# Study of Hadronic Showers in a Tungsten Calorimeter for a Future Linear Collider

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TECHNISCHE UNIVERSITÄT MÜNCHEN

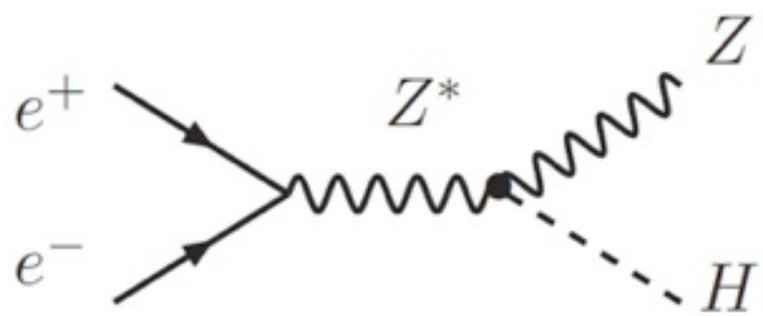
CALICE Calorimeter for ILC

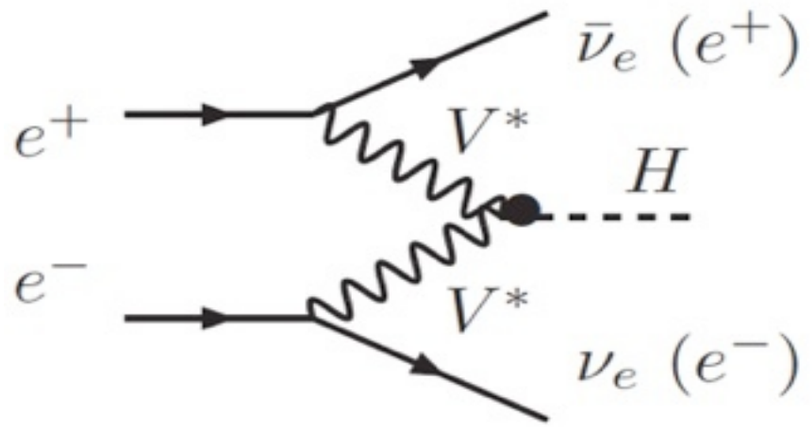
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

# Table Of Content

# Physics at e+/e- LC

- Precision measurement of the recently discovered boson




  - Model-independent measurements of coupling to fermions and bosons
  - Complete study of the Higgs sector

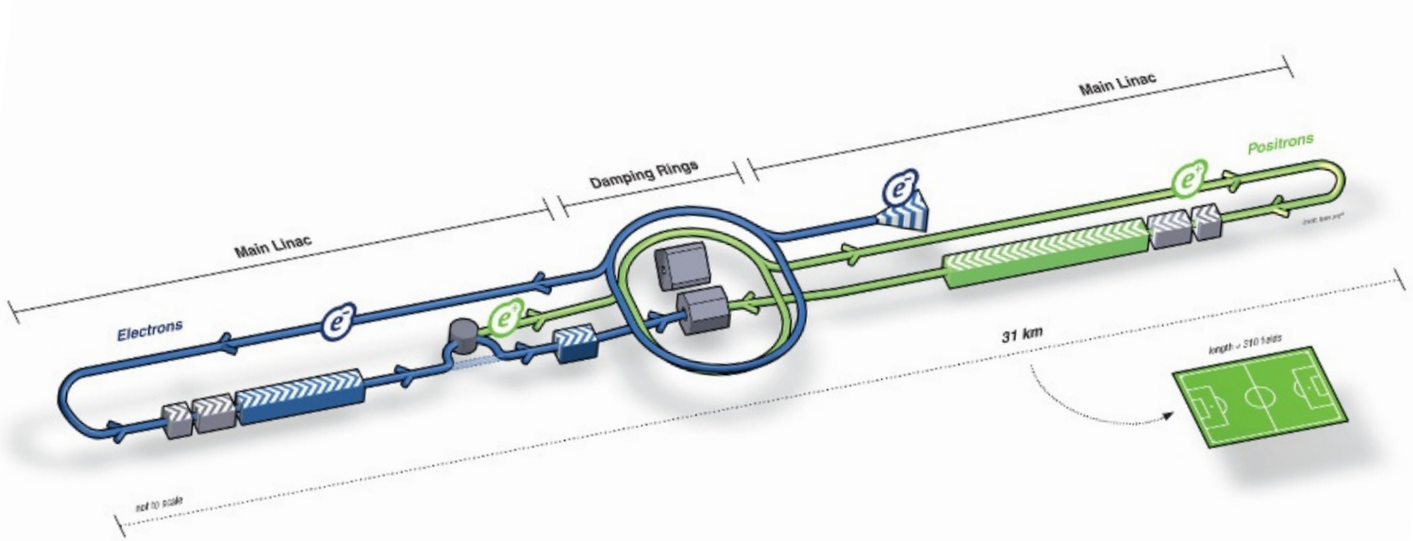
- Precision measurement of standard model particles
  - Top quark properties (mass, width, asymmetries)
  - Gauge bosons, coupling constants

- Direct and indirect search for possible BSM physics at TeV scale
  - particular strength in the weak sector, complementary to LHC

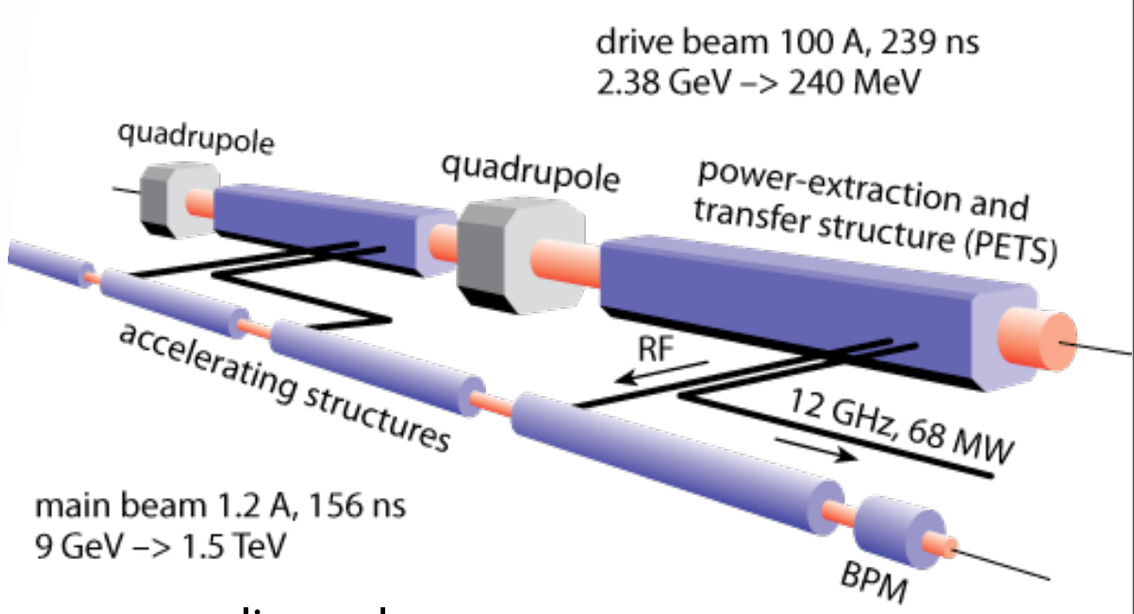
# Introduction

- A lepton collider allows for precision measurements (clean events, well defined initial state)
  - in the TeV range to complement LHC
  - linear to prevent synchrotron radiation energy losses

- Two machine concepts:
  - ILC: superconductive accelerator technology - ready to build
  - CLIC: two-beam accelerator for higher energies - still in development




source: linearcollider.org

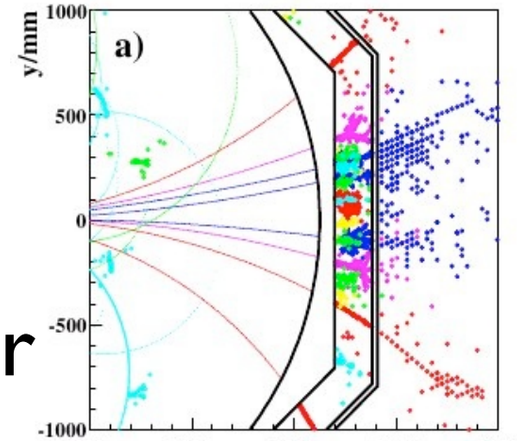



source: clic-study.org

# Detectors

- We need beyond state-of-the-art detector systems, including more sensitive calorimeters

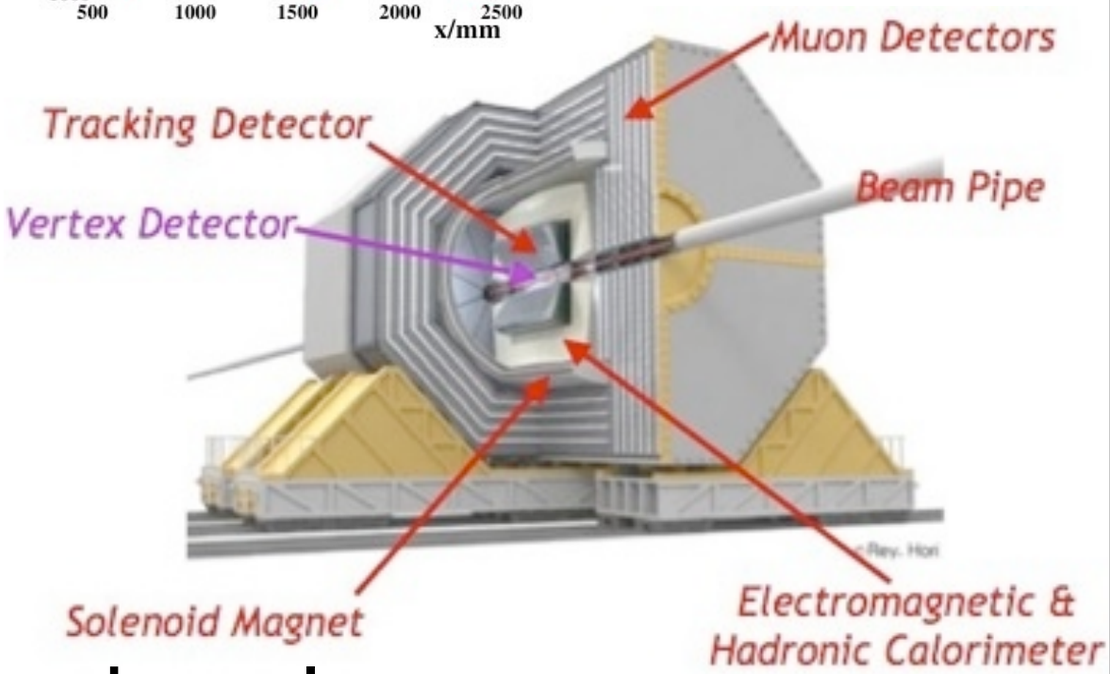
- Event reconstruction based on particle flow algorithms
  ➔ High granularity in the calorimeter




source: ilcild.org

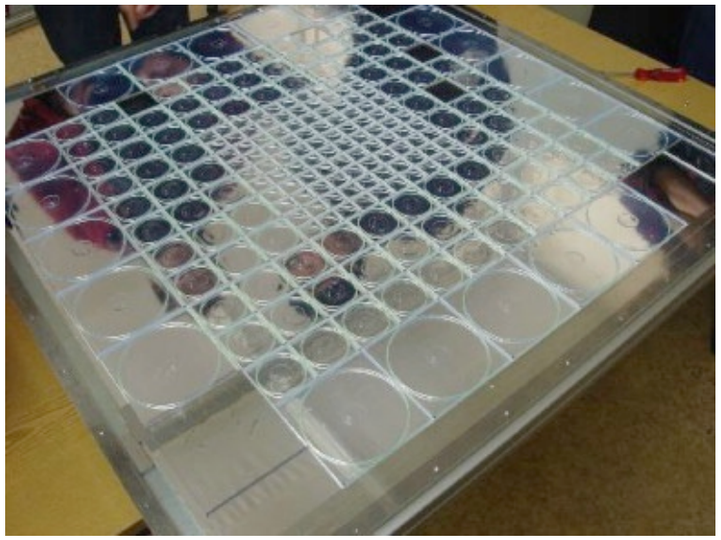
- Precise timestamping of all the subdetectors
  (to cope with background at CLIC)

