A hit timing and double layer criteria for MARS muon collider background reduction in ILCRoot simulation

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Outline

- **Introduction**
- **Timing for MARS background particles and ILCRoot hits** (neutron contribution from previous BX)
- **ILCRoot new release with double layer geometry and new IP muons and MARS background simulation**
- **IP muons analysis**
- **Conclusion**

Introduction

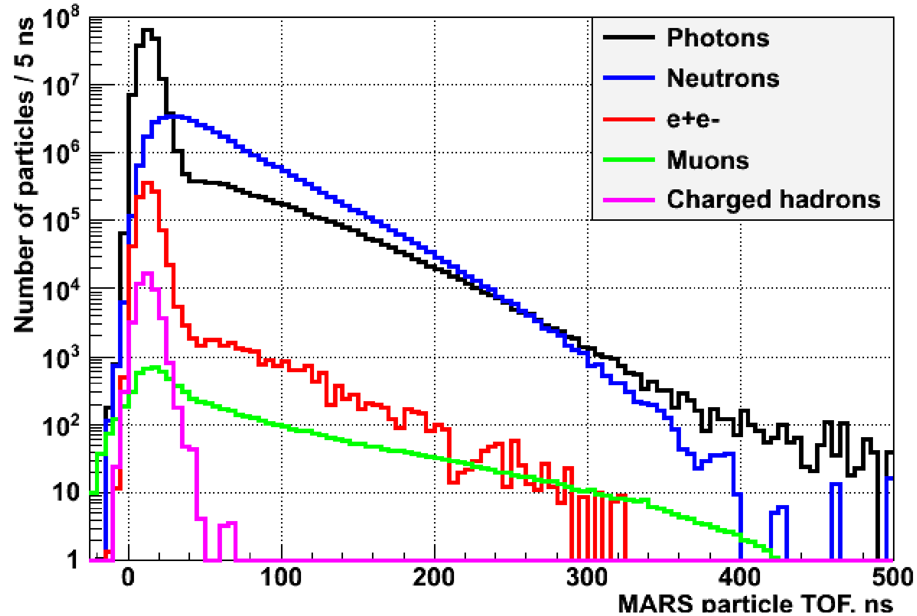
- **Working with MARS background simulation results for (750 + 750) GeV $\mu^+ \mu^-$ beams with $2*10^{12}$ muons/bunch each**
  - http://www-ap.fnal.gov/~strigano/mumu/mixture/
  - Background yields/bunch on 10^0 nozzle surface and MARS thresholds

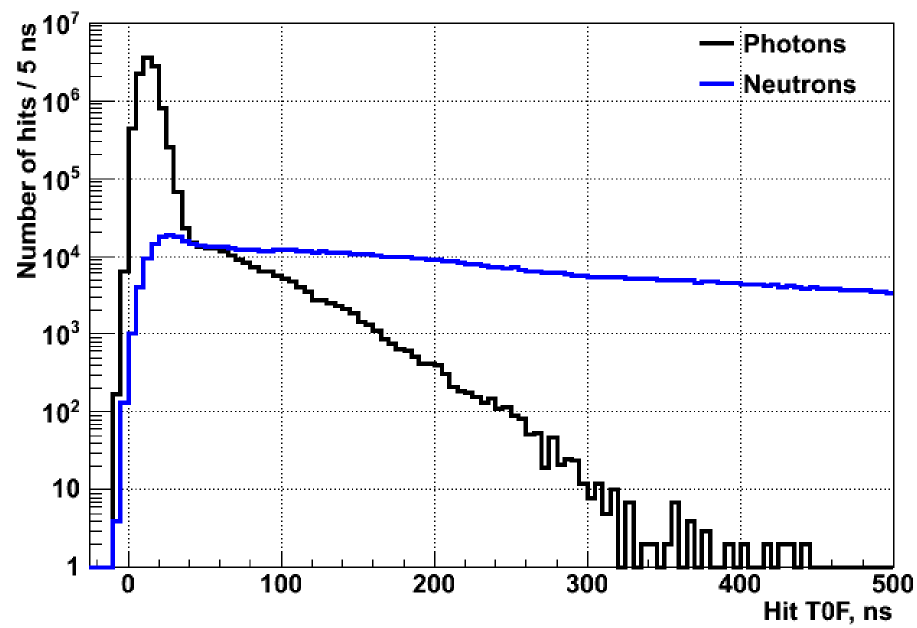
	γ	n	e^{+-}	p	π^{+-}	μ^{+-}
Yield	**1.77e+08**	**0.40e+08**	**1.03e+06**	**3.13e+04**	**1.54e+04**	**0.80e+04**
Ethr, MeV	**0.2**	**0.1**	**0.2**	**1.0**	**1.0**	**1.0**

