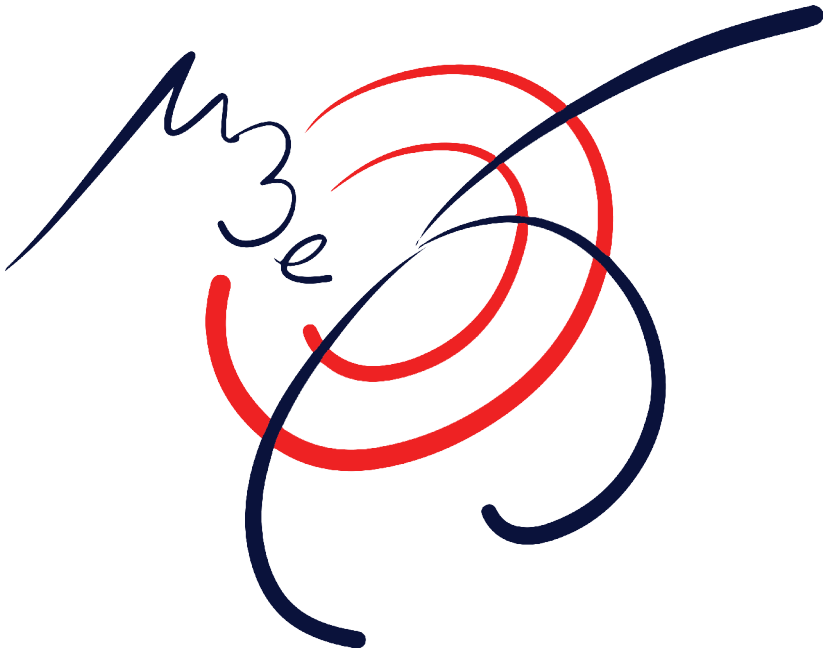
Testbeam Measurement for the MU3E Experiment



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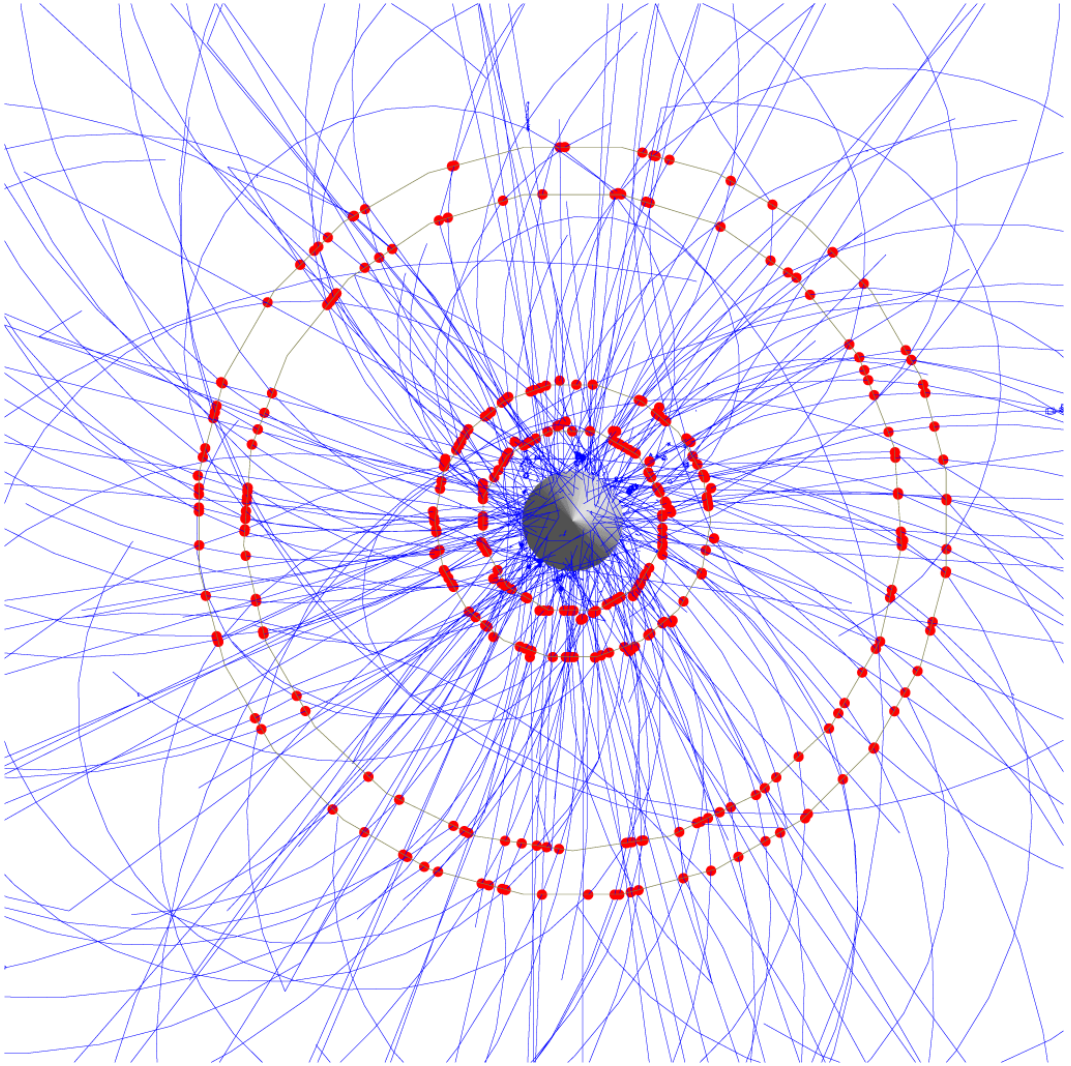
IMPRS Seminar 2012/12/03

INTERNATIONAL MAX PLANCK RESEARCH SCHOOL

PT FS FOR PRECISION TESTS OF FUNDAMENTAL SYMMETRIES

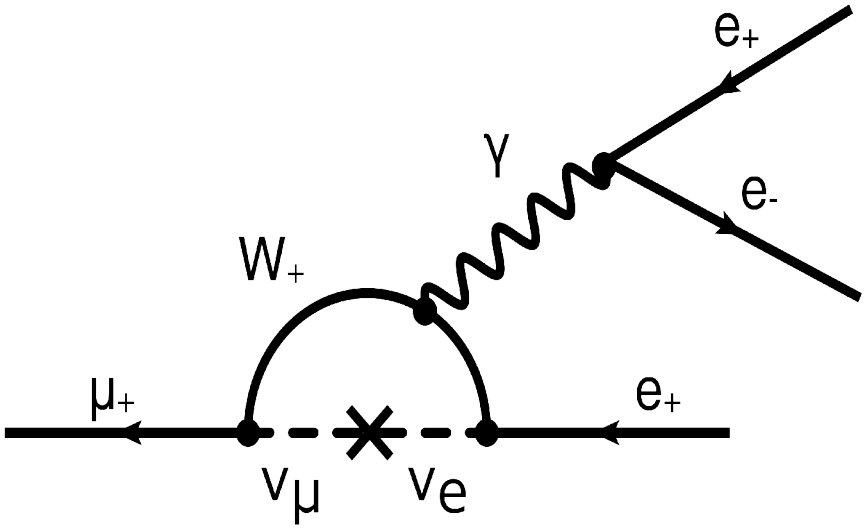
The MU3E Experiment



The MU3E Experiment:

- Search for $\mu^+ \rightarrow e^+e^-e^+$
- Charged Lepton Flavor Violation (LFV)
- Proposed Sensitivity: Branching Ratio (BR) < 10^{-16}
- Indirect New Physics Search

$\mu^+ \rightarrow e^+ e^+ e^-$ in the Standard Modell



Features:

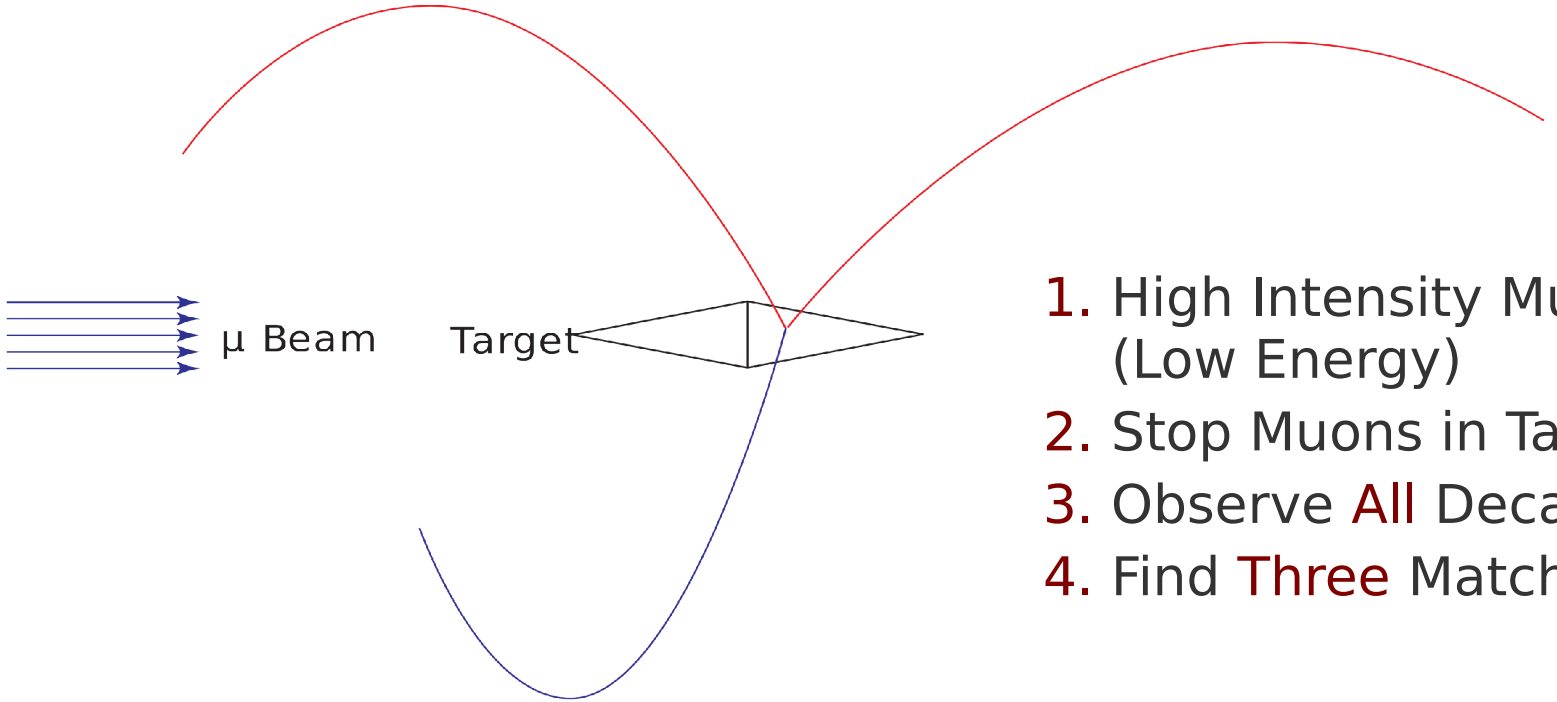
- Lepton Flavor Violating
- Via Neutrino Mixing
- But: Heavily Suppressed
- Expected BR < 10^{-50}
- Current Limit BR < $2.4 \cdot 10^{-12}$

Importance:

- Any Observable BR must come from New Physics

→ Very Sensitive to New Physics

Experimental Concept



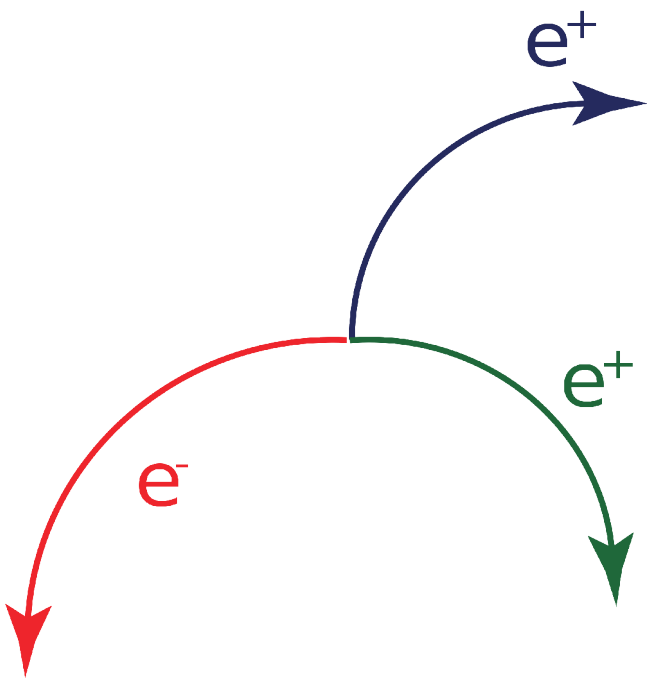
1. High Intensity Muon Beam (Low Energy)
2. Stop Muons in Target
3. Observe All Decay Electrons
4. Find Three Matching Tracks