- Use of tungsten as absorber for the hadron calorimeter of a multi-TeV collider to fit in the magnet barrel

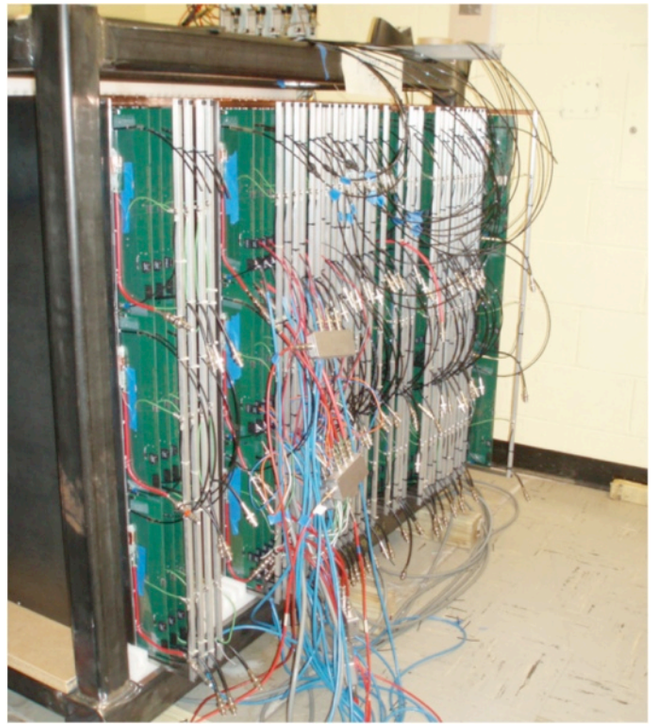


# Hadronic Calorimeter

- Several concepts for the hadronic calorimeter:
  - Plastic scintillators with SiPMs and analog readout (AHCAL)



  - RPCs with digital readout (DHCAL)



38-layer prototype with steel or tungsten absorber

- RPCs with semidigital readout (SDHCAL)

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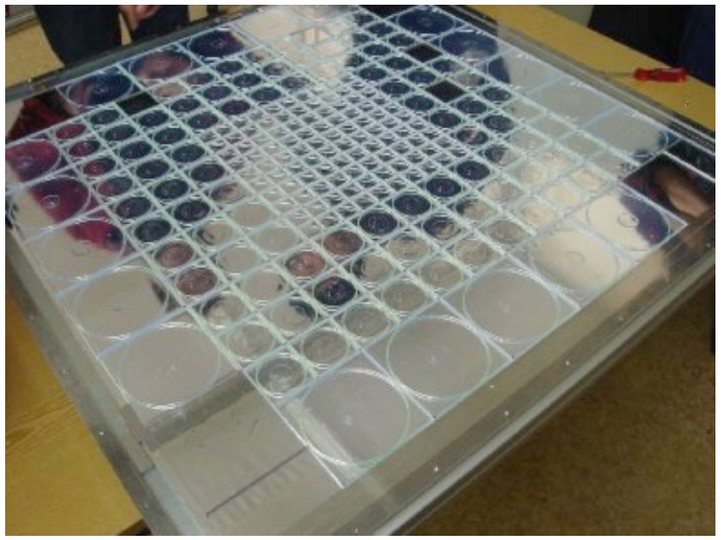

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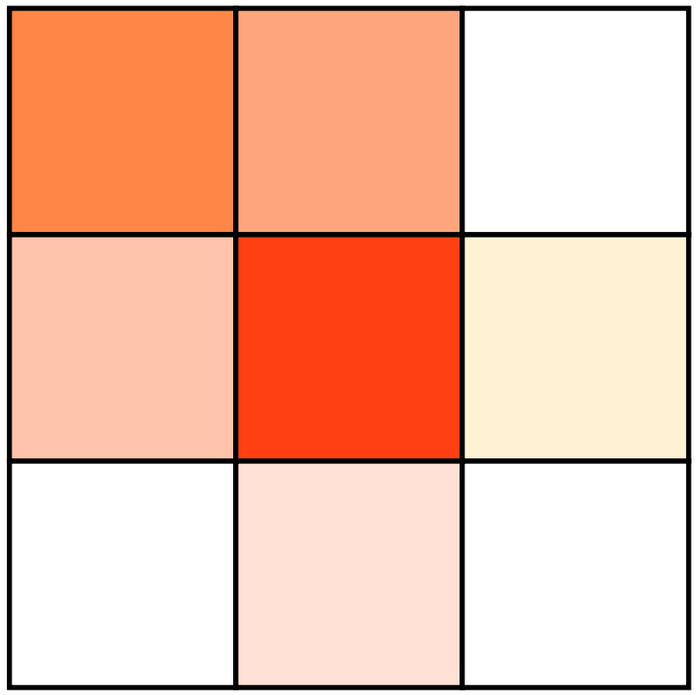

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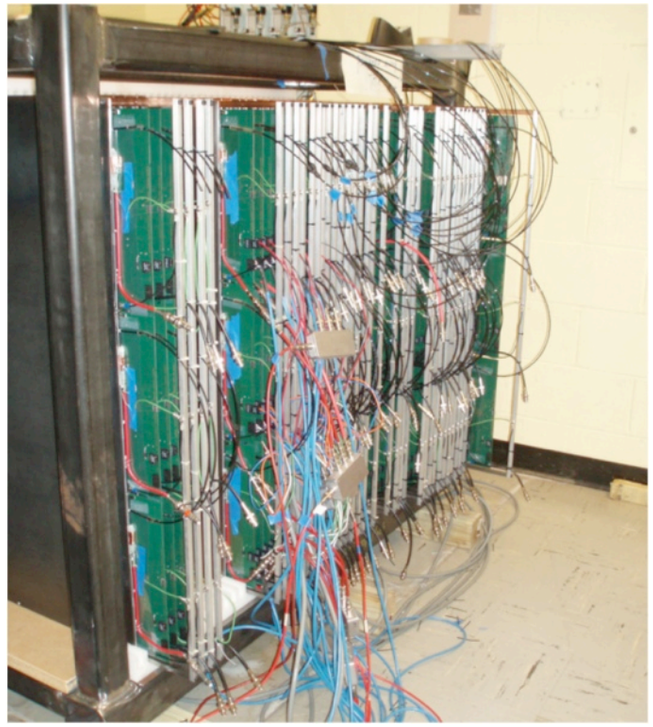

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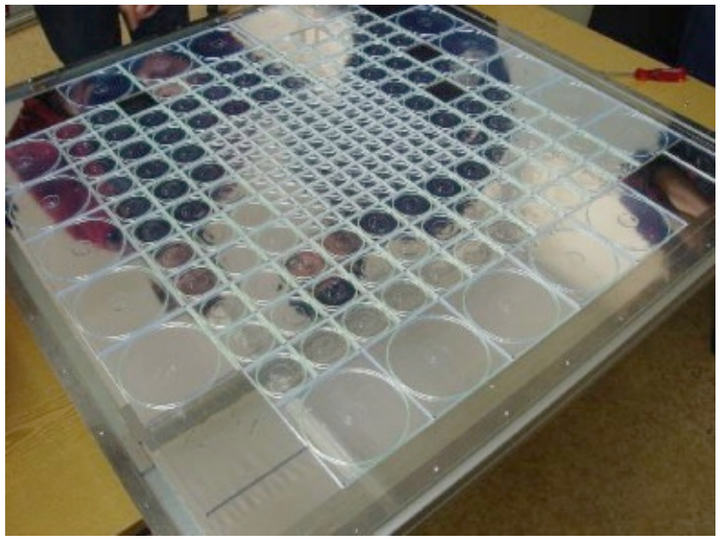

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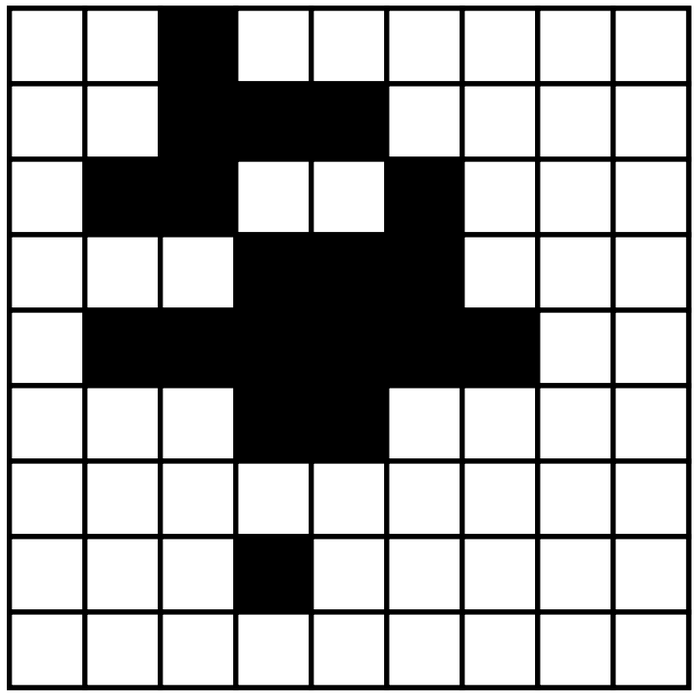