- **All MARS statistics (full bunch crossing, weights included) was used as input for ILCRoot simulation of the Si vertex and tracker hits.**
  - Timing results are based on previous ILCRoot_2.9.1 release simulation with GEANT4 (4.9.4.p01) – single Si layers, 100 microns thick
  - ILCRoot output files with hits were analyzed in standing alone code

Timing

- **Timing for MARS background particles and ILCRoot hits**
  - MARS background is within ~500 ns w.r.t. a bunch crossing (BX)
  - ILCRoot VXD and Tracker hits in the same interval except hits from neutrons
  - Neutron hits tail up to 20 ms
  - Contribution of neutron hits from 10 microsec apart previous bunch crossings is small (~4%) in interval of 0 -150 ns, no impact on timing cut





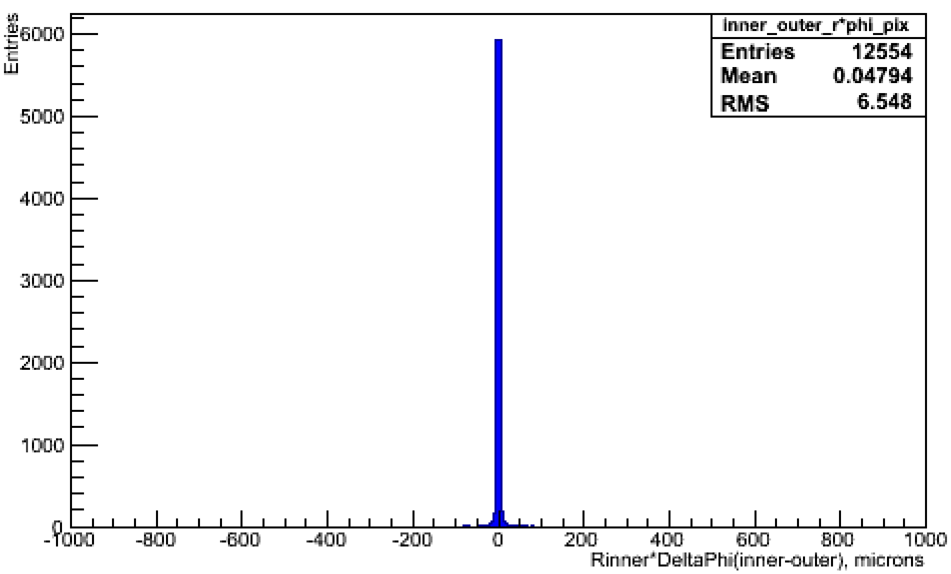
ILCRoot release with double layer geometry