up to $2 \cdot 10^9$ muons / s

→ Many, Low Momentum Electrons
$p < 53$ MeV

Existing / Future Beamlines
Paul Scherrer Institut, Switzerland

Signal

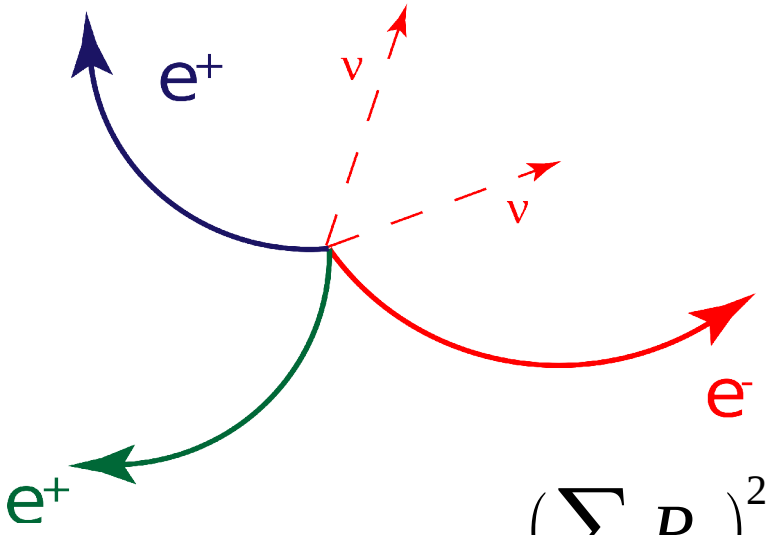


$$\left(\sum P\right)^2 = m_{\mu}^2$$

- Three Electrons (2x e^+, 1x e^-)
- Common Vertex
- Coincident in Time

Backgrounds

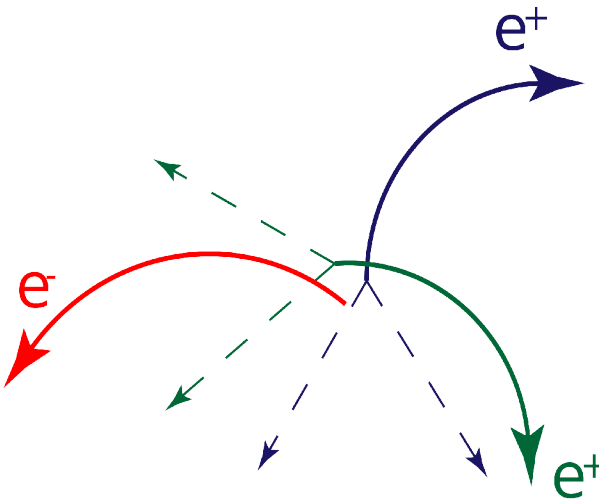
Internal Conversion



$$\left(\sum P_e\right)^2 \neq m_\mu^2$$

Requires:
- high momentum resolution

Combinatorial Background

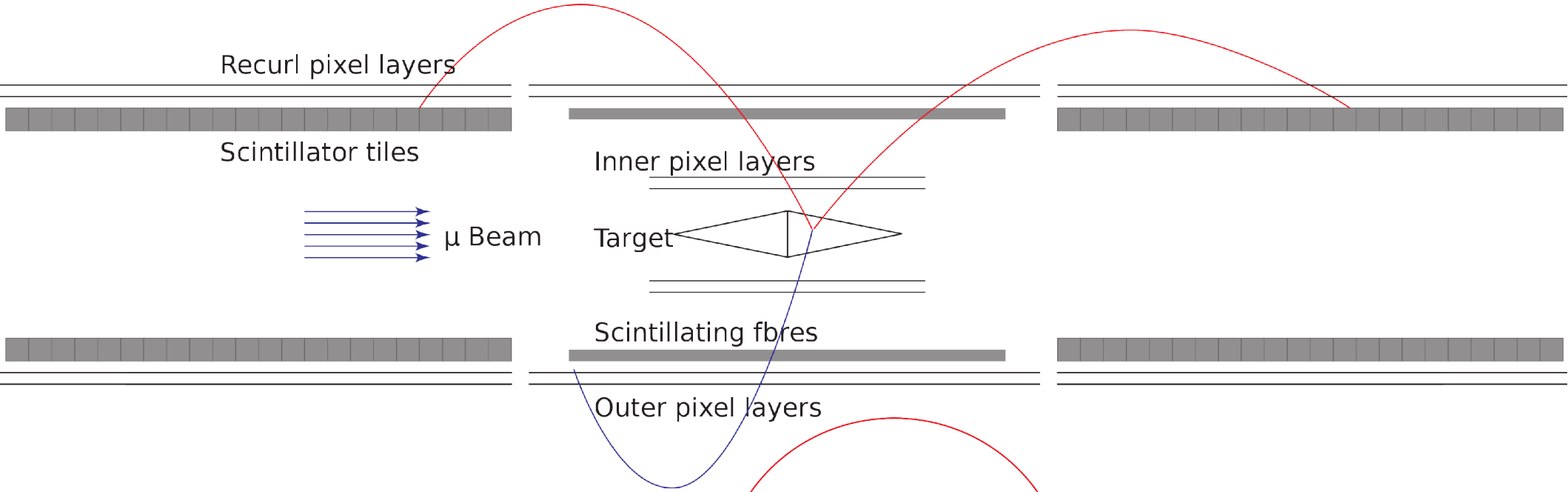


Requires:
- high vertex resolution
- good momentum resolution
- additional timing information

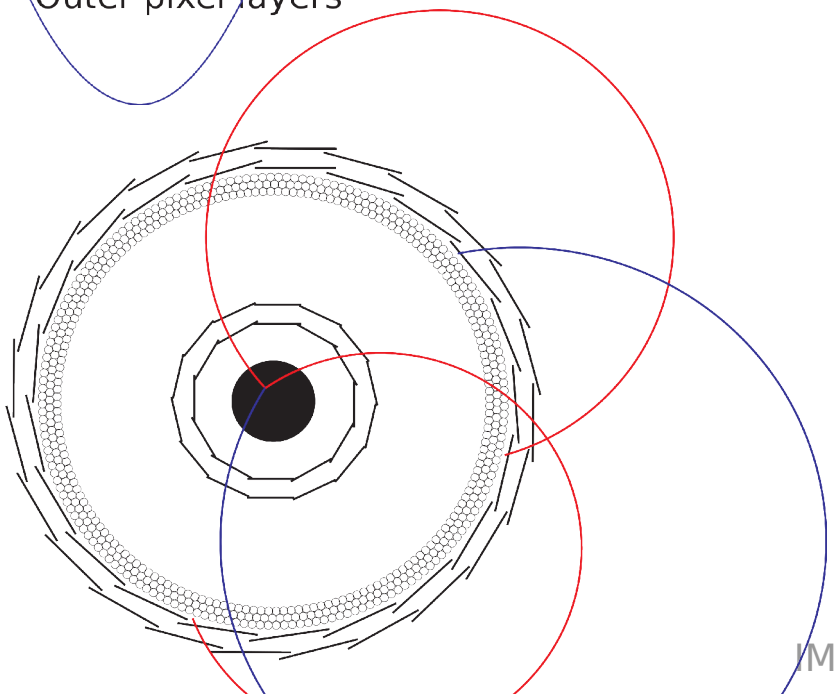
→ Suppress Below BR < 10-16

→ Fast, Precise, Low Momentum Electron Tracker

The MU3E Detector

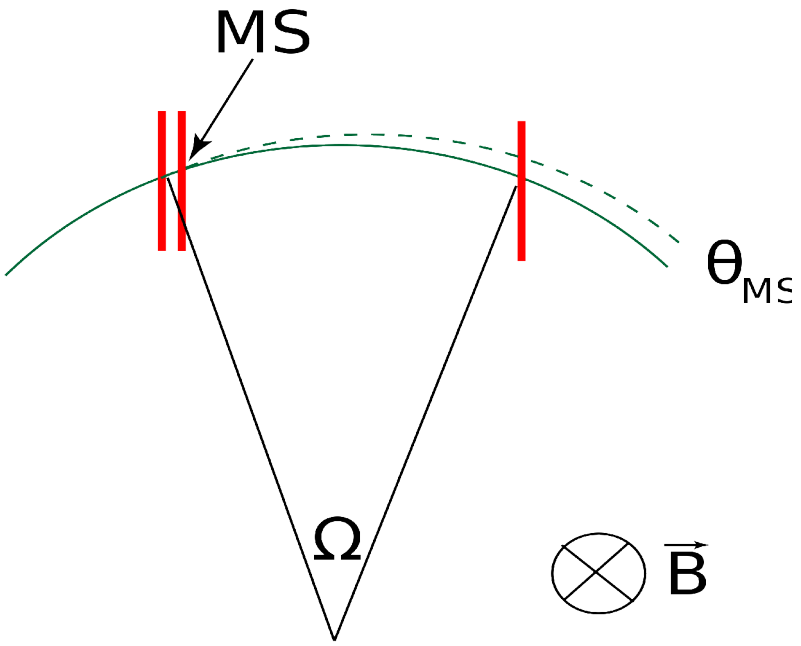


Magnetic Field: ~ 1T

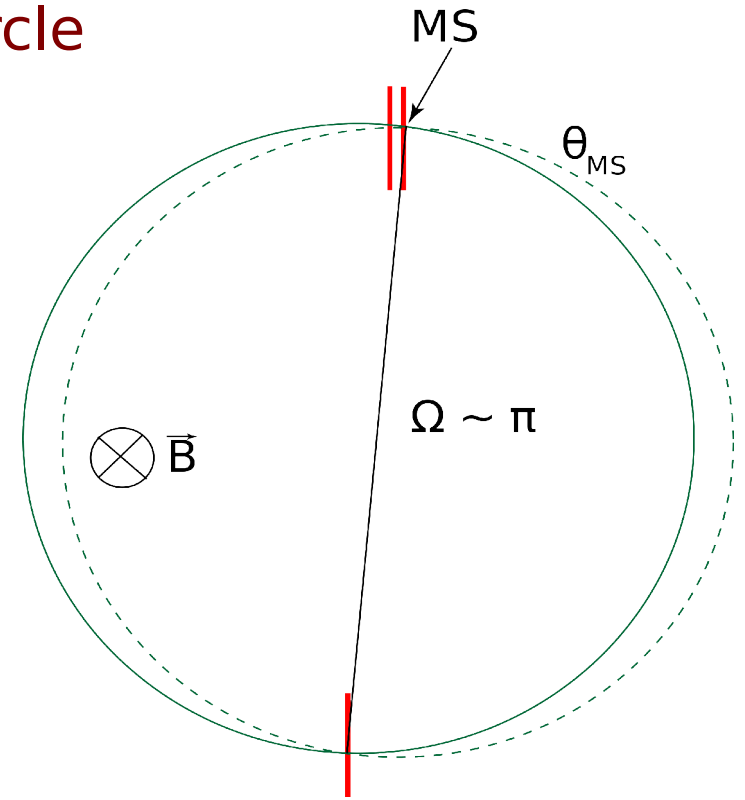


Multiple Scattering

Short Tracks



Semi Circle



$$\theta_{MS} = \frac{13.6\,MeV}{p}\sqrt{\frac{x}{X_0}}$$

Example:

- p = 35 MeV
- x = 200 µm Silicon
- Ω•R = 5 cm

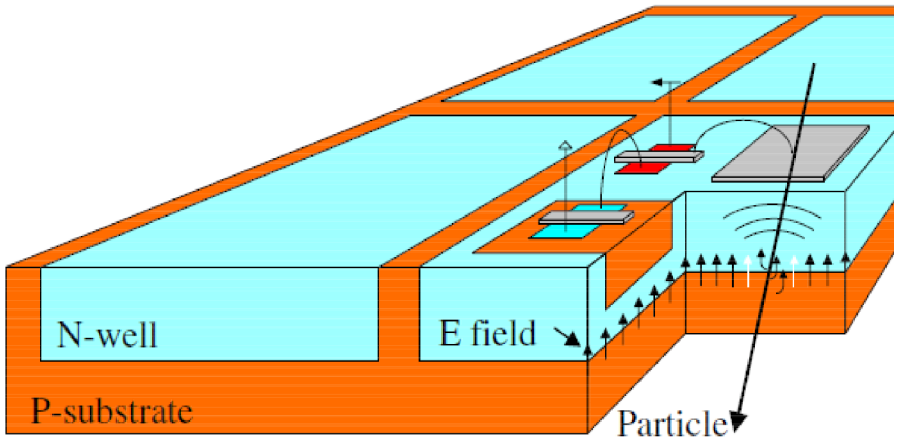
→ Δy =1mm

In First Order / Fixed Momentum:
Reduced Effect from Scattering

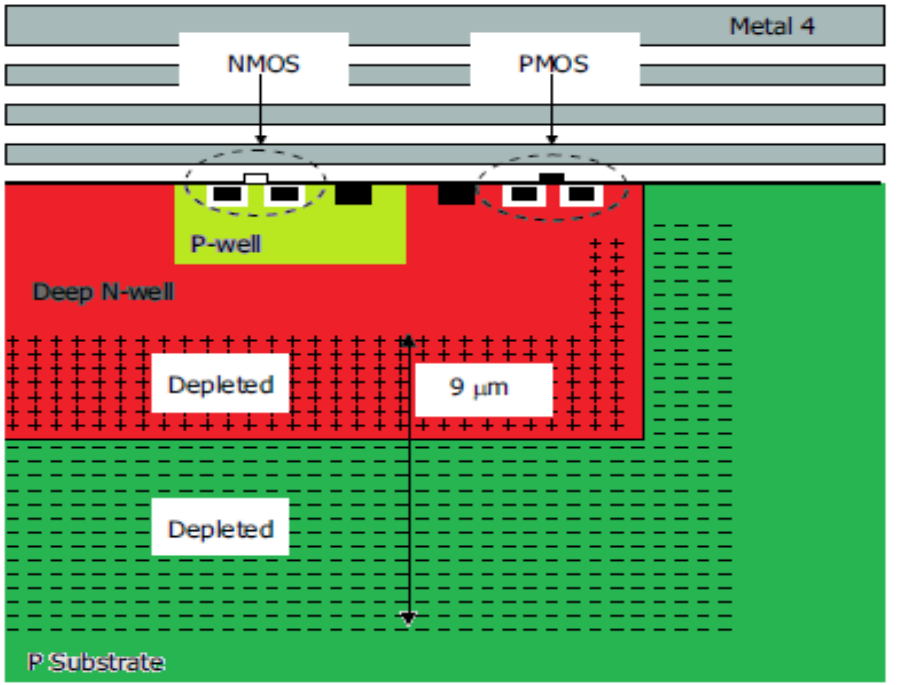
Low Momentum → Minimal Material Budget

High Voltage MAPS

top view



cross section



MAPS:

Monolithic

Active

Pixel Sensors

- integrated readout
- very small active zone
- charge collection via drift (fast)
- thinable down to 50µm

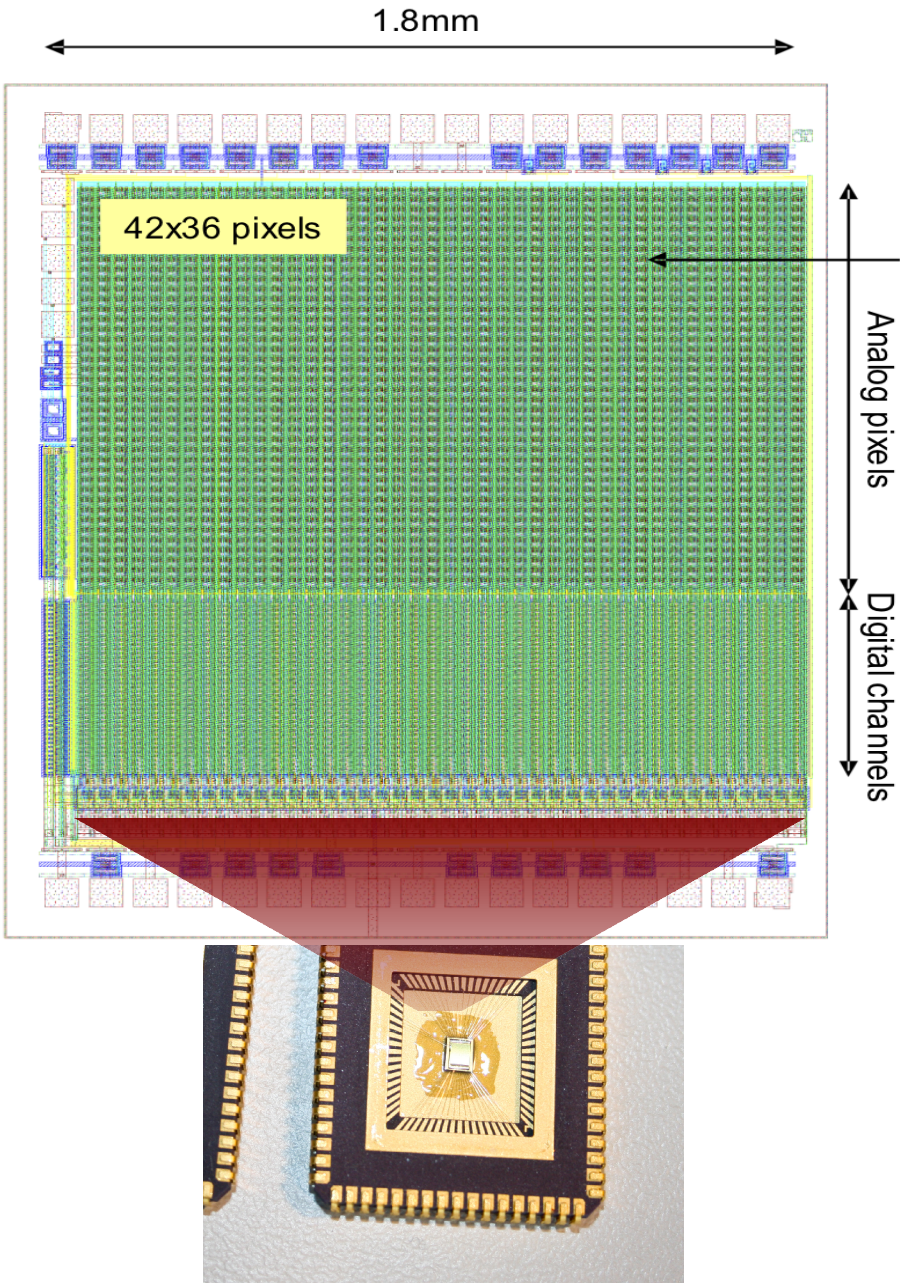
MUPIX Prototype 2

- Designed by Ivan Peric (ZiTi Mannheim)
- 42x36 Pixels @ 39x30 μm^2
- Binary Hits (Single Threshold)
- already tested by colleagues at PI (laser, radioactive sources, ...)