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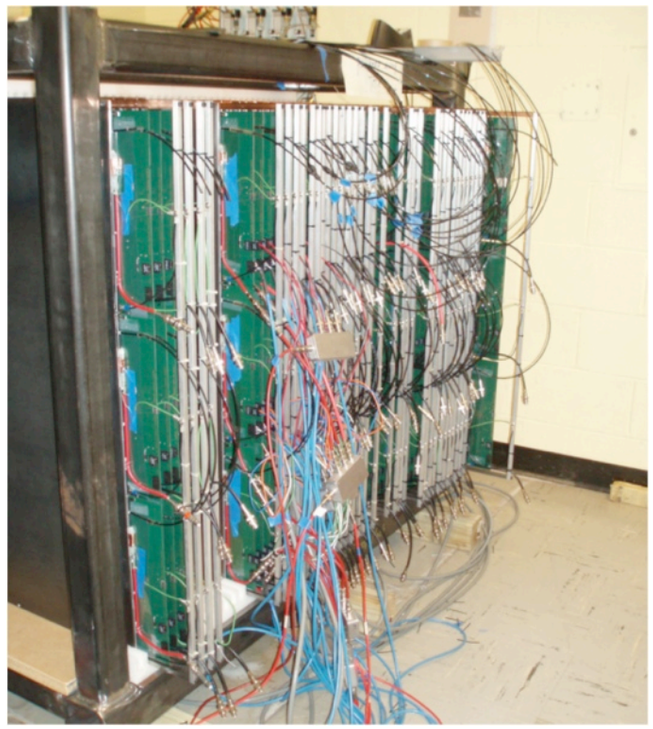
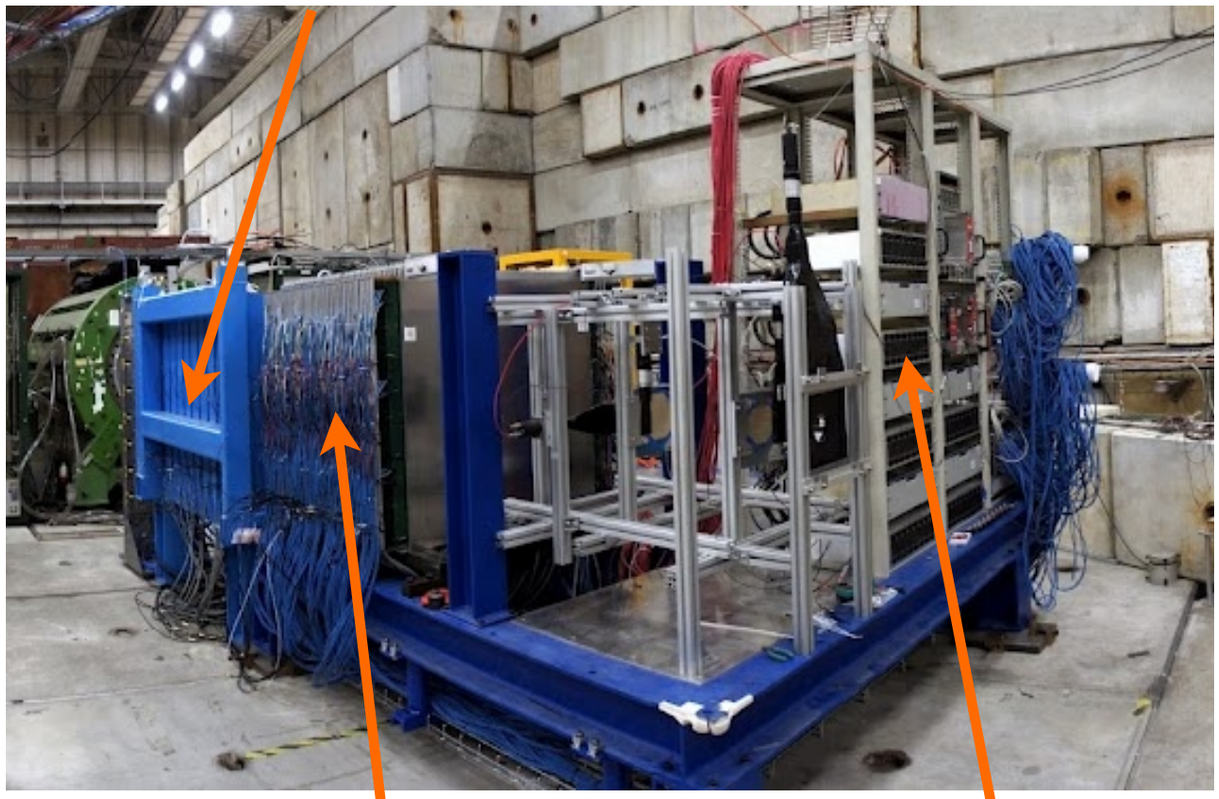


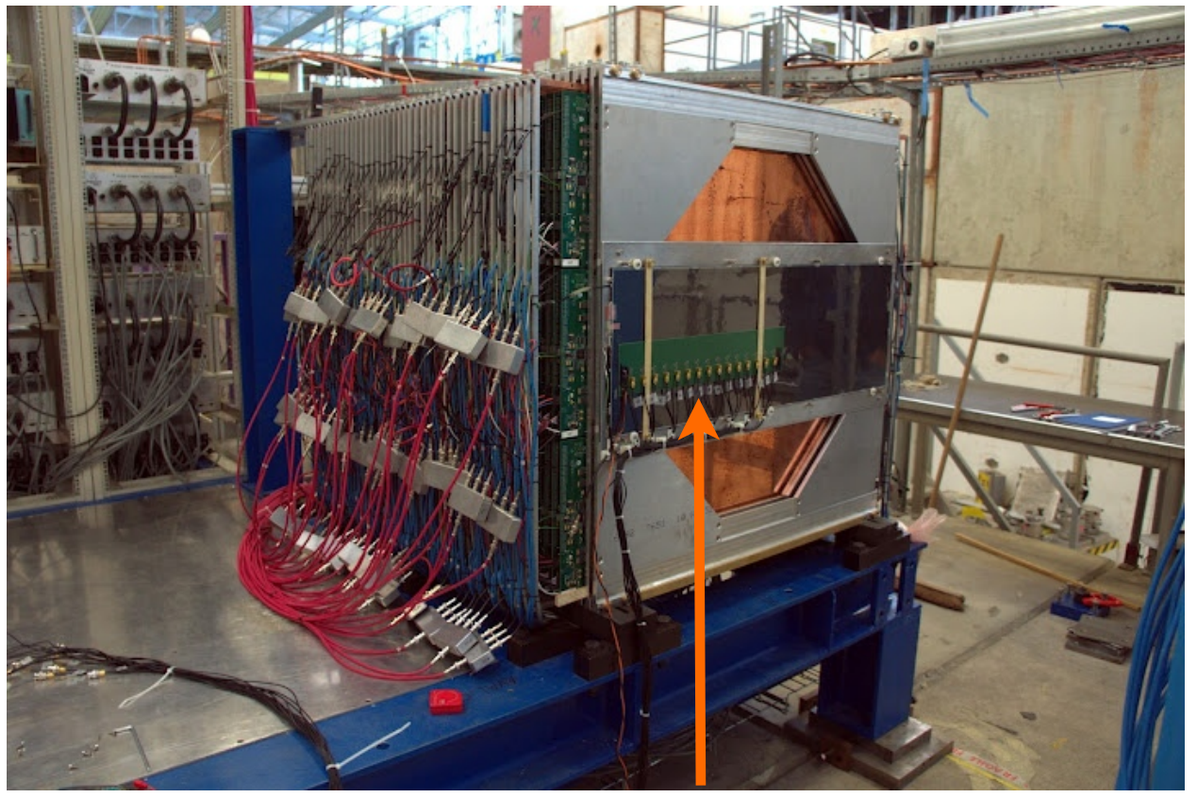
- RPCs with semidigital readout (SDHCAL)

# The FastRPC setup

## Experimental setup in place at CERN PS facility

### Tail catcher with RPC readout

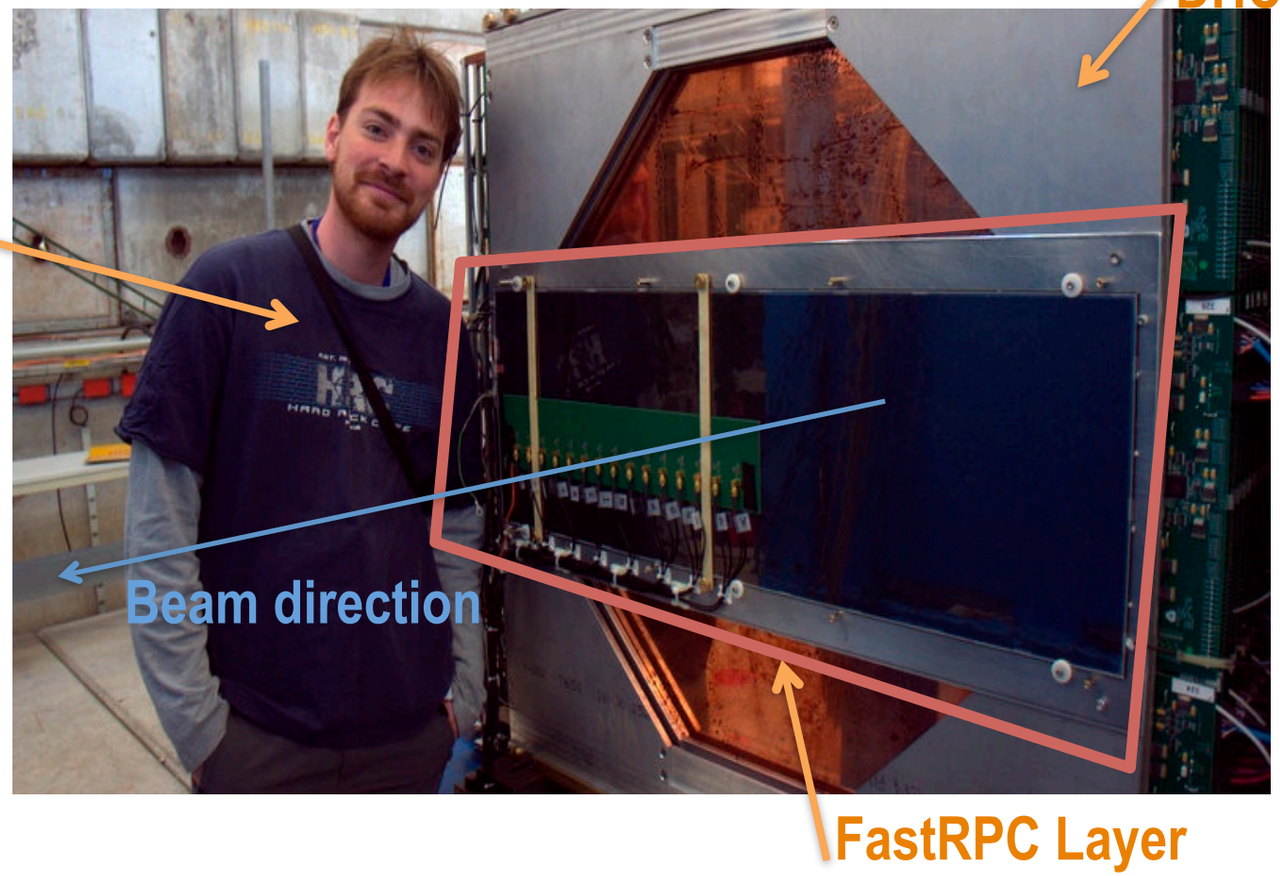



Almost 500000 channels in total:
a record for a calorimeter system!

# The FastRPC setup

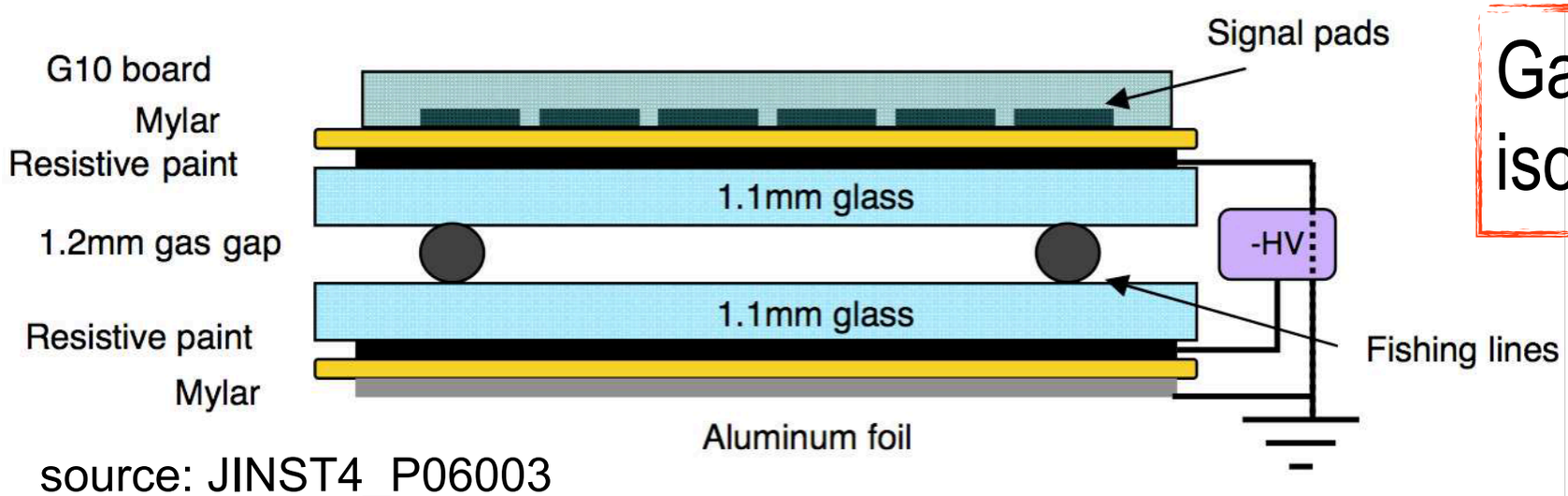
Goal of the experiment: measure the time structure of an hadronic shower using a high time-resolution analog readout




