# Muon Collider Detector Design


Rohit Agarwal, Simone Pagan Griso,
**Elodie Resseguie**
Berkeley lab


12/10/21

# Introduction

- A muon collider is a promising proposal for a future collider
- Combines the benefits of both hadron and lepton colliders
    - Can reach high energies just like a hadron collider
    - Clean environment like a lepton collider
- Dominant background for muon colliders: beam induced backgrounds
    - Originates from muon decay and subsequent interactions within the detector
- Detector design and subsequent reconstruction in progress to minimize this background

# Detector Design

**detector**

hadronic calorimeter

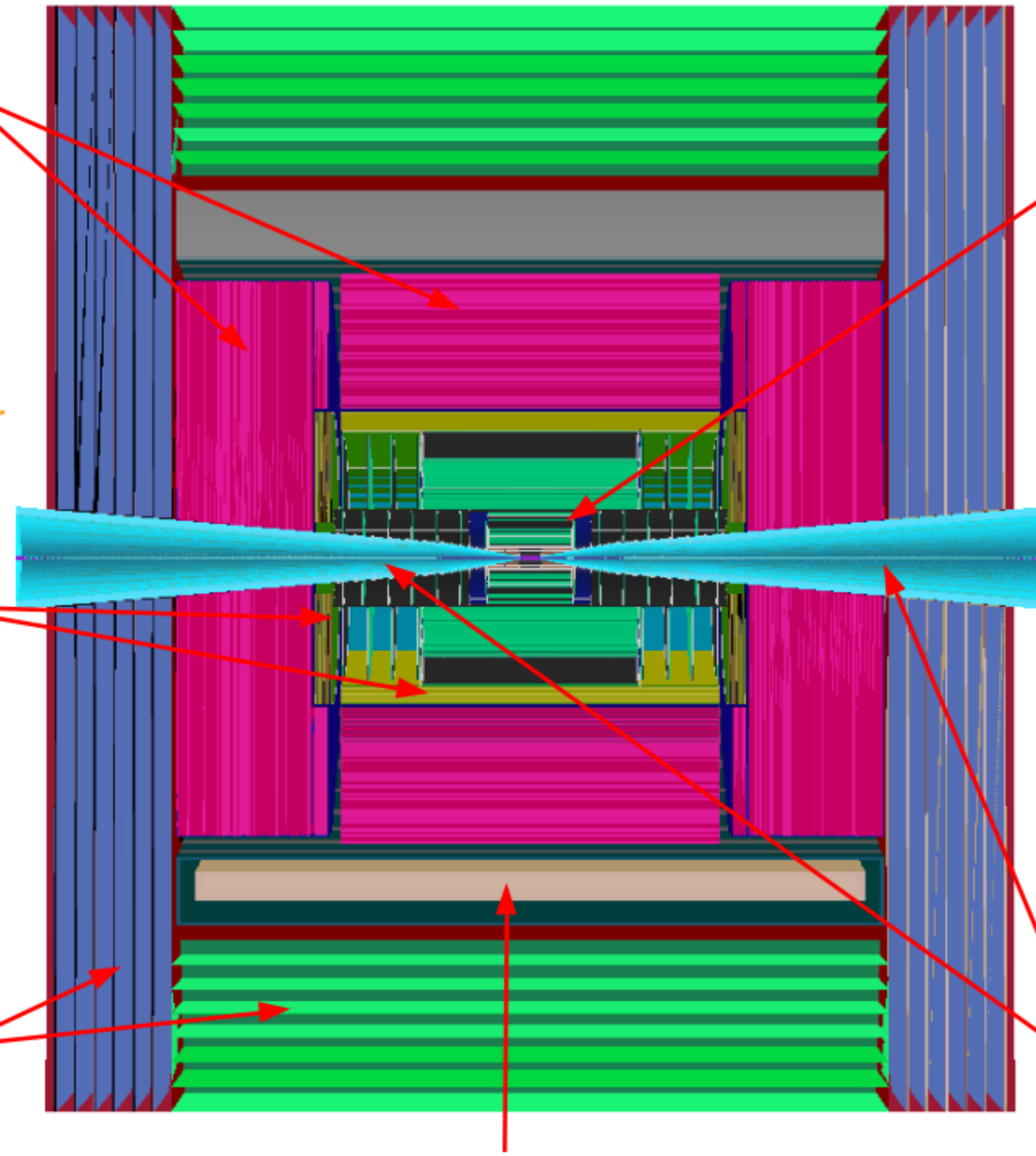
- 60 layers of 19-mm steel absorber + plastic scintillating tiles;
- 30x30 $mm^2$ cell size;
- 7.5 $\lambda_I$.

