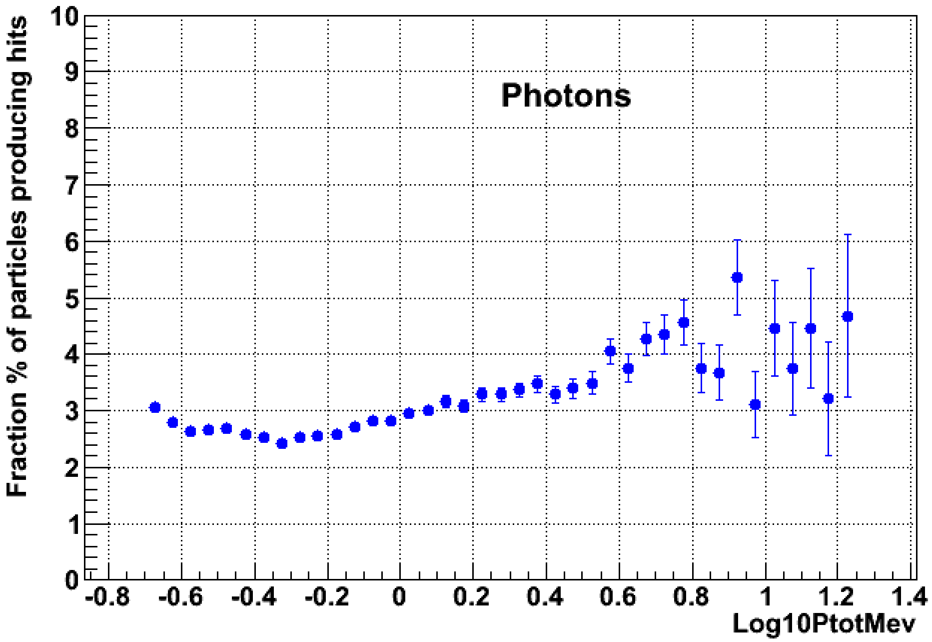
ILCroot CLICCT hits for MARS background

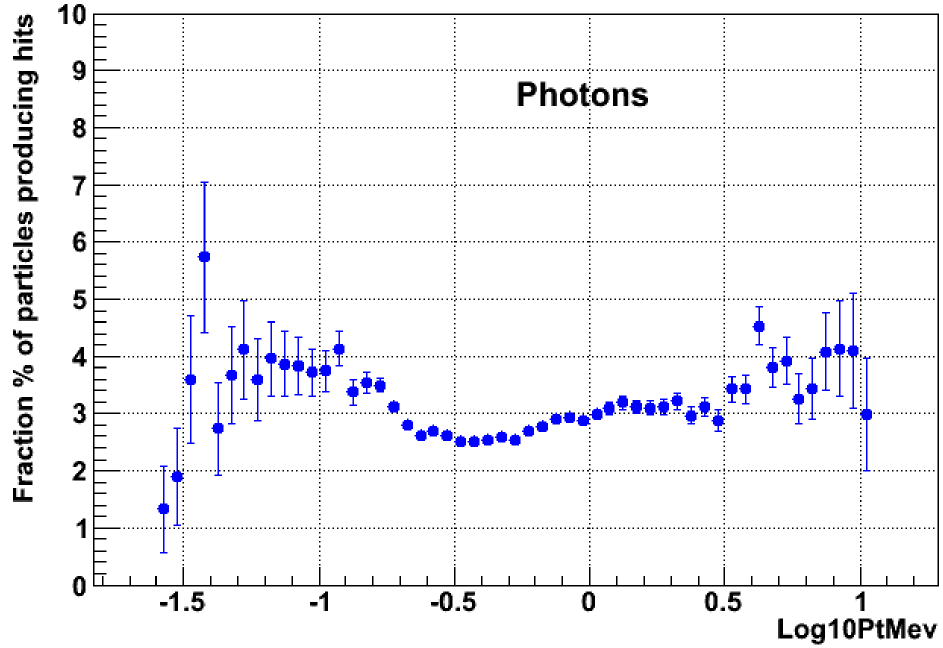
- **Hits from e^+e^- in sensitive volumes of CLICCT**
  - **Most of the hits in first layers of VXD (magnetic field 3.5T)**