Understand the relevance of the time structure for Particle Flow Algorithms and background rejection

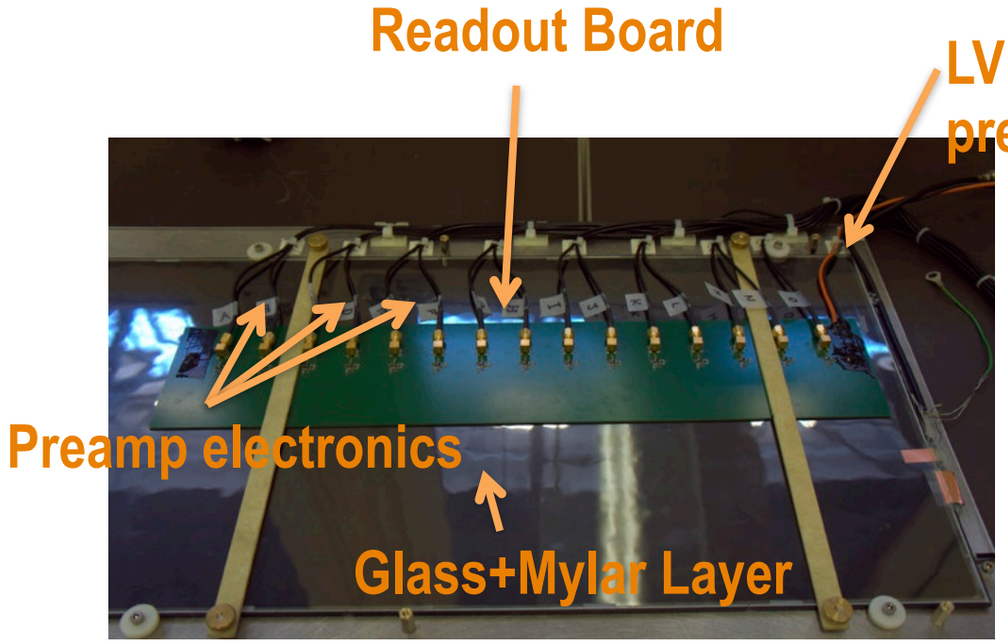
Input for detector simulations

# The Fast RPC setup - detector




source: JINST4_P06003

Gas mixture: R134A 94.5%, isobutane 5.0%, $SF_6$ 0.5%



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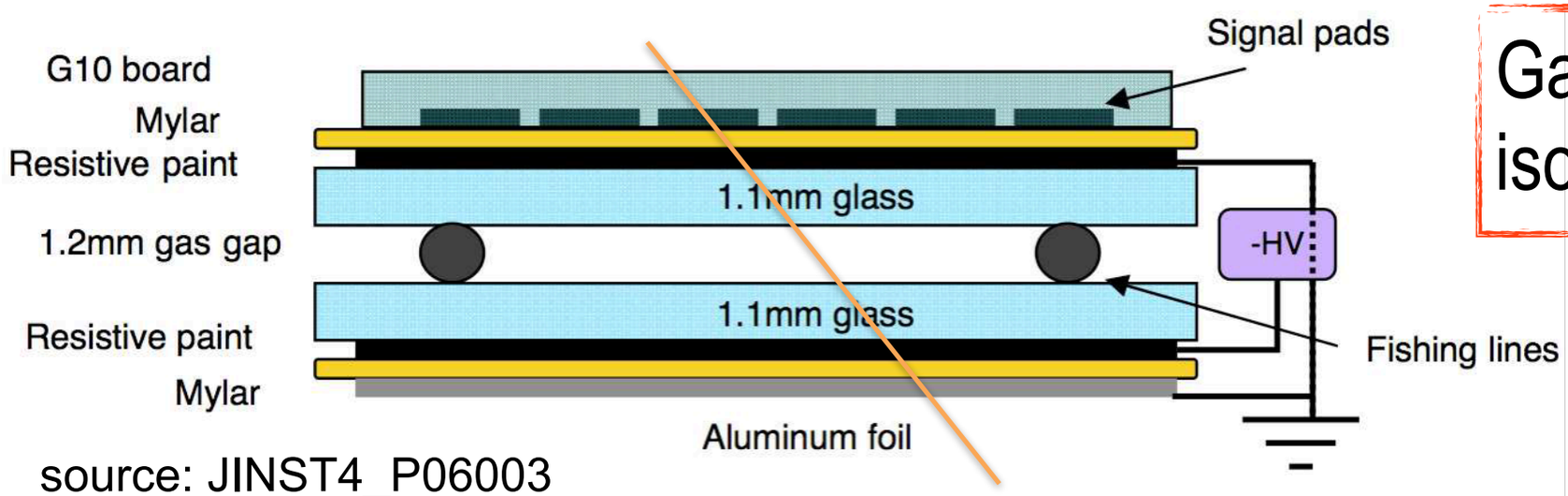


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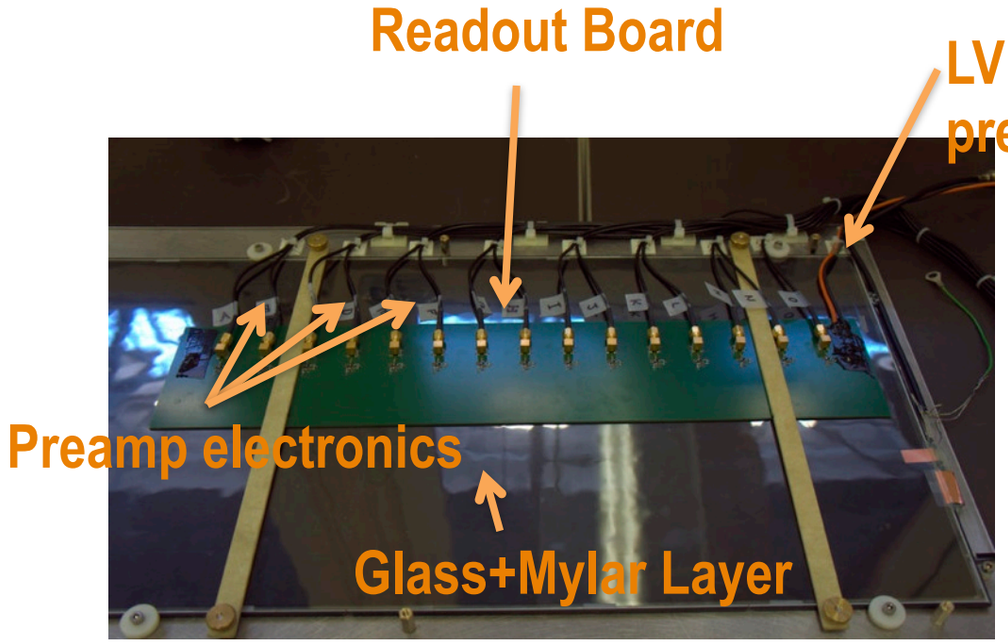

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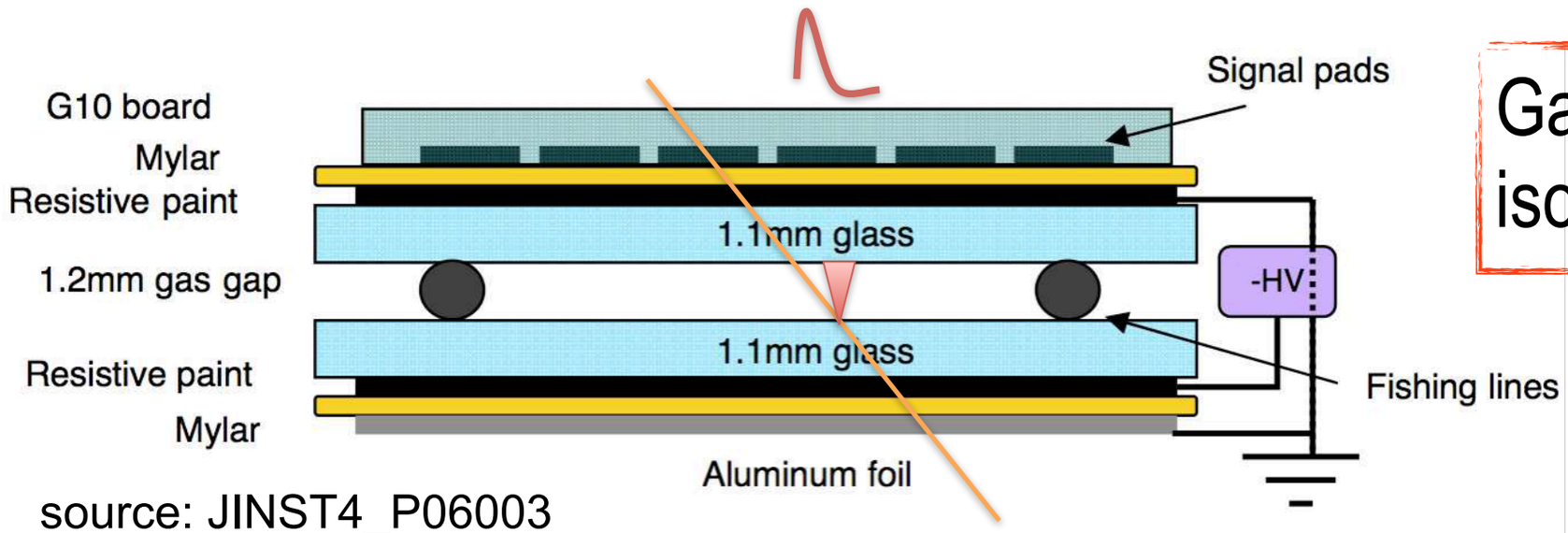


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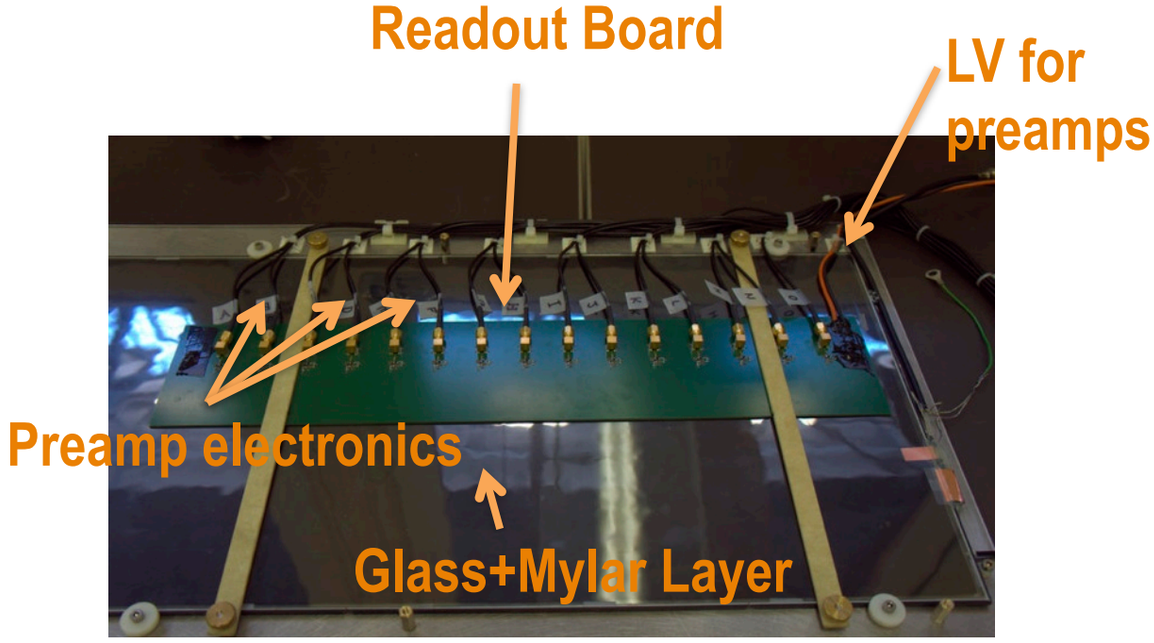