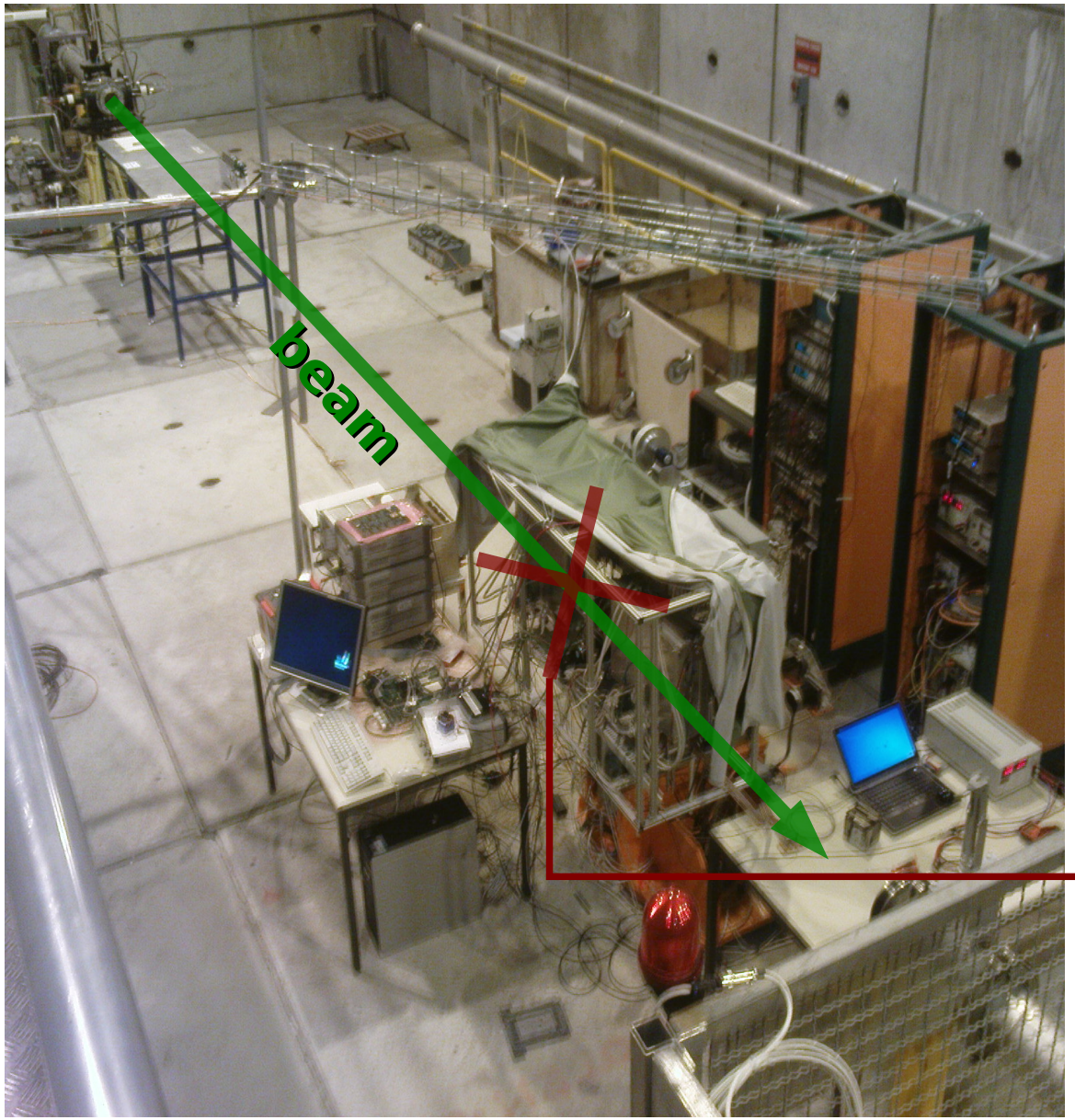
Problems:

- Efficiency?
- Resolution?
- Response to Minimal Ionizing Particles (MIPs)?