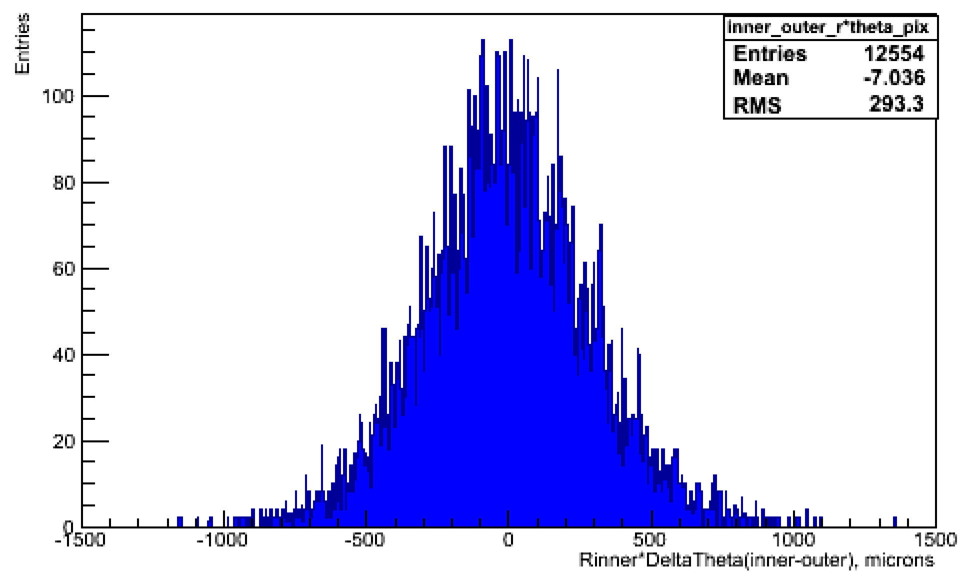
- **A new version of ILCRoot was released on Nov. 29, 2011 by Vito Di Benedetto (INFN-Lecce)**
  - ILCrootMuXDetV3 has new ROOT,GEANT4 and VMC packages
  - Implementation of double layer geometry (two sub-layers in each layer) in the Si Vertex and Tracker detectors with runtime controlled parameters
  - Now ILCRoot is capable of simulating a realistic double layer geometry with ~mm interlayer distance and magnetic field scaling
- **A new ILCRoot simulation for IP muons and MARS muon collider background was done with following geometry:**
  - Only VXD and Tracker
  - 1 mm and 2 mm sub-layer space with 3.5 T and 7 T magnetic field (4 geometry sets), each Si sub-layer is 200 microns thick
  - IP mu+ and mu- in 4 geometry sets
    - at P=0.2 - 100 GeV/c
    - IP smearing in Z (gauss sigma = 1 cm) and X,Y (gauss sigma 6 microns)
    - total 20,000 muons
  - 3 types of all statistics MARS background (all particles, gamma and neutrons) in 4 geometry sets

IP muons analysis

- **A goal – define and tune the cuts for effective selection of muon hits in both sub-layers of the given layer in VXD and Tracker**
  - Will be used to reduce the MARS muon collider background readout hits occupancy
  - Defined for the hits along one and the same muon track in both sub-layers
  - In R, Phi and Theta calculations set IP to be at XYZ (0,0,0)
- **Phi cut as Rxy * Delta(Phi)**
  - Rxy is the radius of the hit position in XY in inner sub-layer
    Delta(Phi) = Phi(inner-outer) for azimuthal angles of the hits in inner and outer sub-layers
  - Rxy * Delta(Phi) distribution depends on Pt
- **Theta cut as Rxyz * Delta(Theta)**
  - Rxyz is the radius of the hit position in XYZ in inner sub-layer
    Delta(Theta) = Theta(inner-outer) for polar angles of the hits in inner and outer sub-layers
  - Rxyz * Delta(Theta) depends on IP Z smearing
- **Currently set 98% efficiency per cut (resulting in 96% efficiency per muon track in given layer)**

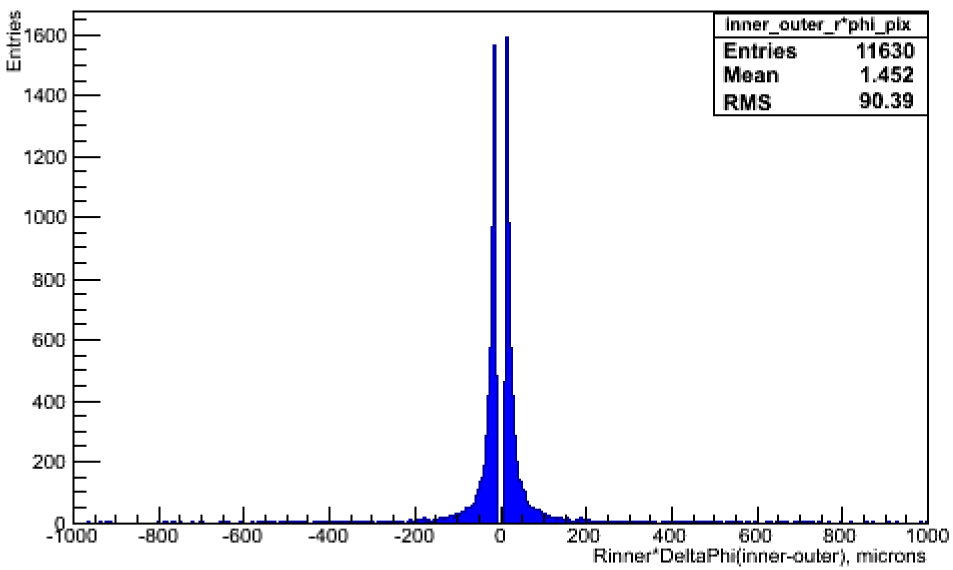
- **Rxy * Delta(Phi) and Rxyz * Delta(Theta) in VXD barrel layer (Rxy~3cm), sub-layer space 1mm, B=3.5T**
- **In barrel layers close to IP:**
  – Small width of Rxy*Delta(Phi) for muons with almost all Pt
  – Large smearing in Rxyz*Delta(Theta) due to impact of Z distribution of IP (gauss sigma 1 cm)