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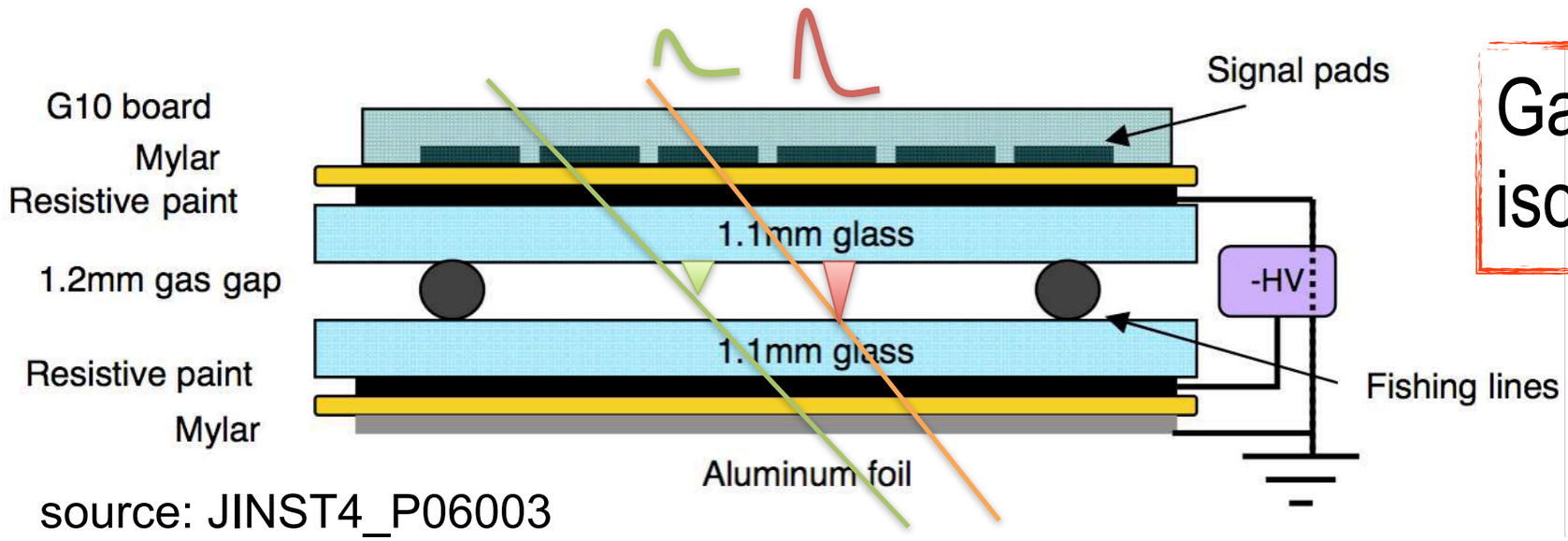


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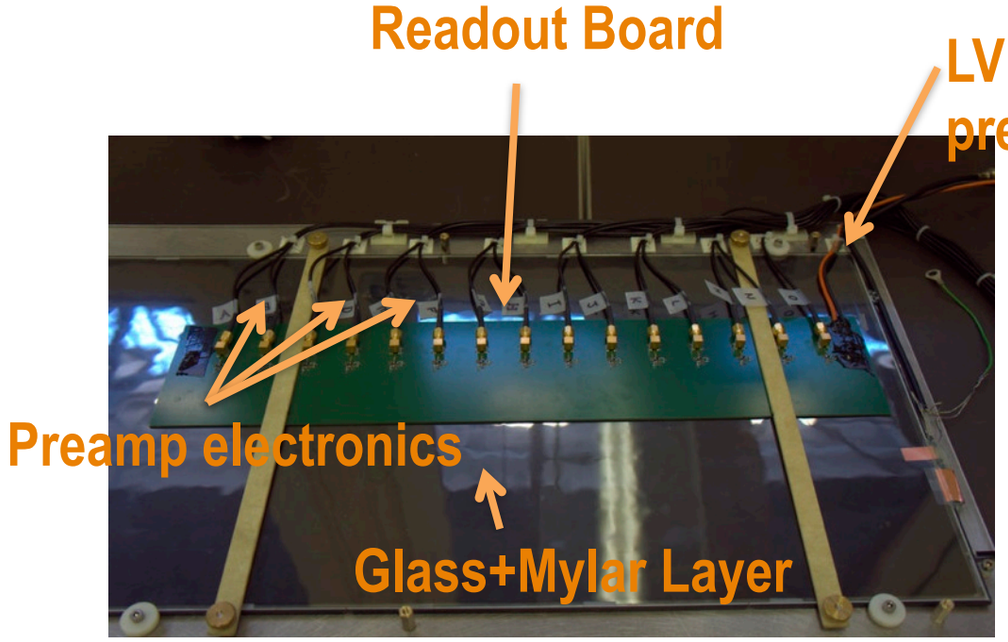

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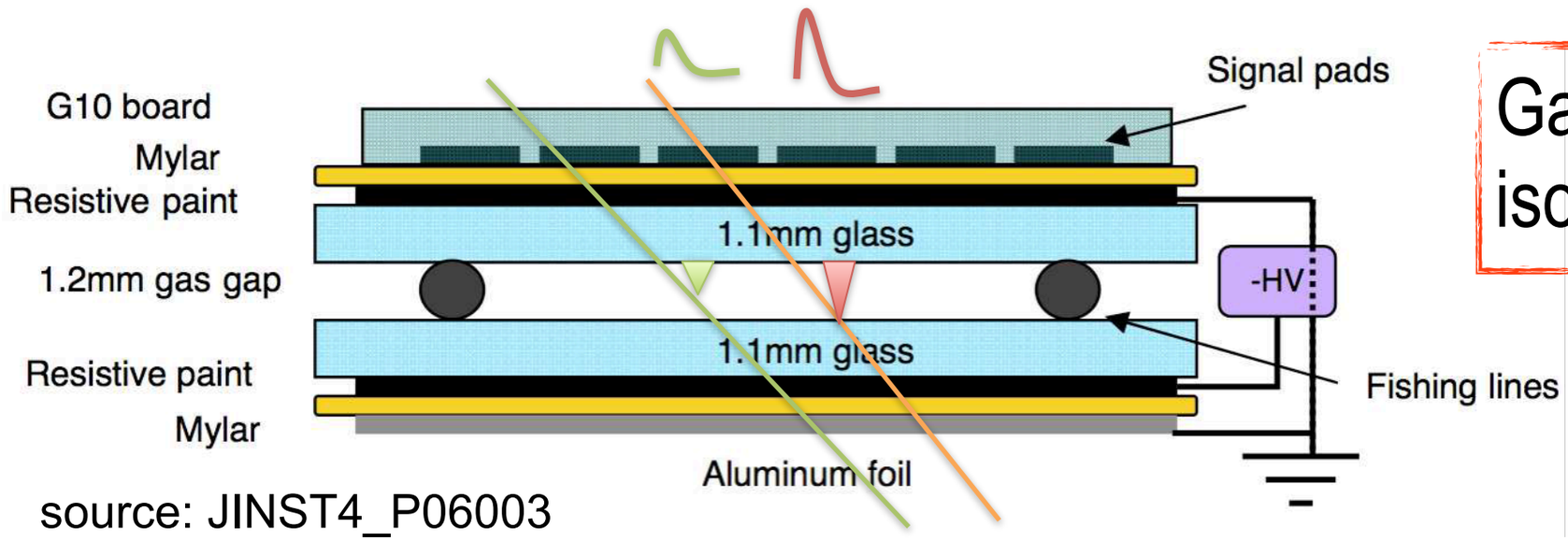


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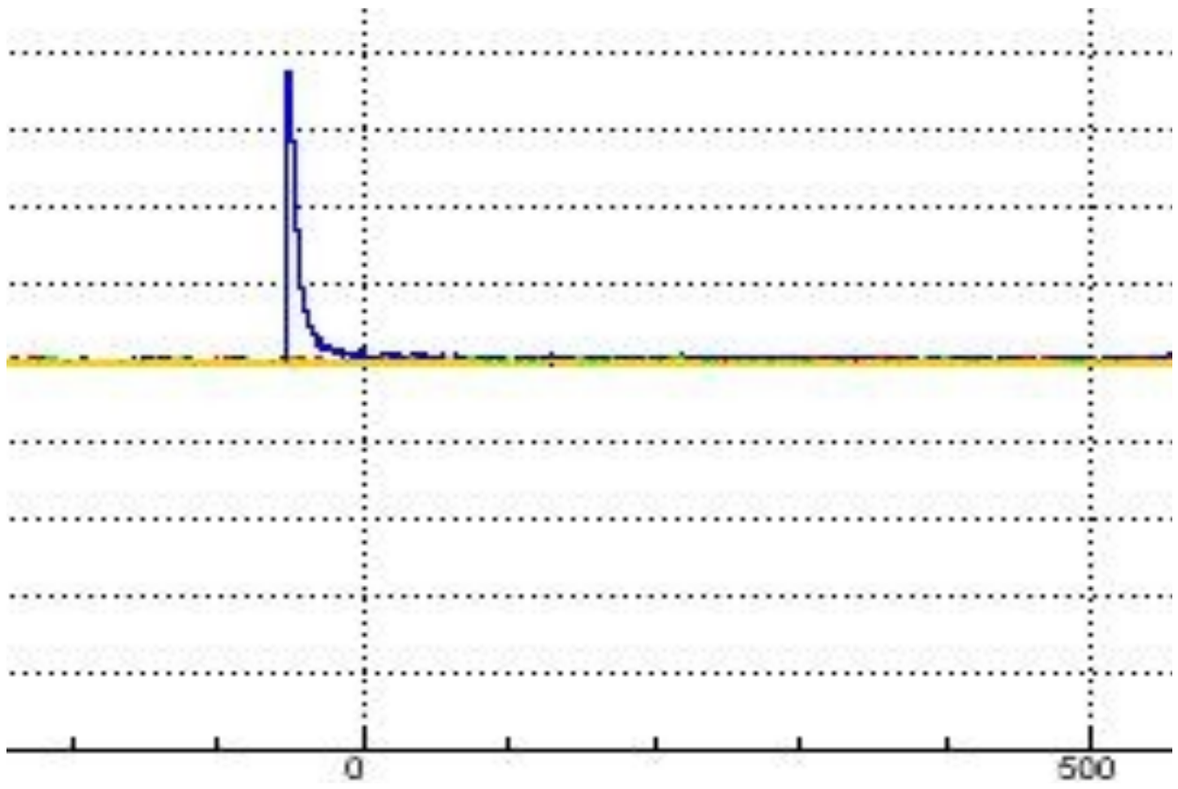
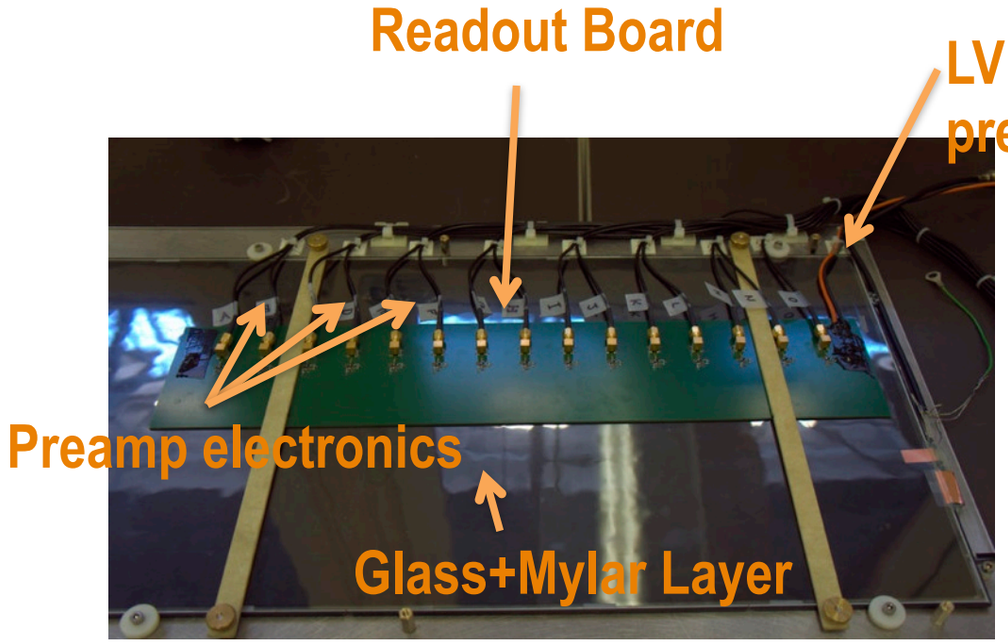
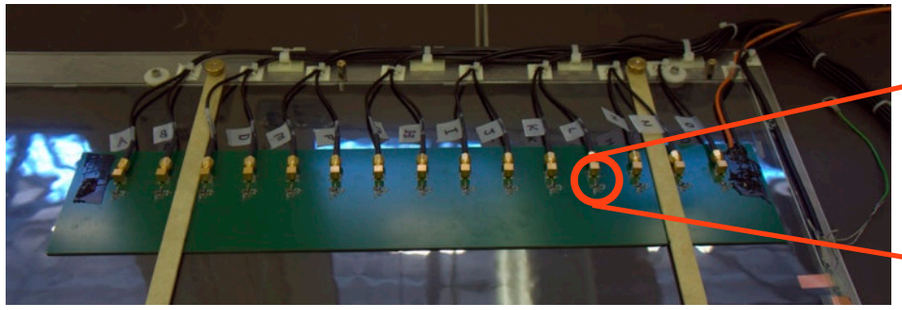