electromagnetic calorimeter

- 40 layers of 1.9-mm W absorber + silicon pad sensors;
- 5x5 $mm^2$ cell granularity;
- 22 $X_0$ + 1 $\lambda_I$.

muon detectors

- 7-barrel, 6-endcap RPC layers interleaved in the magnet's iron yoke;
- 30x30 $mm^2$ cell size.



superconducting solenoid (3.57T)

tracking system

- Vertex Detector:
  - double-sensor layers (4 barrel cylinders and 4+4 endcap disks);
  - 25x25 $\mu m^2$ pixel Si sensors.
- Inner Tracker:
  - 3 barrel layers and 7+7 endcap disks;
  - 50 µm x 1 mm macro-pixel Si sensors.
- Outer Tracker:
  - 3 barrel layers and 4+4 endcap disks;
  - 50 µm x 10 mm micro-strip Si sensors.

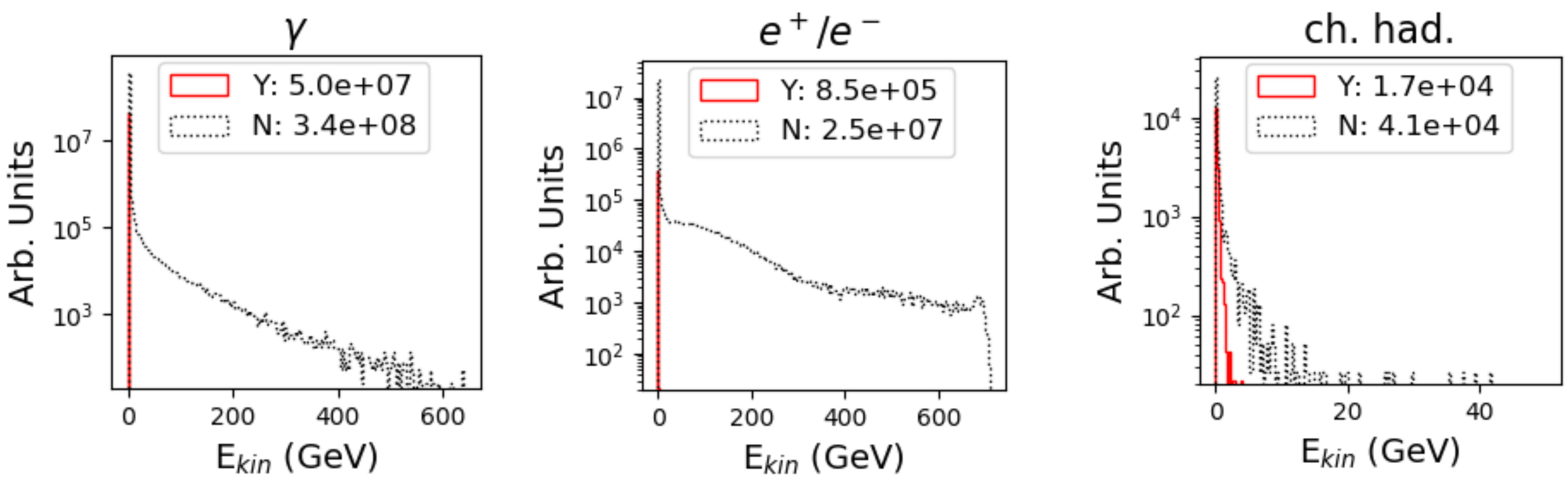
shielding nozzles

- Tungsten cones + borated polyethylene cladding.