ILCroot CLICCT hits for MARS background

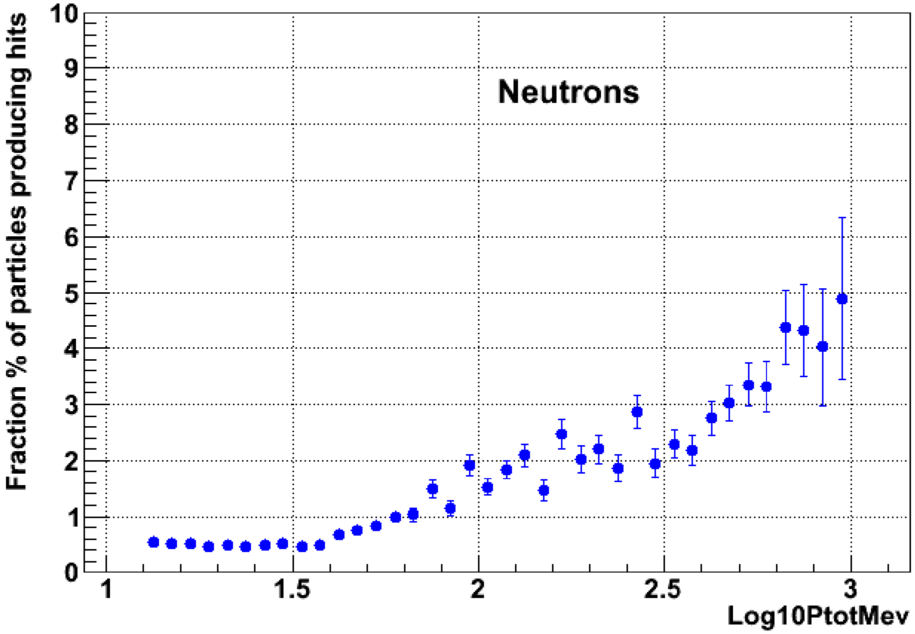
- **Fraction of photons producing hits vs. P_{tot} and P_t (through secondary particles)**