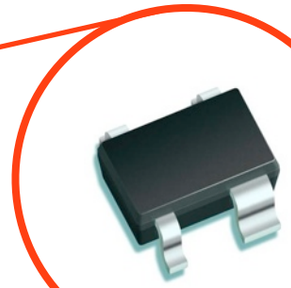



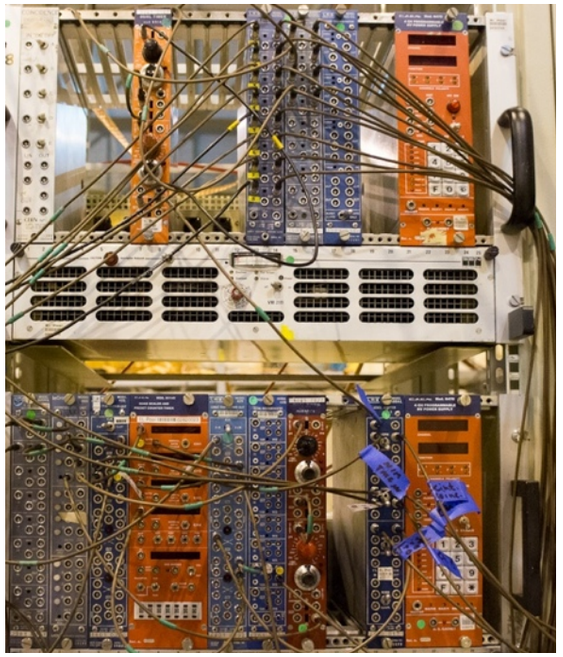
# The Fast RPC setup - readout

15 x 3x3 $cm^2$ pads



Infineon BGA614 preamp





USB

spill info
scintillator triggers
DHCAL synchronization

4xPicoscope 6000 (16 channels in total)
8bit - 1.25GHz - 2.4µs sampling window

# Testbeam at CERN

- Commissioning at PS
  hadrons & muons runs up to 10GeV

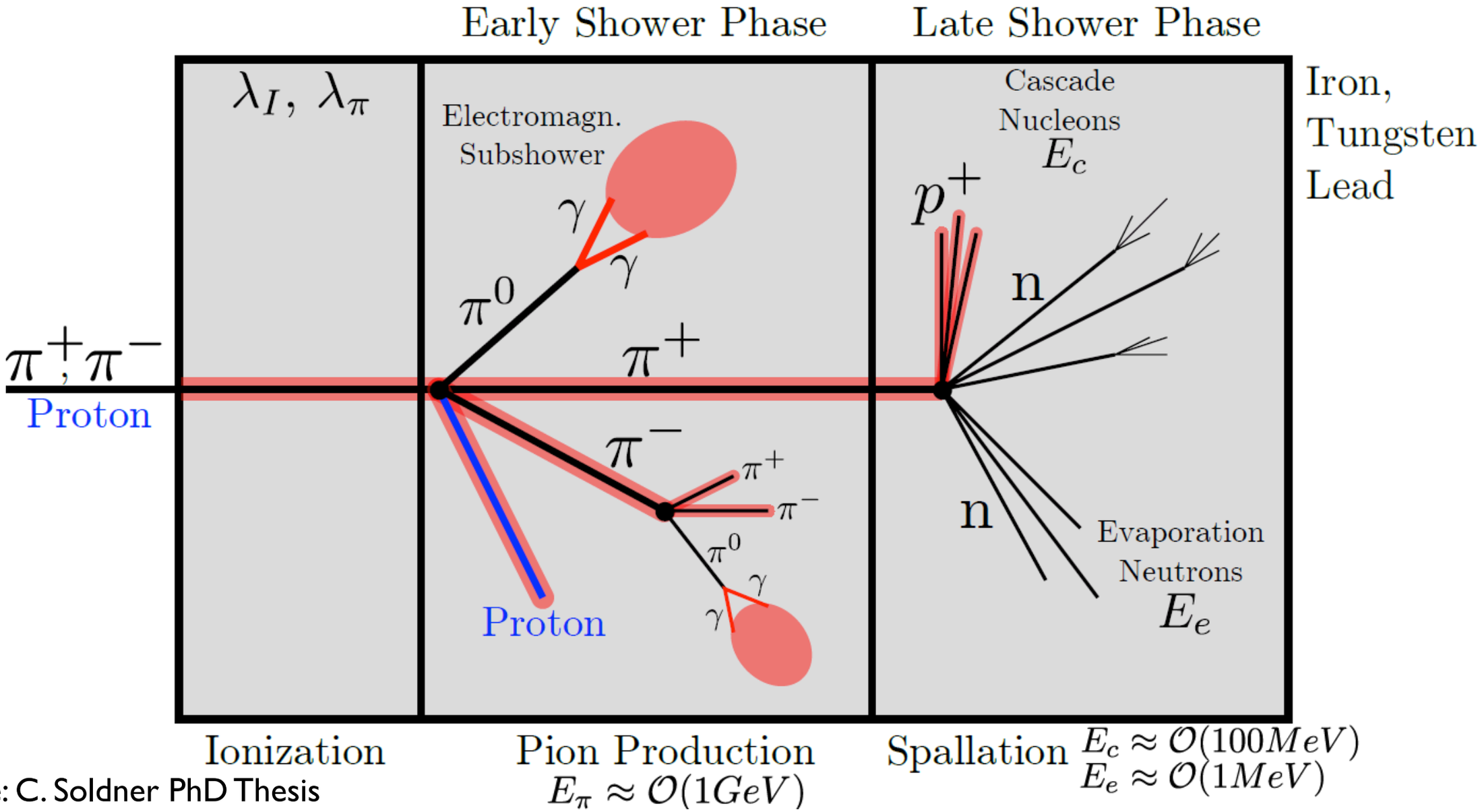
- Very good run with ~1.5Mio muon and ~16Mio hadron triggers

- Physics run at SPS
  hadrons & muons runs up to 180GeV

- ~3Mio muon and ~7Mio hadron triggers (luminosity limited by DHCAL trigger rate)

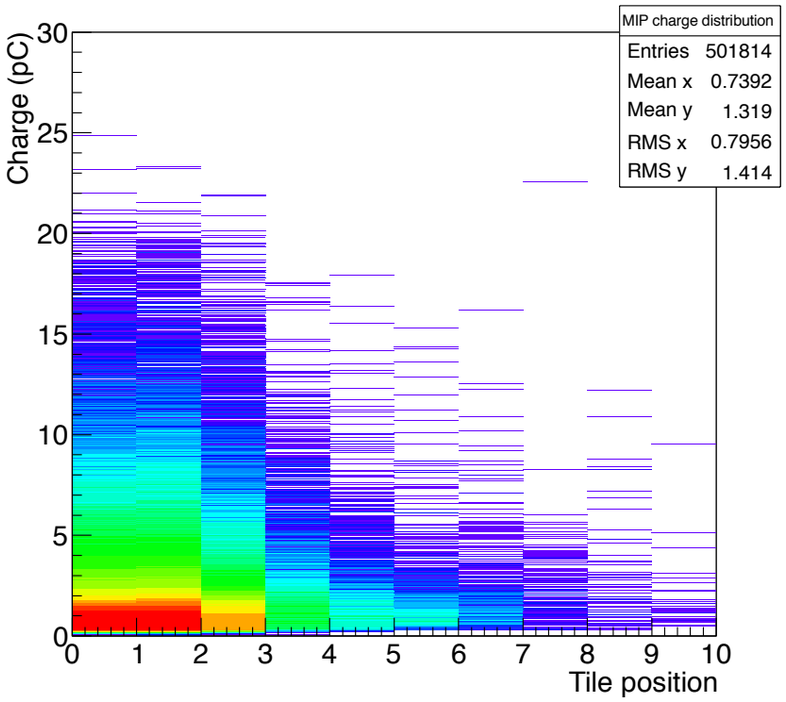
# Hadronic Showers - structure

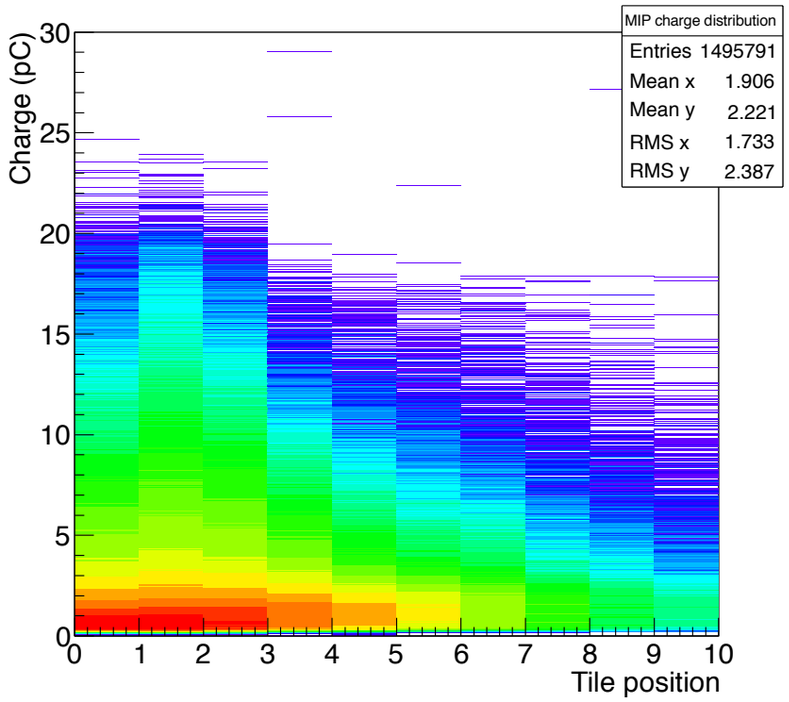
Hydrogen content in a gaseous detector is much lower than in plastic scintillators ➔ less sensitive to neutron late components