- Vertex detector is the focus at Berkeley lab: barrel

# Impact of the nozzle on BIB

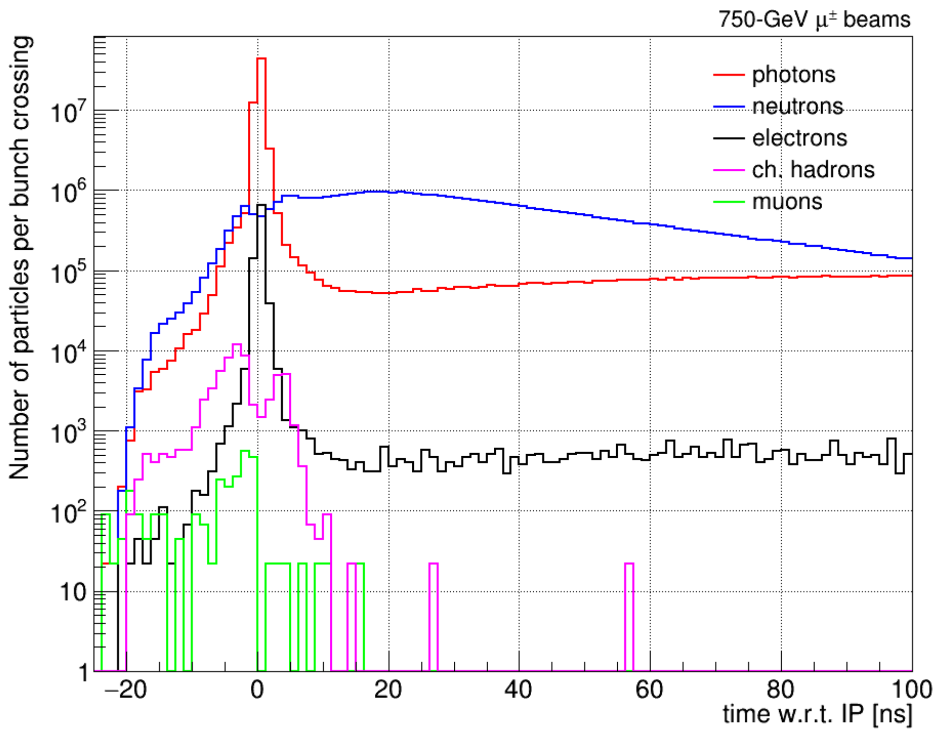
arXiv:2105.09116

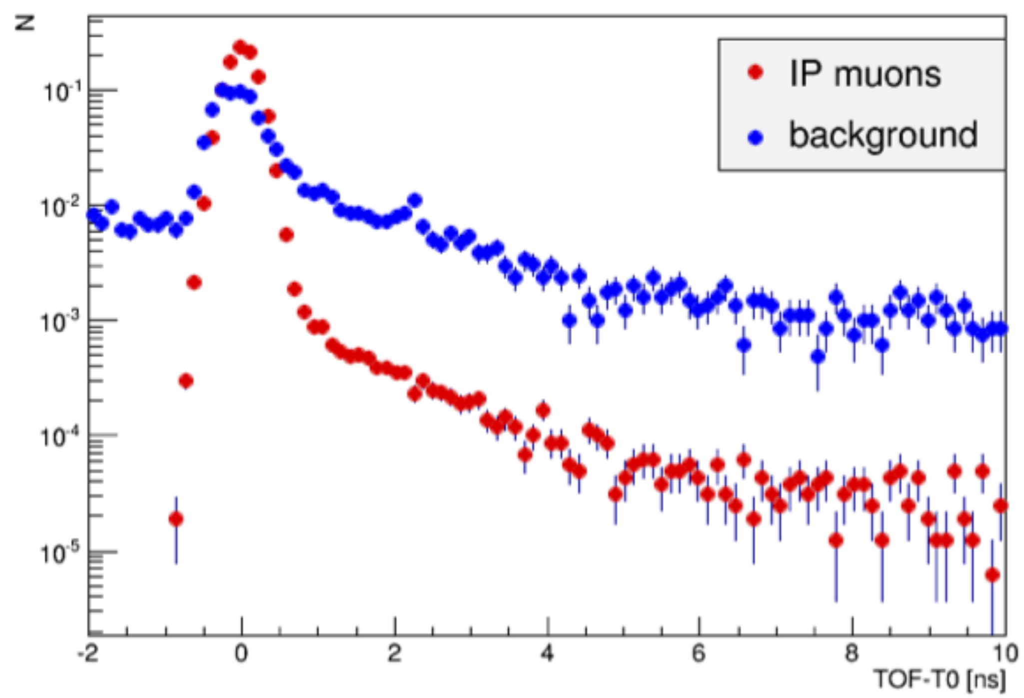



- BIB composed of: photons, neutrons, electrons, charged hadrons, muons
- Comparison of BIB with the nozzles (Y) and without (N)
- Major increase in particle flux without the nozzles for electrons and photons, smaller for charged hadrons and muons
- Energy spectra also affected without nozzles:
  - Reach very high energies
  - Compromise detector performance