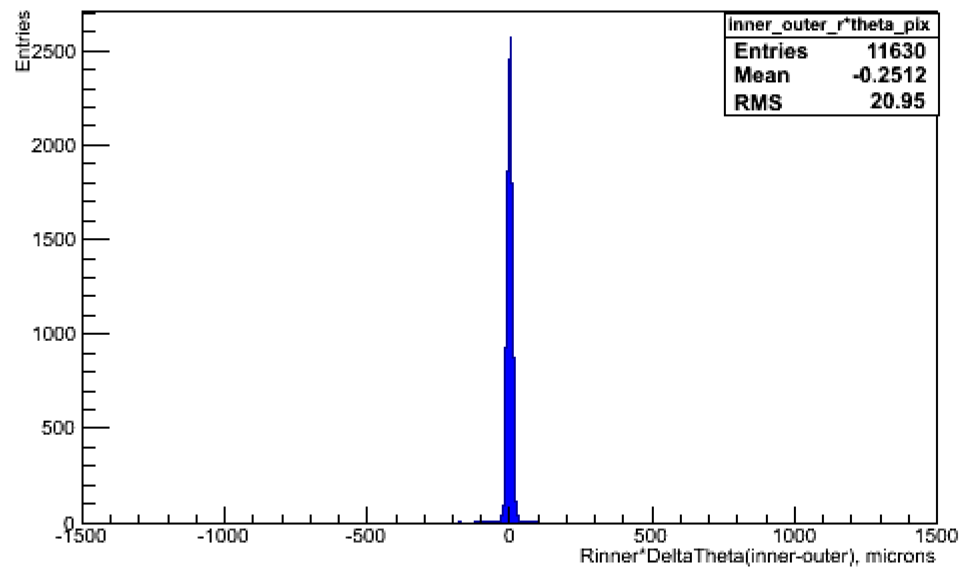




IP muons analysis

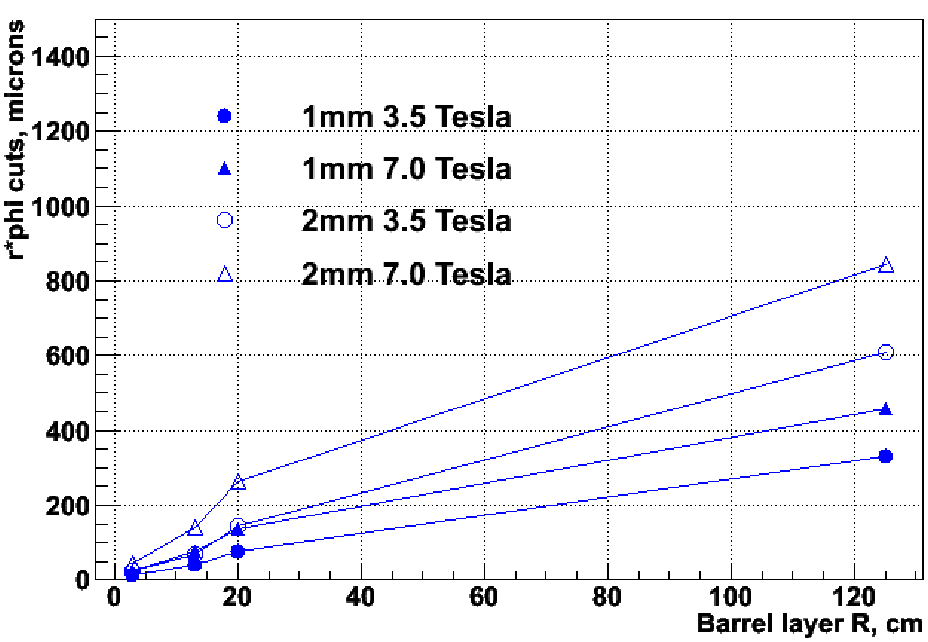
- **Rxy * Delta(Phi) and Rxyz * Delta(Theta) in Tracker barrel layer (Rxy~125cm), sub-layer space 1mm, B=3.5T**
- **In barrel layers far from IP:**
  - Increased width of Rxy*Delta(Phi) for mu+ and mu- with all Pt
  - Small impact of Z smearing in IP on Rxyz*Delta(Theta)