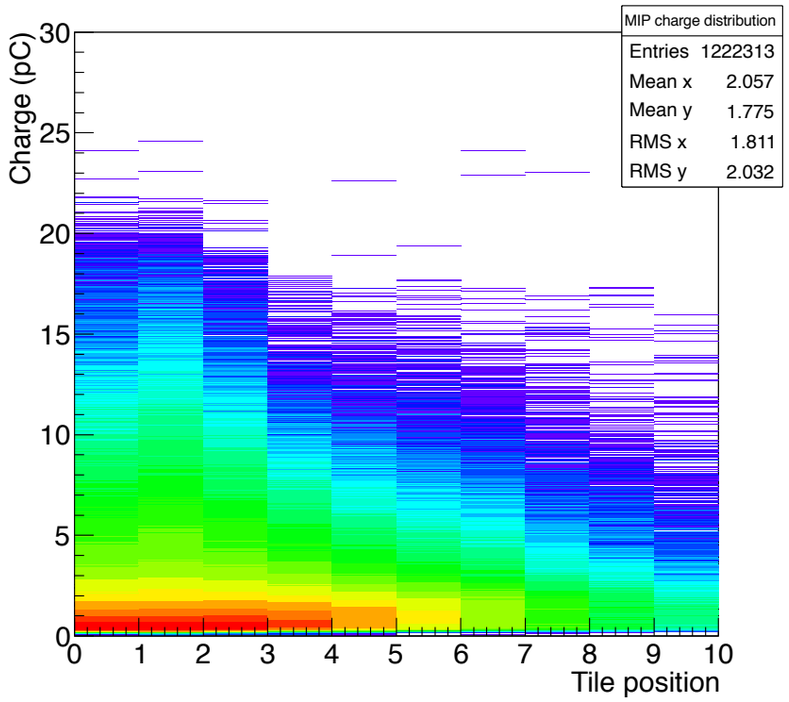


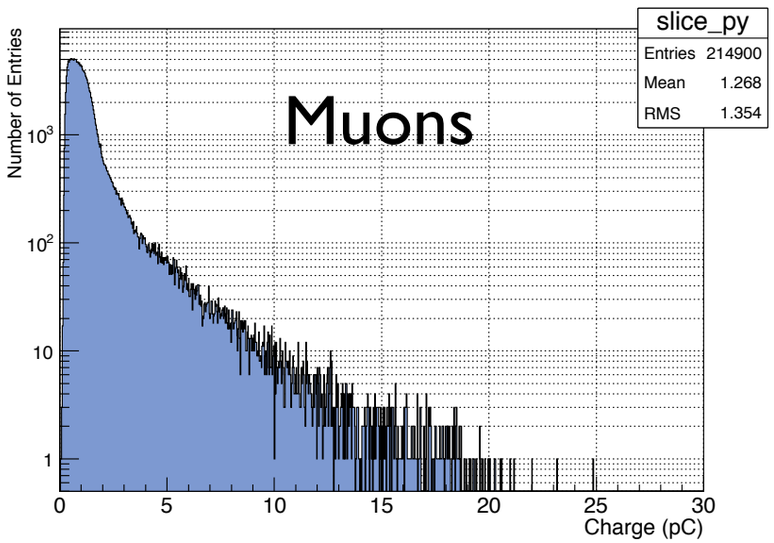

source: C. Soldner PhD Thesis

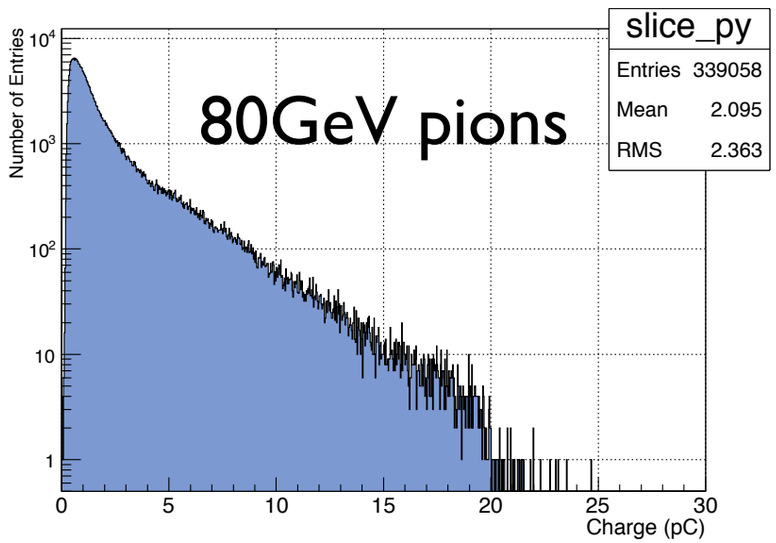
# Data Analysis - charge

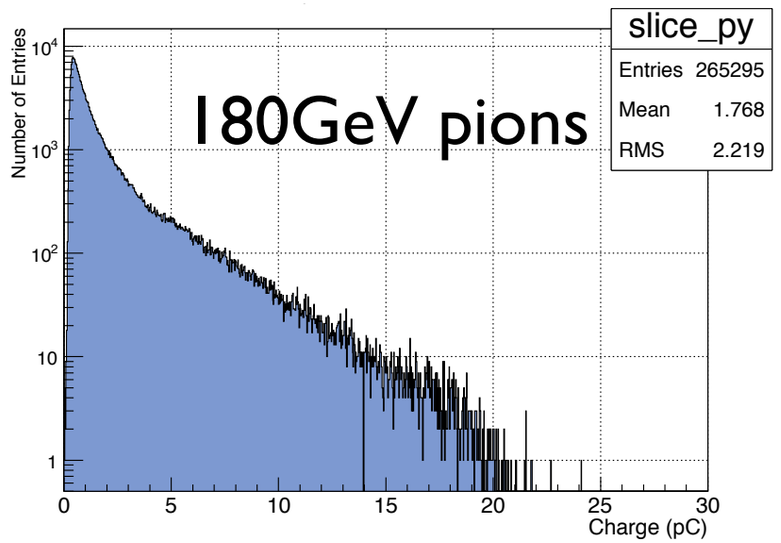



Good agreement with previous measurements from the Argonne group (NIMA A 578:1,88-97(2007)

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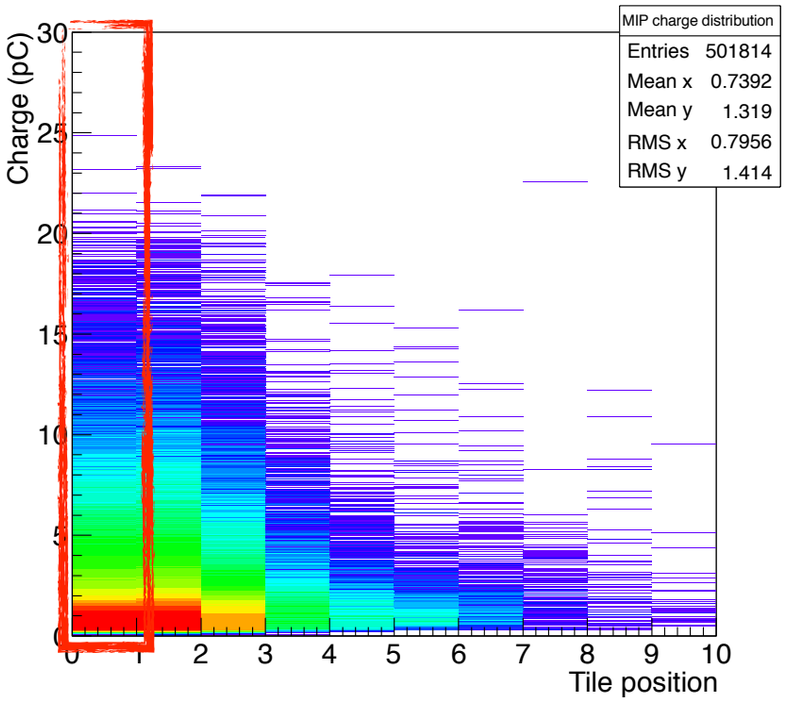