→ Requires Testbeam Measurements



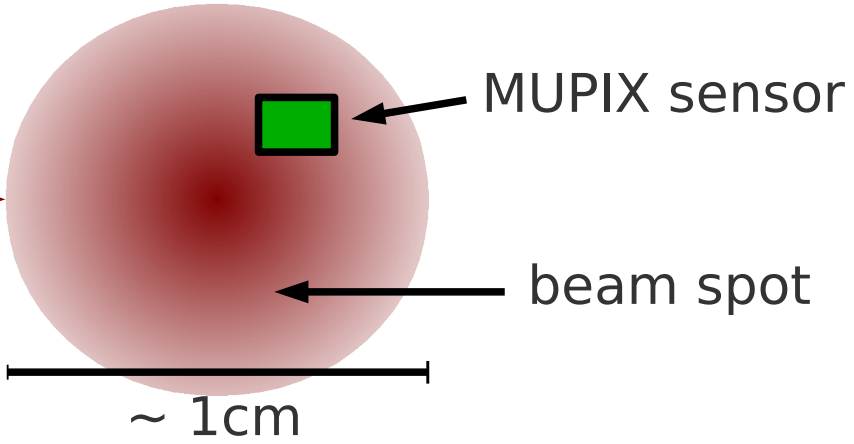
SPS Testbeam at CERN



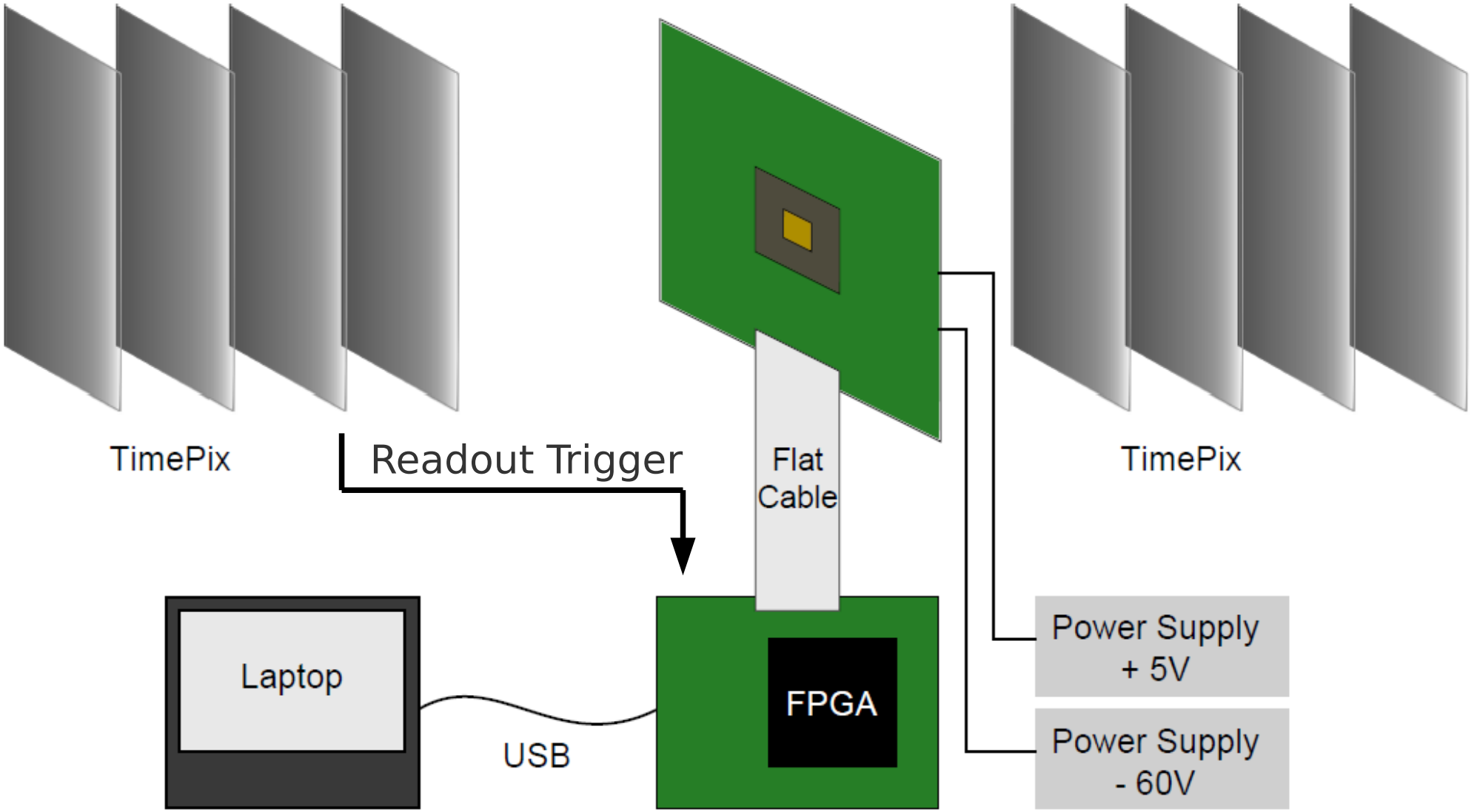
Testbeam August 2012

- Testbeam Area T4-H8A
- 180 GeV/c pions
- TIMEPIX Beam Telescope

But: ~ few hours of data taking

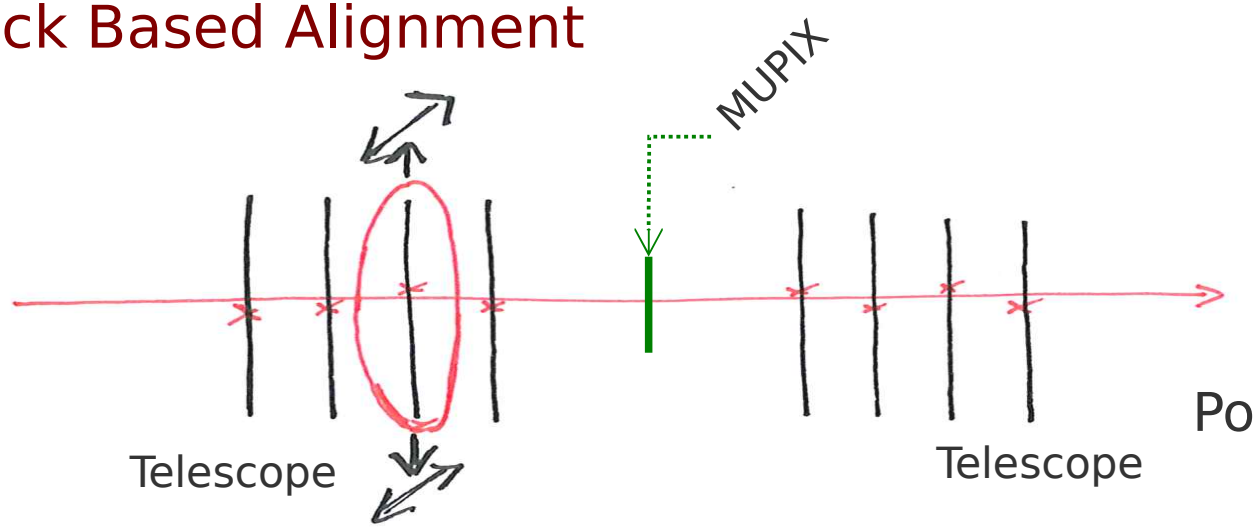


Timepix Beam Telescope



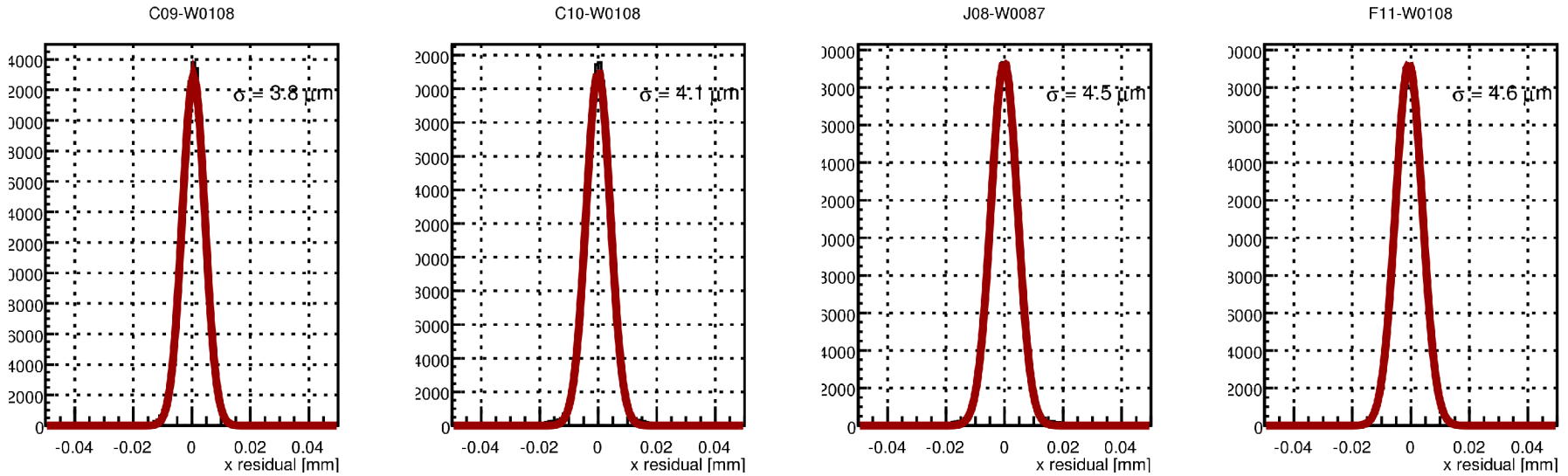
Telescope Alignment

Track Based Alignment

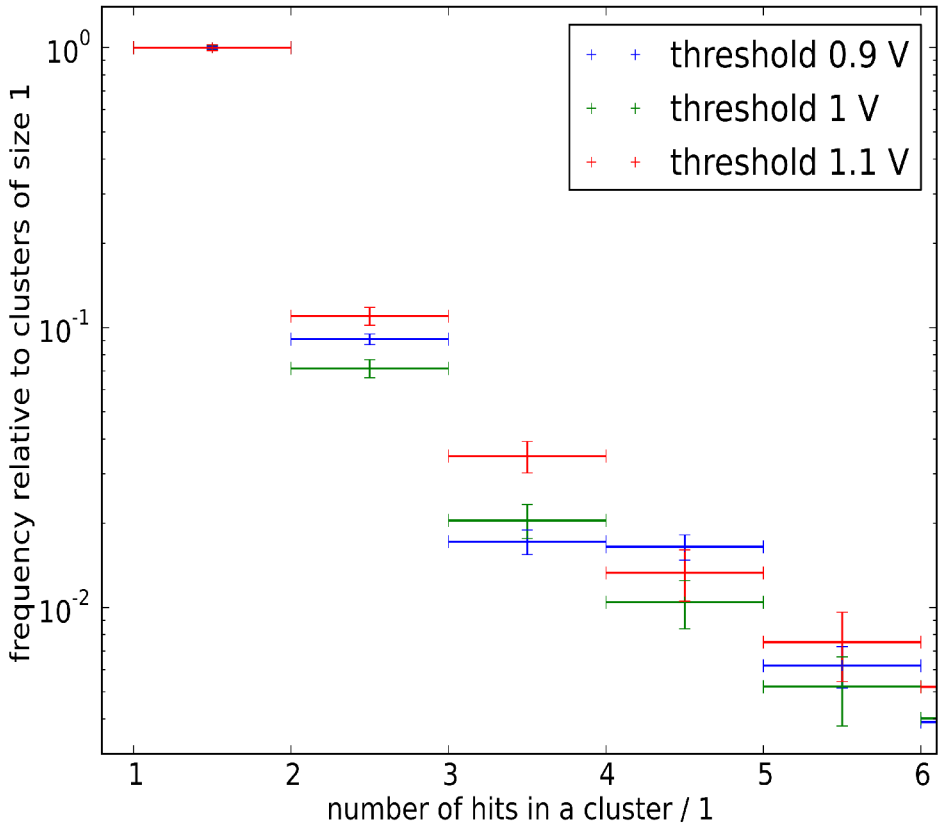


Position Resolution ~ 5µm

Track Residuals (First 4 Telescope Layers)