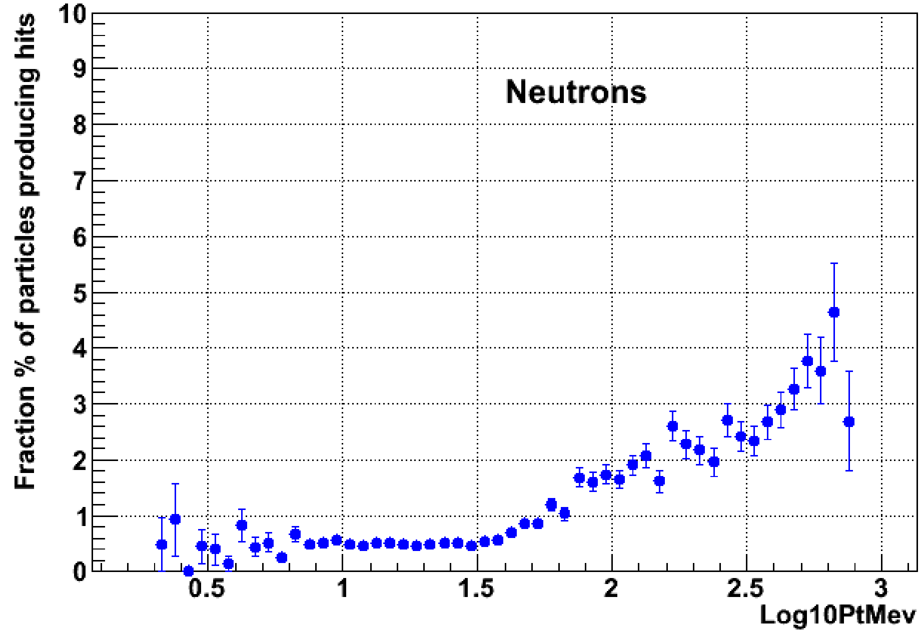




ILCroot CLICCT hits for MARS background

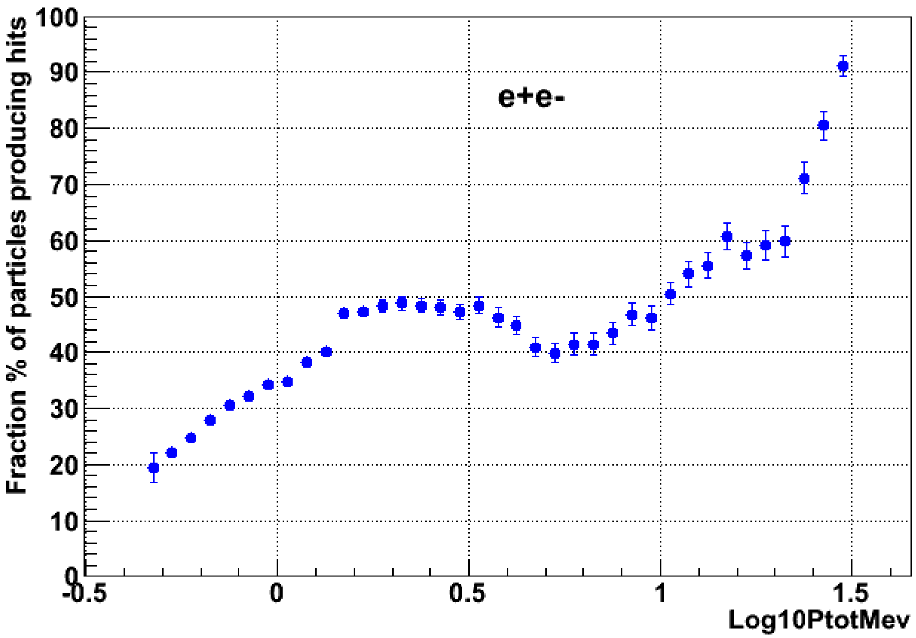
- **Fraction of neutrons producing hits vs. P_{tot} and P_t (through secondary particles)**

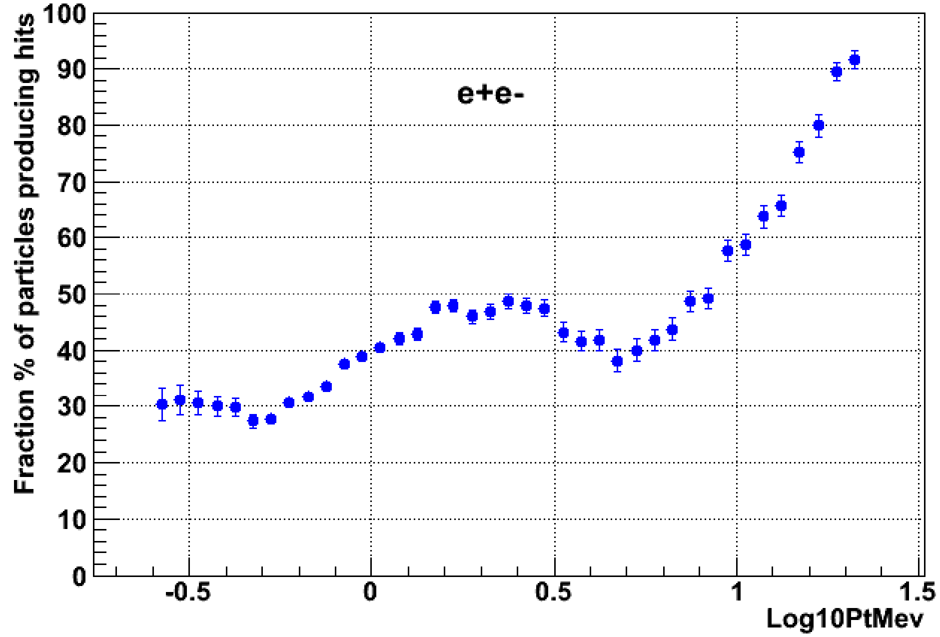




ILCroot CLICCT hits for MARS background

- **Fraction of e^+e^- producing hits vs. P_{tot} and P_t**





ILCroot CLICCT hits for MARS background

- Fractions of photons, neutrons and e^+e^- making hits in sensitive volumes of CLICCT