# BIB characteristics

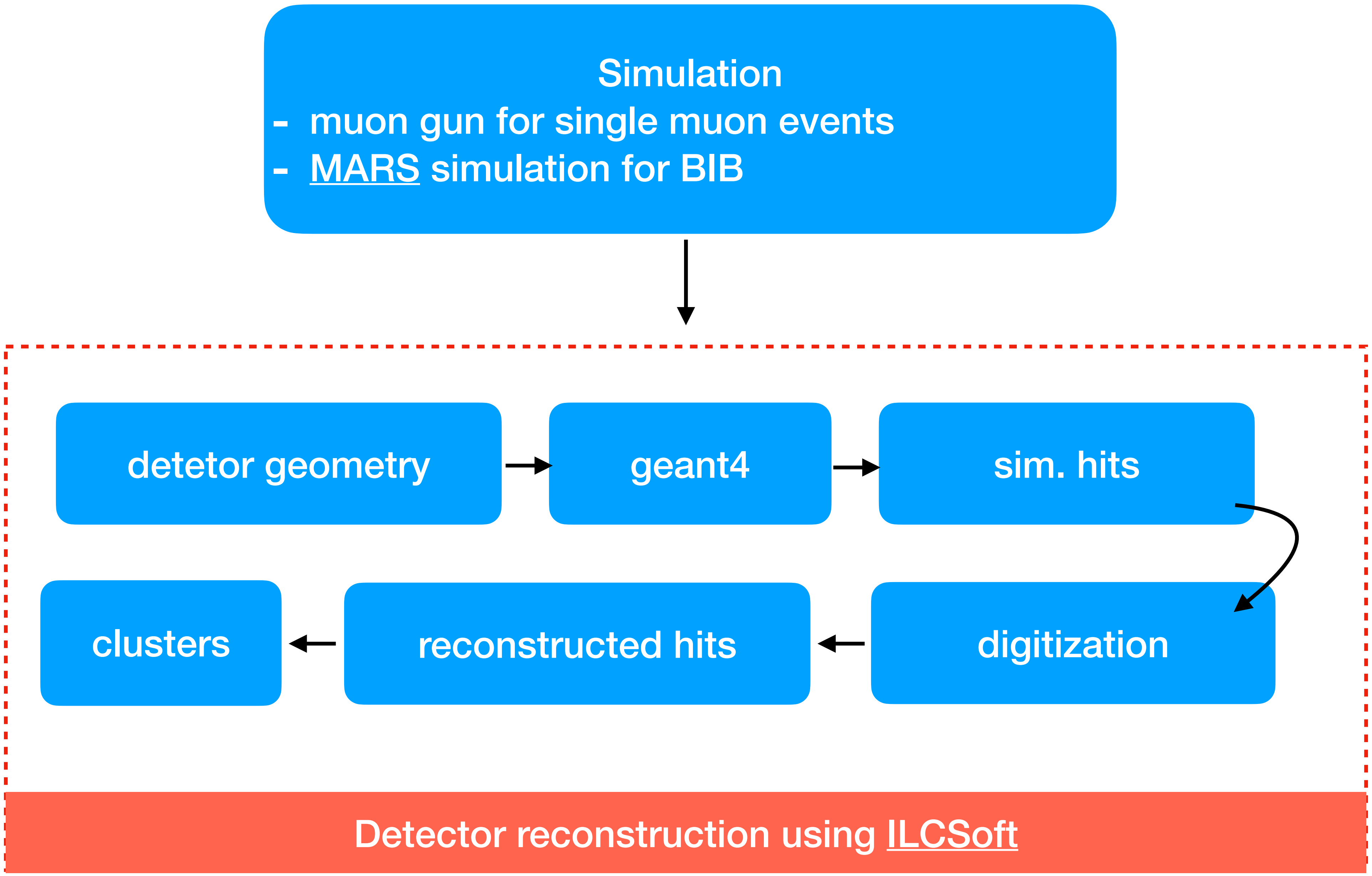
arXiv:2105.09116



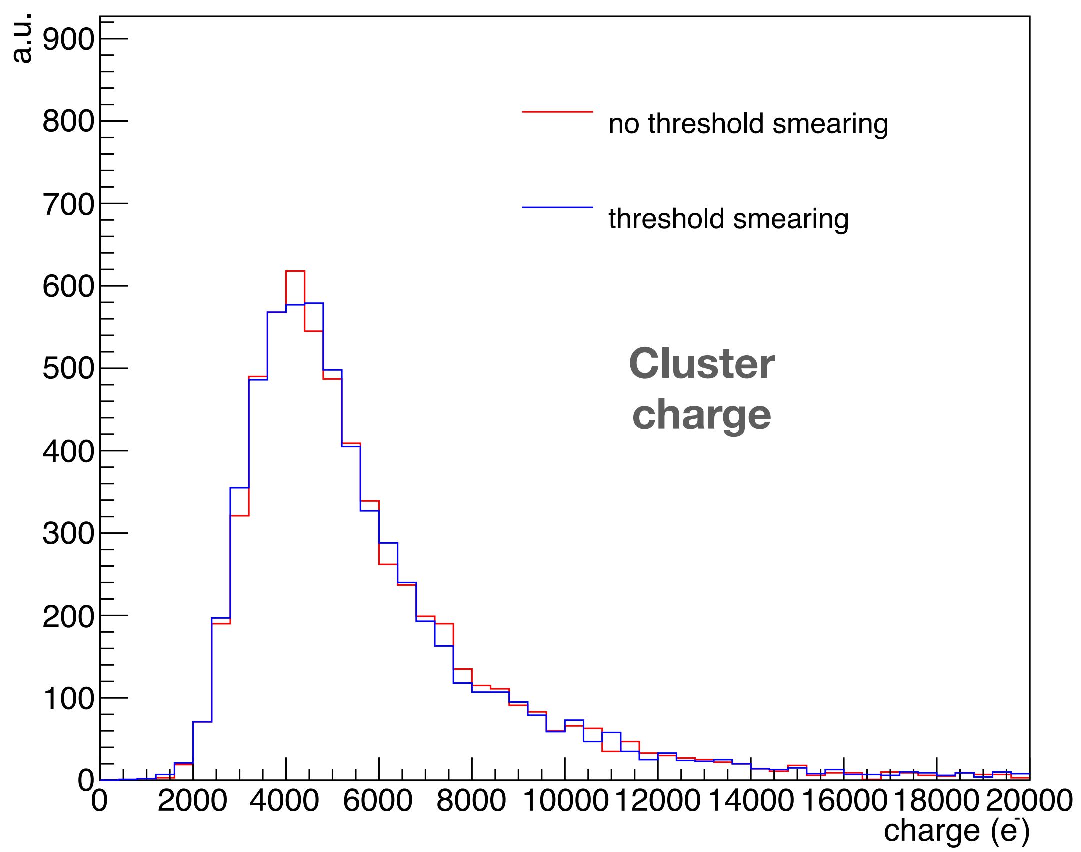

- Late hits almost always due to BIB (assuming interaction at t = 0)
- Selecting a small window (ns) around the expected