Cluster Size



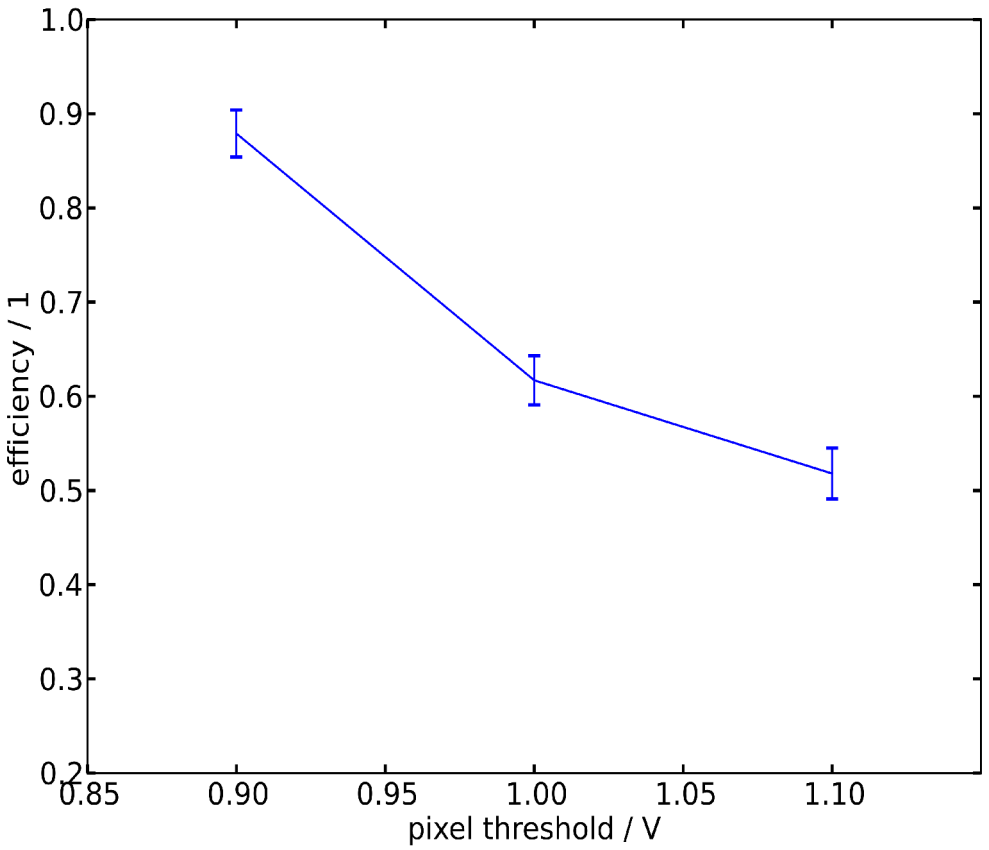
Mostly Single Hit Cluster

- Very Little Charge Sharing
- Expected: Small Active Volume

No Significant Threshold Dependence

- Expectation: Fewer Big Cluster for Higher Thresholds
- Limited Statistics

Hit Efficiency

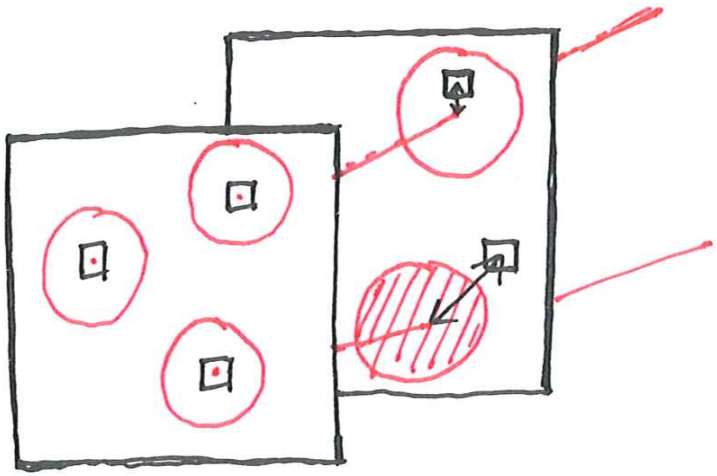


How to Calculate:

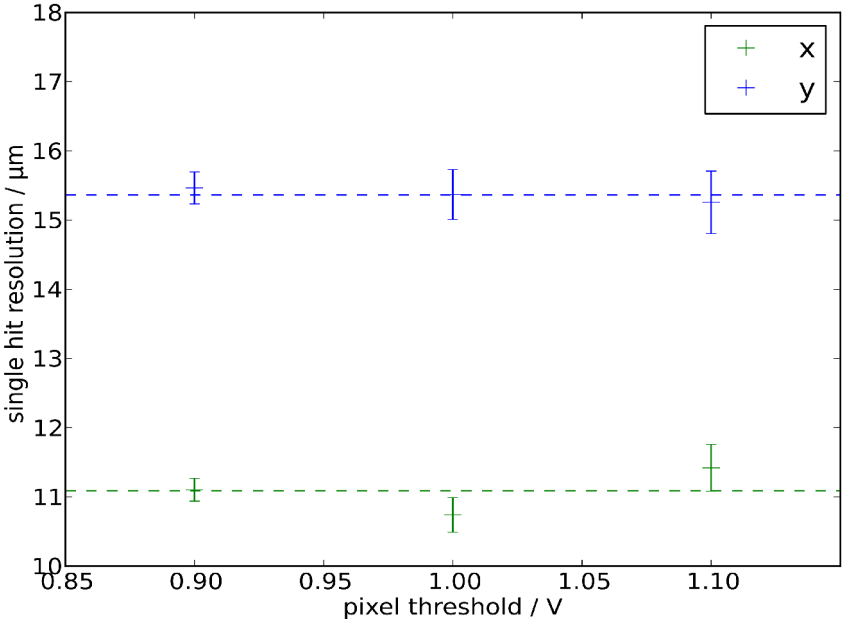
1. Extrapolate Track to MUPIX plane
2. Check for Close-By Clusters (less than 2 pixel away)
3. Keep Closest Cluster
4. Ratio Tracks w/ or w/o Cluster

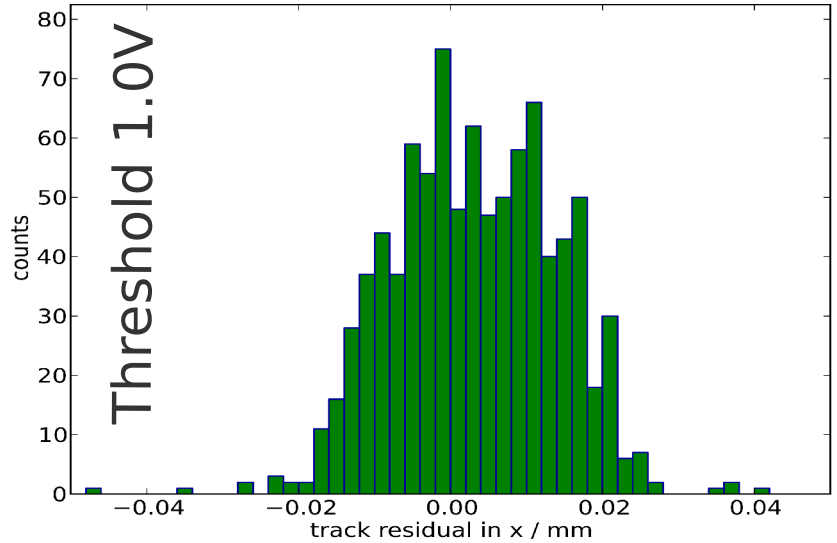
Problems:

- Some Dead Pixels



Resolution

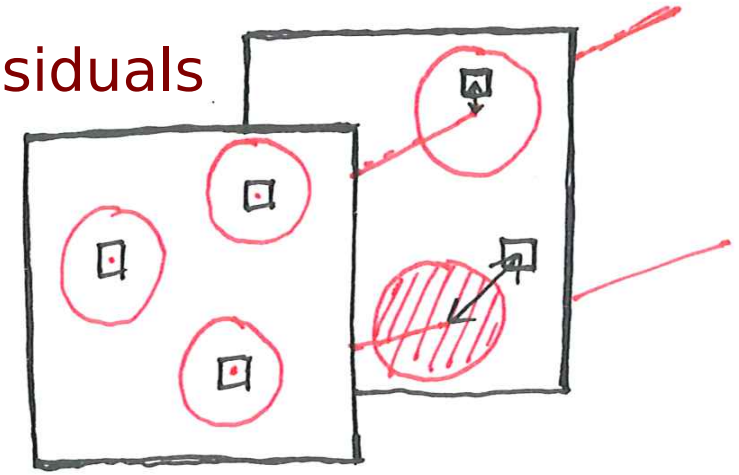




- Independent of Threshold
- Combination of Pixel Size and Telescope Resolution

$$\sigma = \sqrt{\sigma_{Telescope}^2 + \frac{d_{Pixel}^2}{12}}$$

Track Residuals



Summary & Outlook

The MU3E Experiment

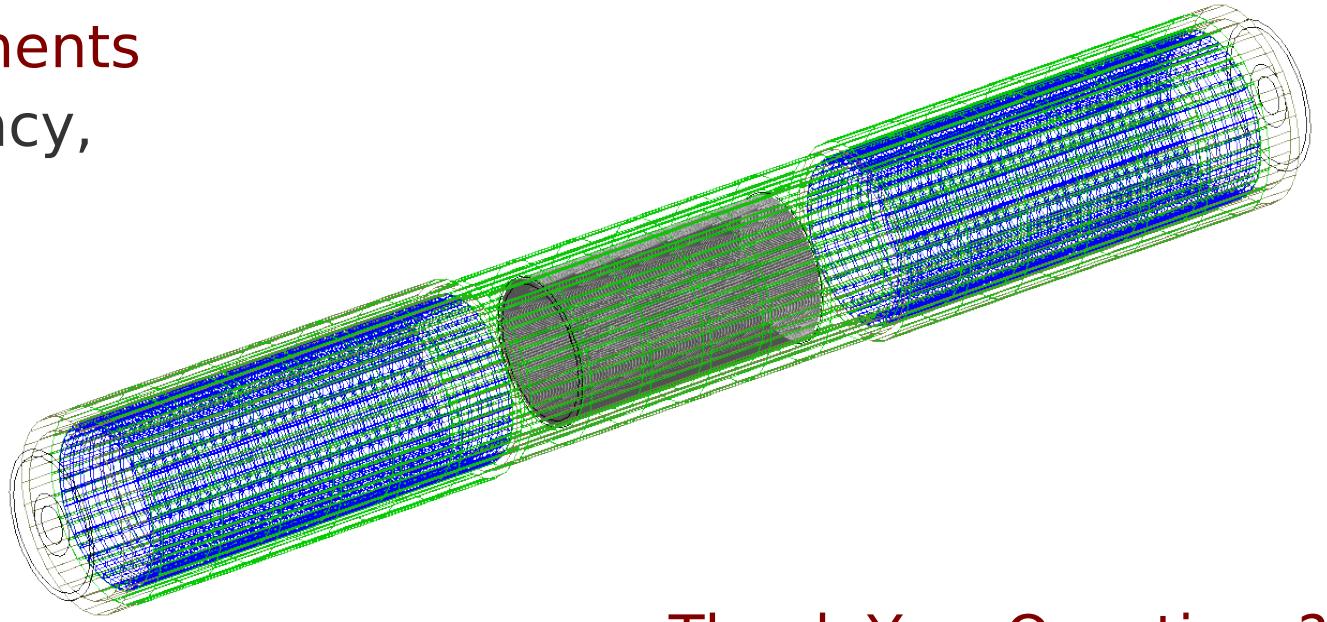
- Search for Charged LFV
  $\mu^+ \rightarrow e^+e^-e^+$
- Planned Sensitivity BR < 10^{-16}
- New Detector Design
- New Pixel Sensor

What's Next?

- Finalize Testbeam Analysis
- New Prototype: MUPIX v3
- First Data Taking ~ 2014

Testbeam Measurements

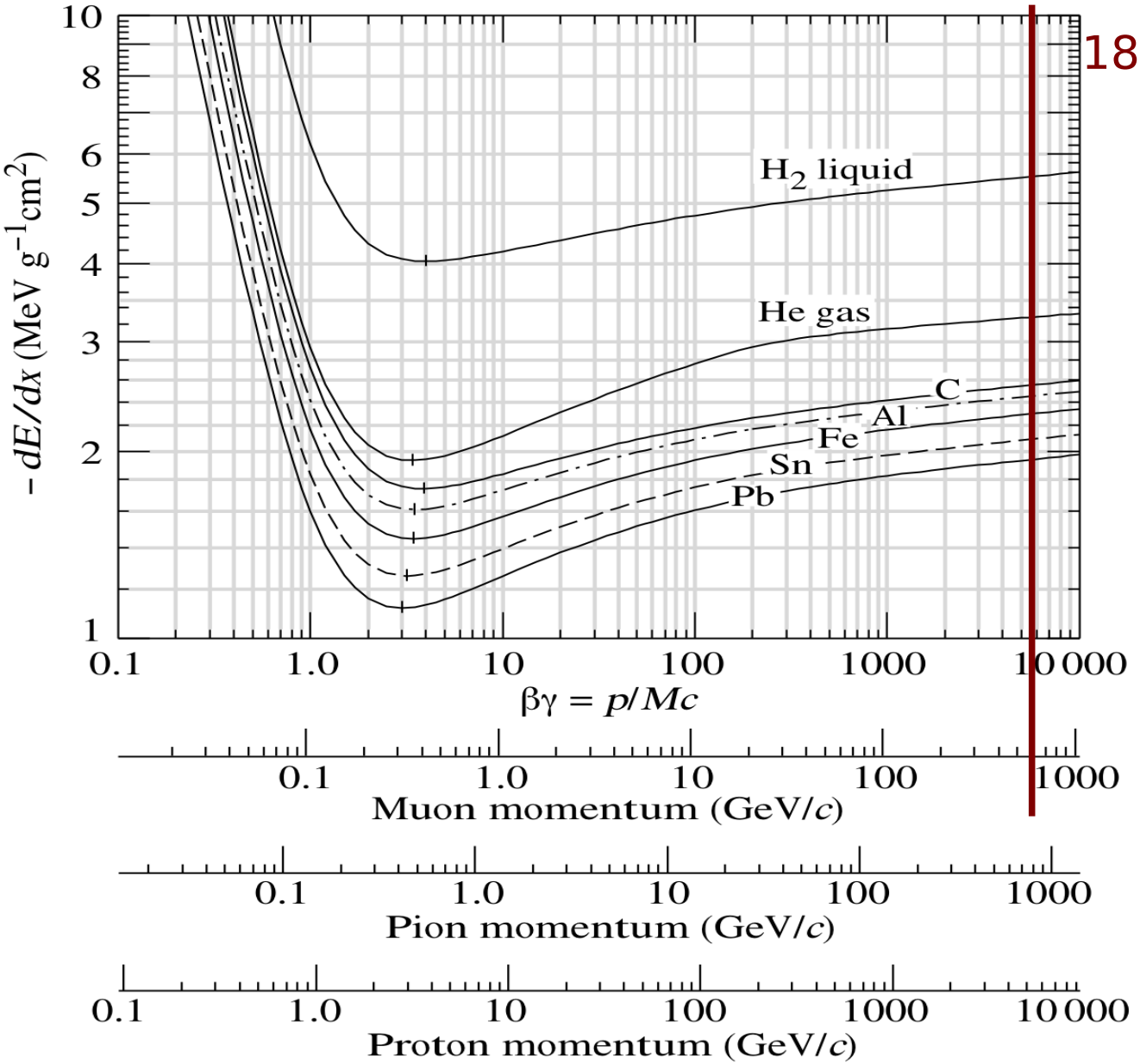
- Cluster Size, Efficiency, Resolution, ...



Thank You. Questions?

Backup

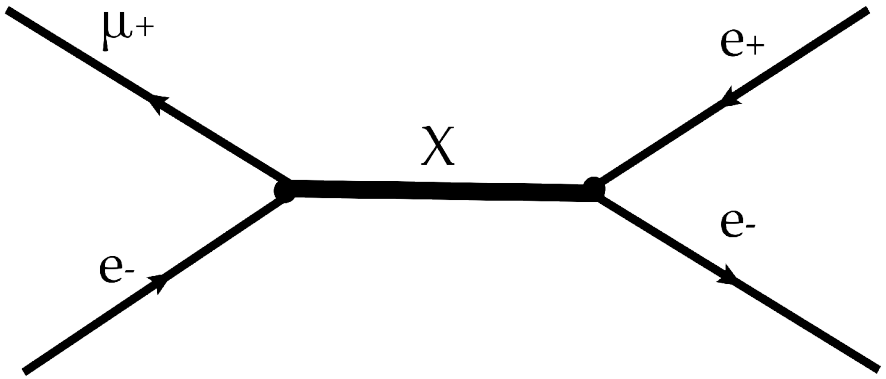
Bethe-Bloch



J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)

New Physics Diagrams

Generic Tree Level



Supersymmetry