	photons	neutrons	e^+e^-
Absolute MARS yields, # of particles (weight included, both beams)	1.77e+08	0.40e+08	1.03e+06
Fraction of particles producing hits in CLICCT sensitive volumes	~2.8%	~0.6%	~43%
# of MARS particles "seen" by CLICCT	5.0e+06	0.24e+06	0.44e+06

- Photons Ekin ~ 0.2 – 100 MeV
  Neutrons Ekin ~ 0.1 – 1000 MeV
  e^+e^- Ekin ~ 0.2 – 100 MeV

Merging MARS background with muon physics events

- Before to start ALL statistics background simulation in ILCroot and merge it with physics events
  - Do it step by step, start from small background samples, 1e+05 and 1e+06 particles
  - Merge them with physics events with 10 μ per event
  - Look at muon track reconstruction efficiency in CLICCT vs. background level
- Made successful attempt to merge 1e+05 sample of MARS background (all IDs) with one physics event (10 μ per event) in ILCroot
- The reconstruction code was successfully run for one 10 μ event merged with MARS 1e+05 background

Conclusion

- **MARS15 model for realistic IR magnets design and optimized shielding**
  - Encouraging results on 0.75-TeV beams MC detector backgrounds with 10^0 shielding nozzle
  - Breakthrough in reduction of statistical weight spread
  - New high-statistics files are available
- **ILCroot simulation, reconstruction and analysis framework available at Fermilab**
  - It allows merging of signal and background event
  - Reconstruction of tracks (full Parallel Kalman Filter) and showers in calorimeter
  - Work on ILCroot specific for Muon Collider is in progress
  - New interface to MARS is working smoothly for Muon Collider studies

Conclusion

- **The latest MARS background samples for photons, neutrons (with statistics ~1M) and e^{+-} (~0.05M) were simulated in ILCroot for CLICCT (tracker and vertex detectors)**
  - **The fractions of background particles producing hits in sensitive volume of CLICCT were found to be:**
    photons ~ 2.8%,
    neutrons ~ 0.6%
    e^{+-} ~ 43%
- **Successful attempt was made to merge MARS background and physics event and reconstruct the muon tracks in CLICCT**
- **Plan:**
  - **Work on analysis of merged data to get muon track reconstruction efficiency vs. MARS background level**