arrival time can suppress a large fraction of the background

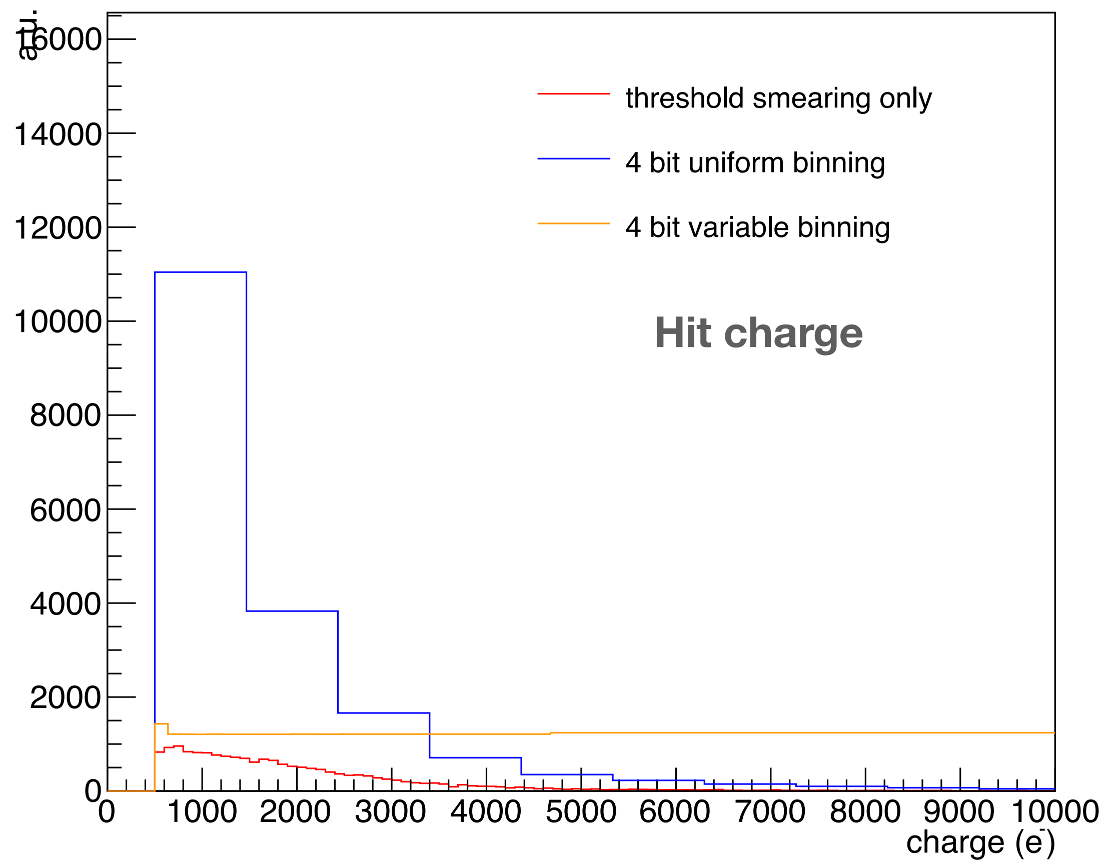
# Event simulation and reconstruction




- Part of the work at LBNL is on digitization
- Make use of cluster properties to minimize BIB background