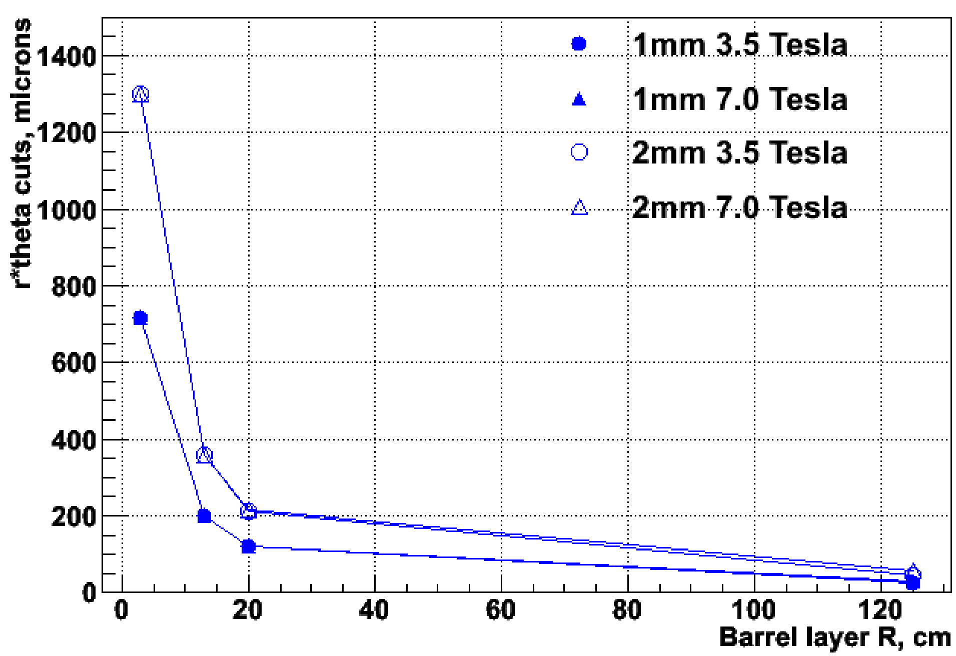




IP muons analysis

- **Rxy*Delta(Phi) and Rxyz*Delta(Theta) cuts vs. barrel radius R at different sub-layer space and magnetic field B**
  - Inner barrel layers require small Rxy*Delta(Phi) and large Rxyz*Delta(Theta)
  - Outer barrel layers require large Rxy*Delta(Phi) and small Rxyz*Delta(Theta)
  - Rxyz*Delta(Theta) cut not sensitive to magnetic field B
  - Different cuts for different barrel layers to keep one and the same IP muon hit efficiency (96% per layer)





Conclusion

- **The IP muons and MARS muon collider background data sets were simulated in new ILCRoot version with double layer geometry and magnetic field scaling**
- **The R*Phi and R*Theta cuts with 96% per layer IP muon hit efficiency were defined for VXD and Tracker barrel layers in 4 geometry sets with 1 and 2 mm sub-layers space and magnetic field of 3.5 and 7 T**
  - Different barrel layers require different cuts
- **To do now (for MAP meeting in SLAC):**
  - Implement these cuts (along with timing cuts) for MARS background hits reduction in at least 1 from 4 geometry sets
- **After that:**
  - Include VXD end caps into analysis
  - Define and try cuts corresponding to 98% muon hit efficiency per layer
  - Add geometry sets with new sub-layer space and magnetic field parameters make new IP muons and MARS background ILCRoot simulation and analysis