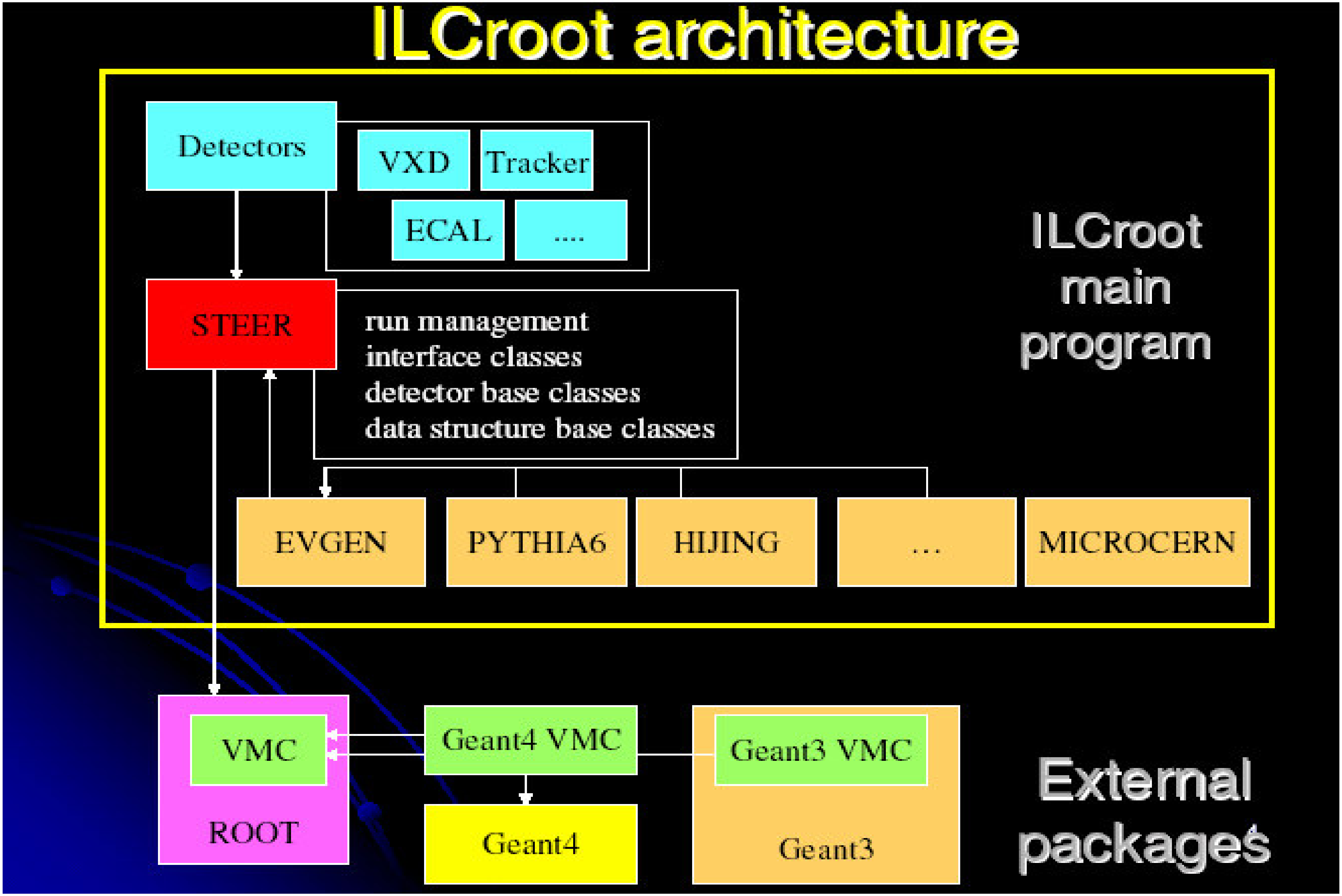
Backup slides

ILCroot: essential add-ons to Aliroot

1. Interface to external files from Event Generators in various format (STDHEP, text, ***MARS***, etc.)
2. Standalone VTX track fitter
3. Pattern recognition from VTX (for Si central trackers)
4. Track fitters for different trackers technologies (Si Pixels, Si Strips, Drift Chambers, Straw Tubes, TPC's) and a ombination of them
5. Full simulation of ***Dual Readout calorimeters***
6. Parametric beam background (# integrated bunch crossing chosen at run time)

Very important for detector and Physics studies of New Projects

Growing number of experiments have adopted it: Alice (LHC), Opera (LNGS), (Meg), CMB (GSI), Panda (GSI), 4th Concept, (SiLC ?) and LHeC


ILCroot architecture
Detectors
VXD
Tracker
ECAL
....
STEER
run management
interface classes
detector base classes
data structure base classes
ILCroot main program
EVGEN
PYTHIA6
HIJING
...
MICROCERN
VMC
ROOT
Geant4 VMC
Geant4
Geant3 VMC
Geant3
External packages

Physics Carnegie Mellon

14 Detectors in ILCroot + 12 from Alice

Detector	Layouts	Digit./Cluster.
VXD (SIDMay06)	1 (parametric)	Full
FTD (SiLC)	1	Full
DCH (CluCou)	2	Gauss Smear.
TPC (Hybrid readout)	1	Gauss. Smear.
Si-Tracker (SID01-Polyhedra)	1+1	Full
μCollider/CLIC Tracker	1	Full
Hadron Calorimeter	2	Full
ADRIANO Calorimeter	1	Full
EM Calorimeter	2	Full
Muon Spectrometer (straw tubes)	1	Gauss. Smear.

NEW