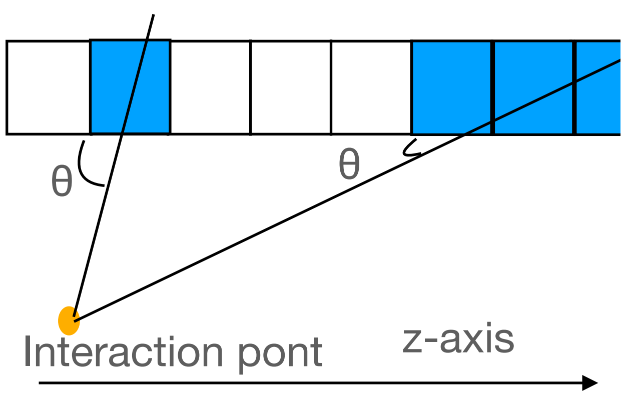
# Digitization requirements for vertex detector



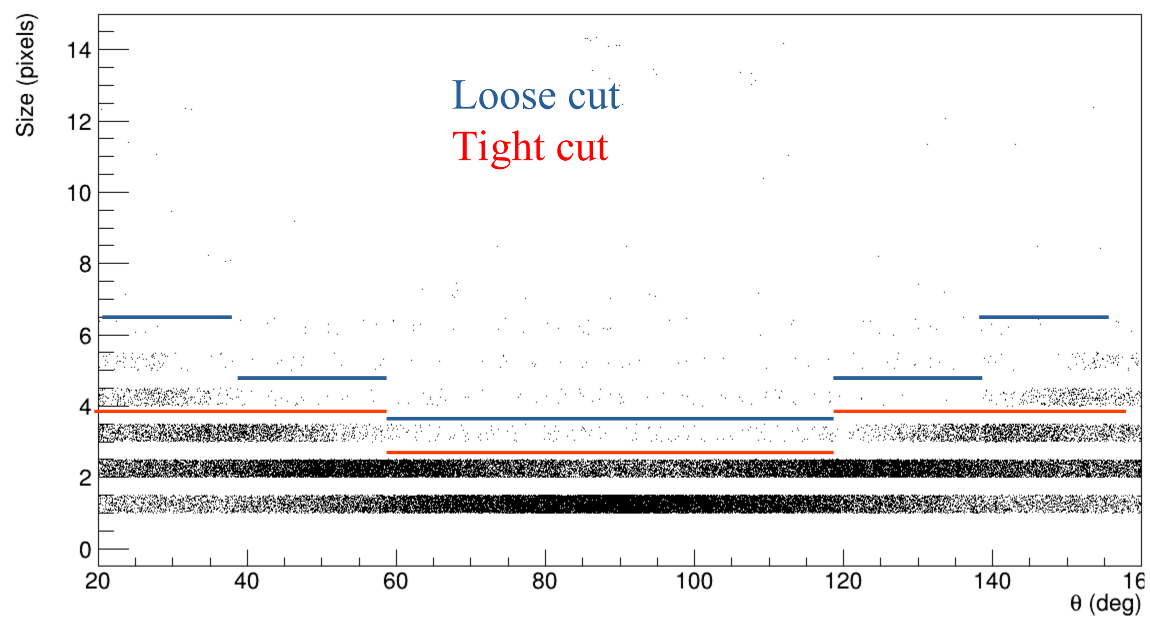



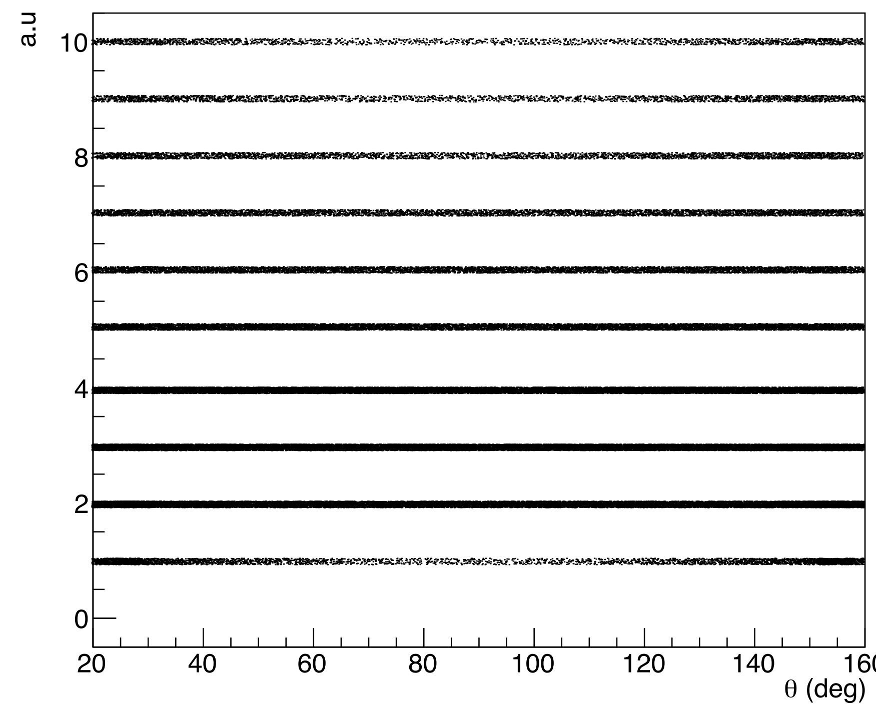

- Digitization accounts for detector performance and effects
- **Threshold dispersion:** account for threshold non-uniformity
  - Threshold differences from HL-LHC readout chips used to determine dispersion
- **Charge discretization:** finite resolution of readout
  - 4 bits selected based on current ATLAS readout
  - Compromise between small bit size and performance
- Also wants to discretize timing in 4 bits based on time-of-flight
  - BIB has different beta values than signal muons

# Pixel size and incidence angle to filter out BIB




**Incidence angle:**
larger angle = longer path



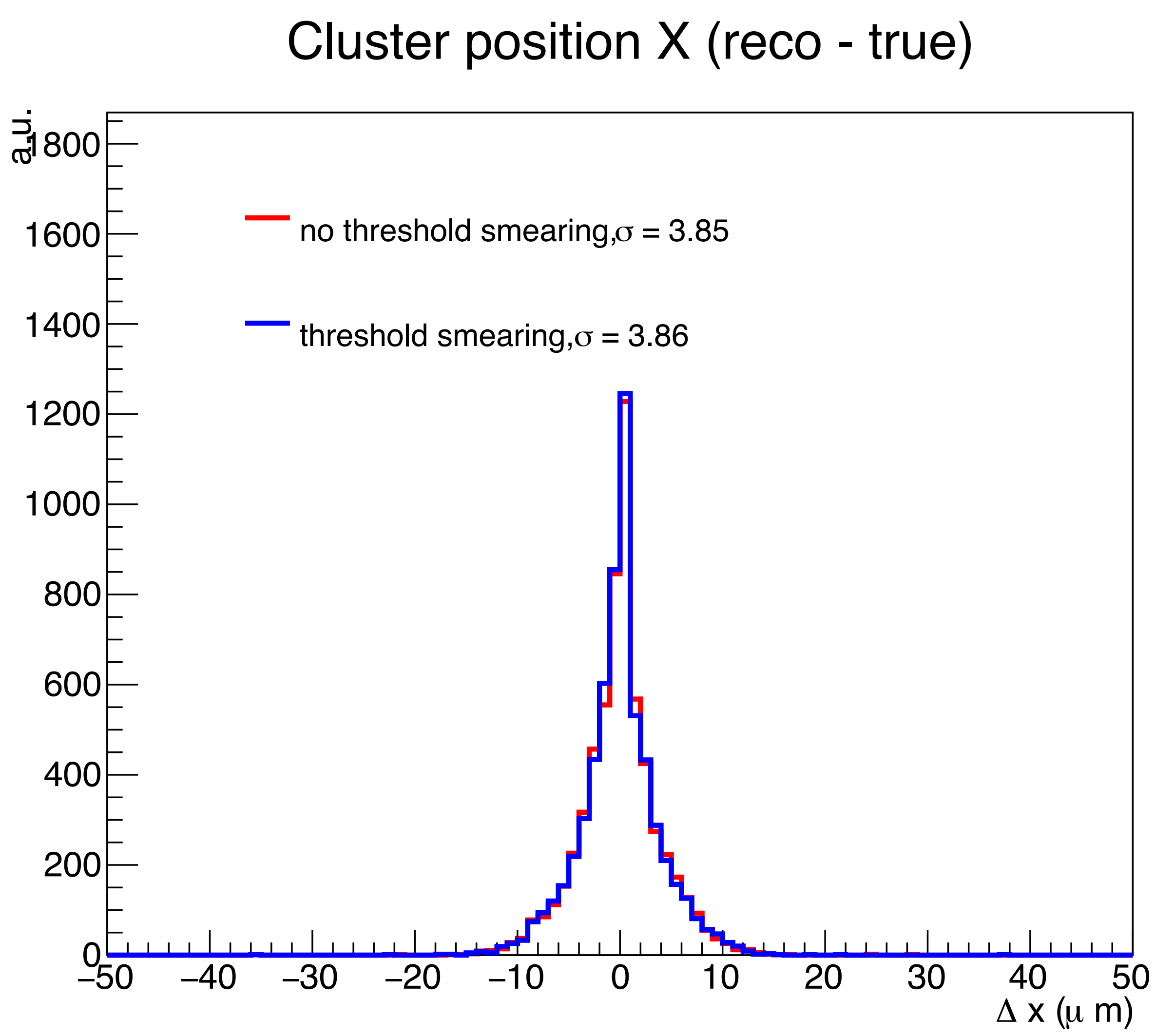

- We can make use of cluster properties used to differentiate BIB from single muon events
- Muon events show correlation between cluster size vs. incident angle
  - Larger cluster size has larger θ
  - Filter hits using the angular and pixel size information
- Hit filtering reduces the BIB by 50% while retaining single muon requirements

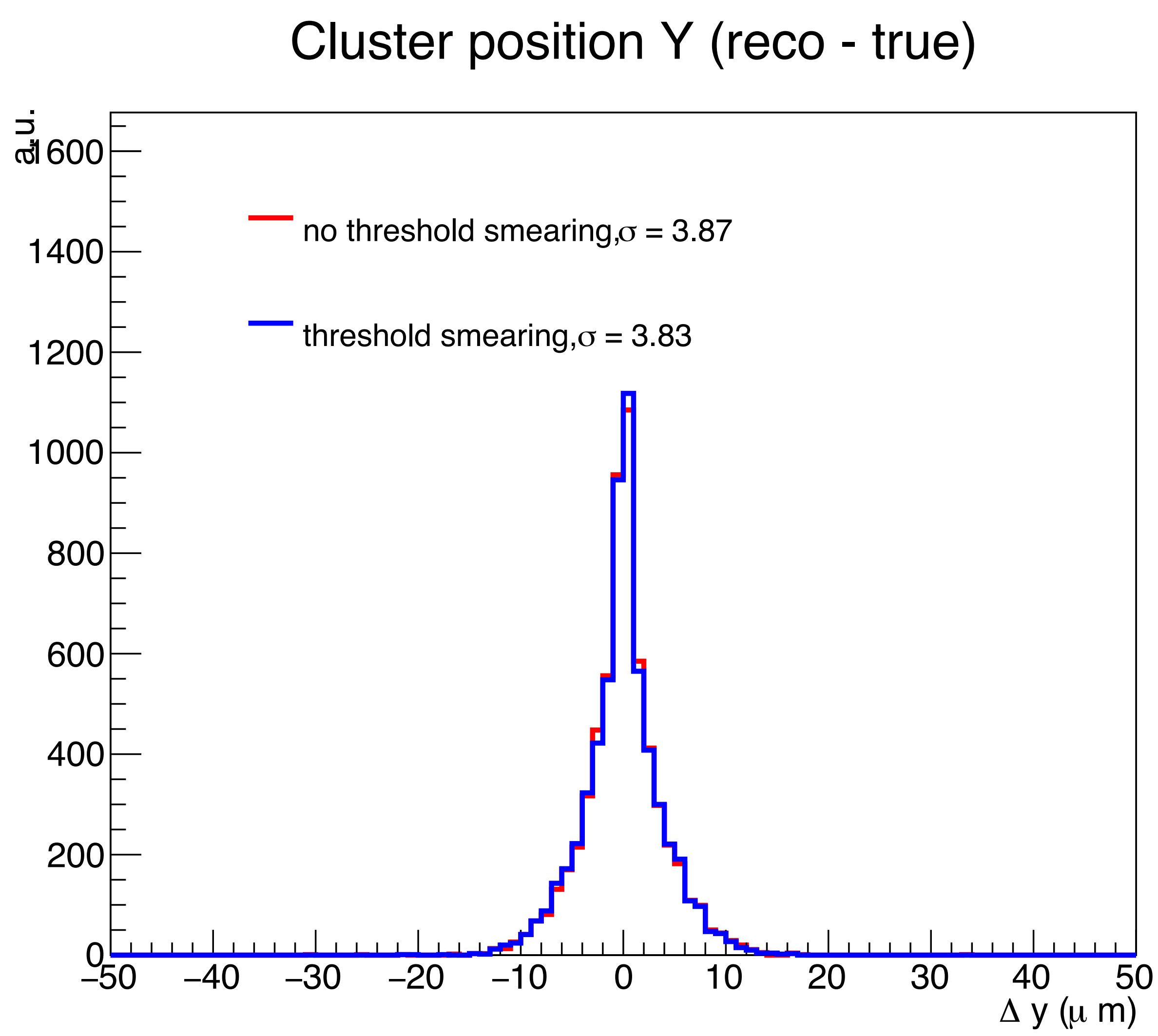
# Additional studies to suppress BIB

- Additional features can be used to suppress the BIB
- Want to make use of machine learning to help discriminate between signal muons and BIB
- Also want to test separation between muons and other heavier particles such as protons

# Backup

# Impact of threshold smearing




- No large impact due to threshold smearing
- More of a validation that this was implemented correctly