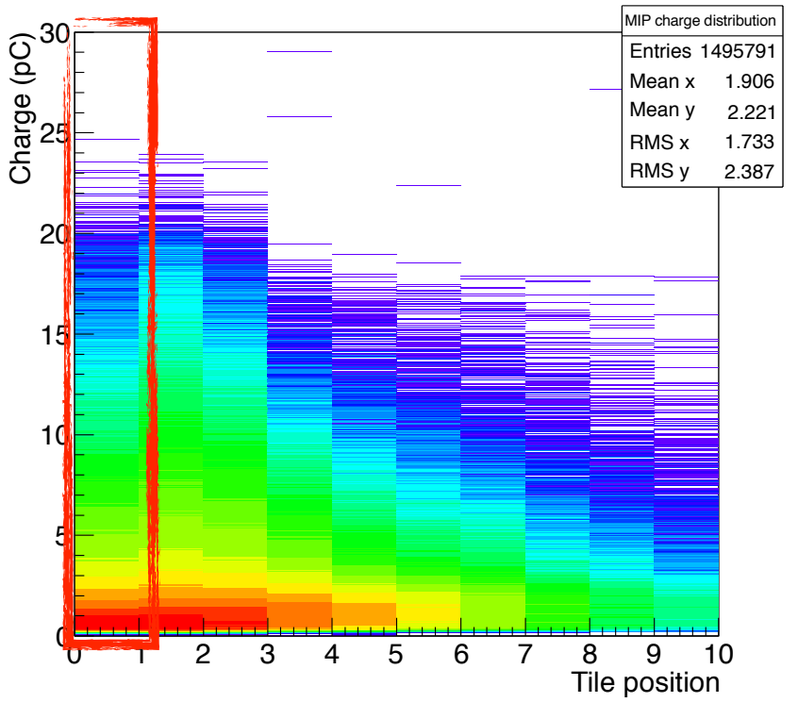


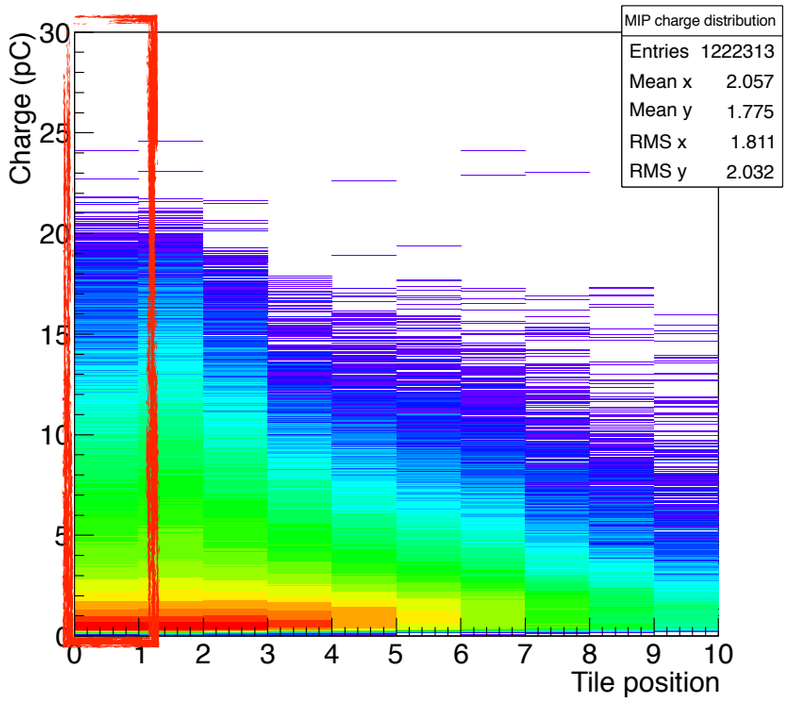


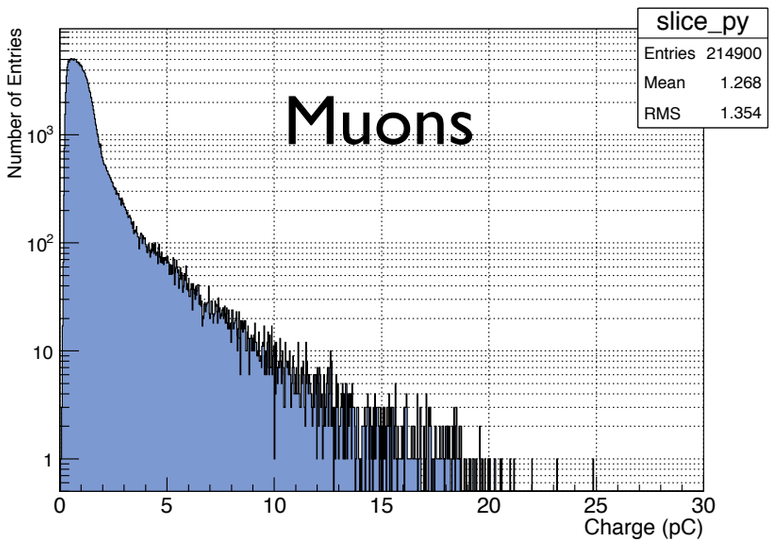


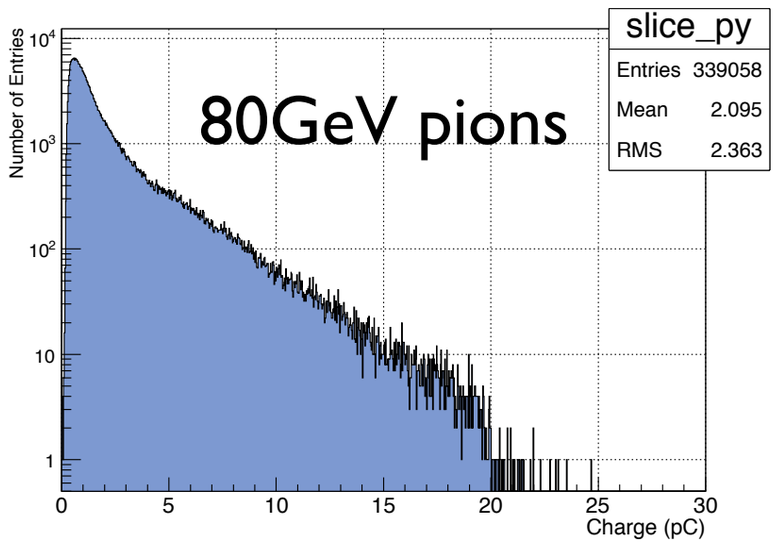


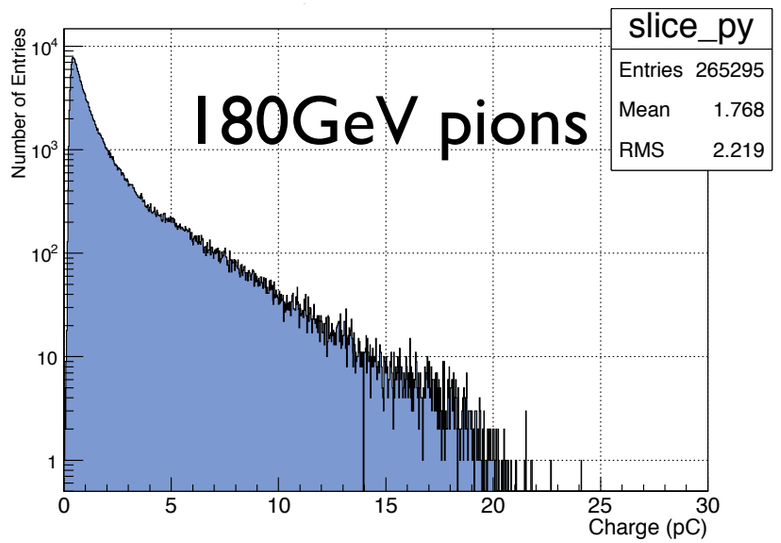


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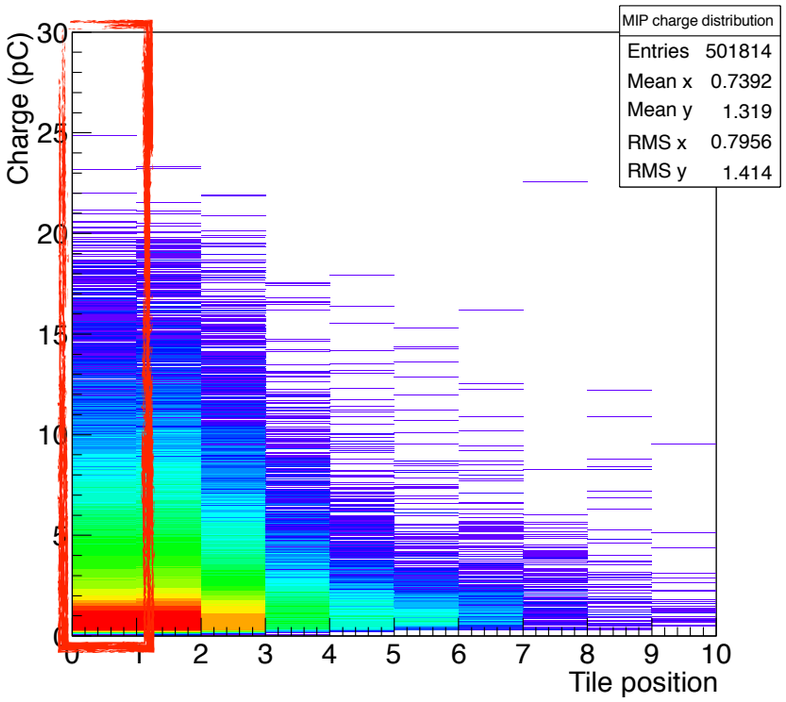
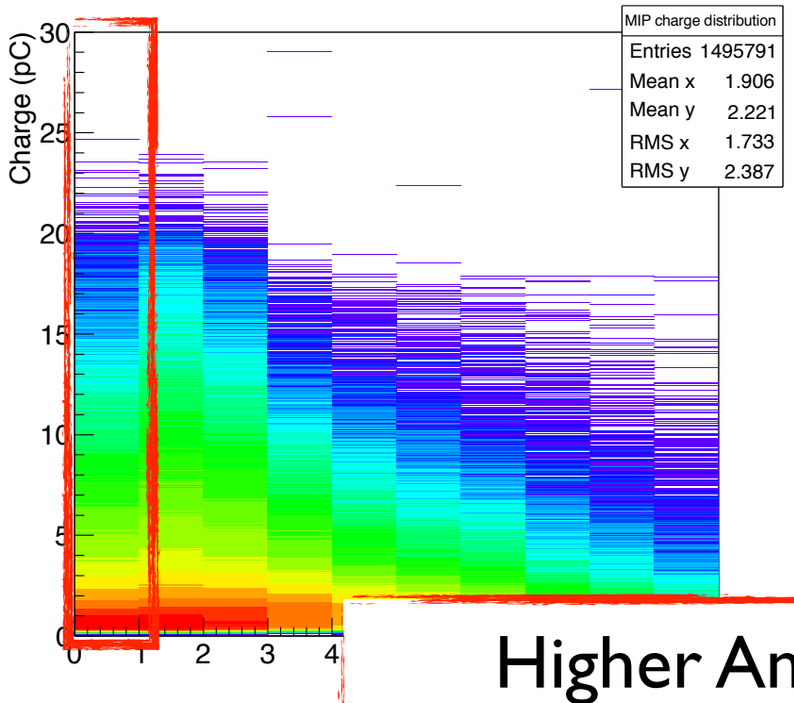
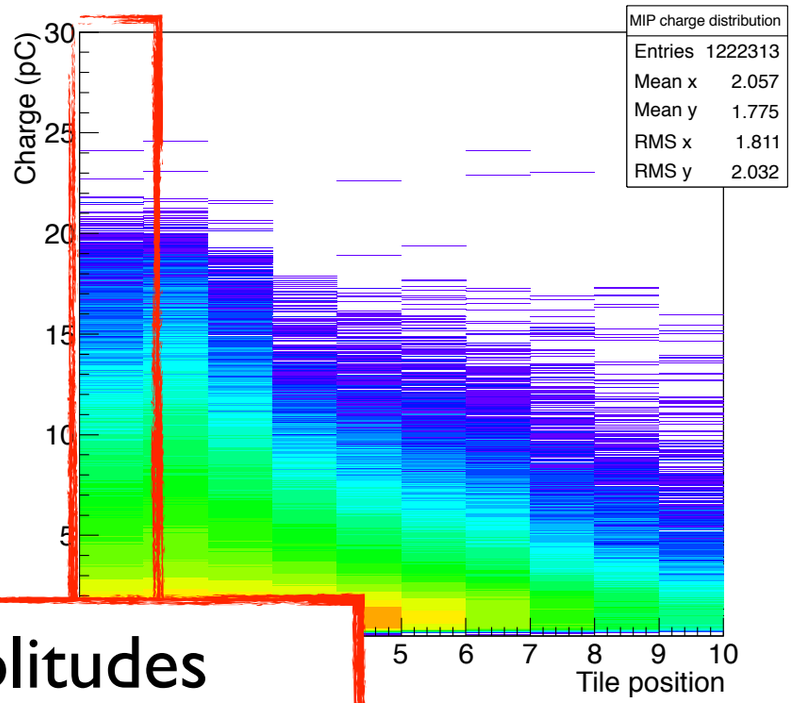
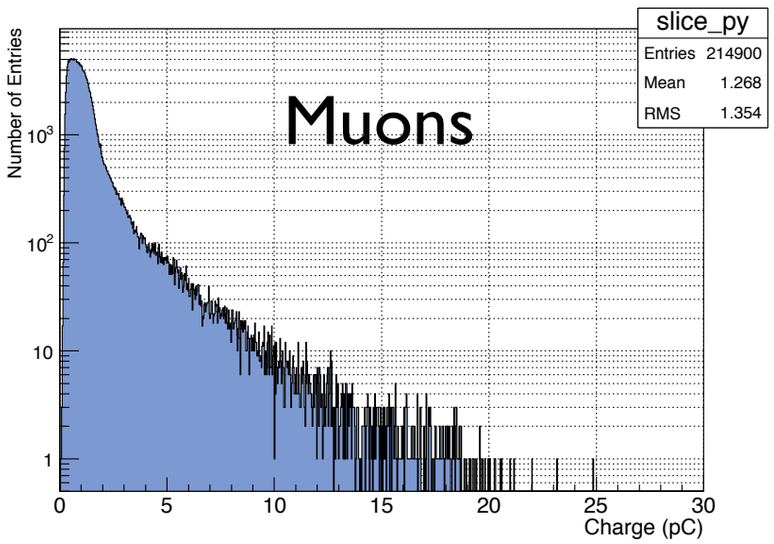
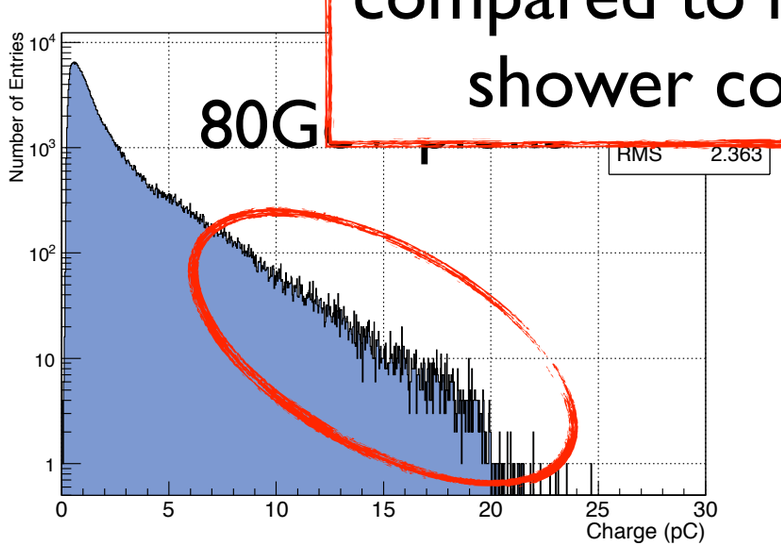


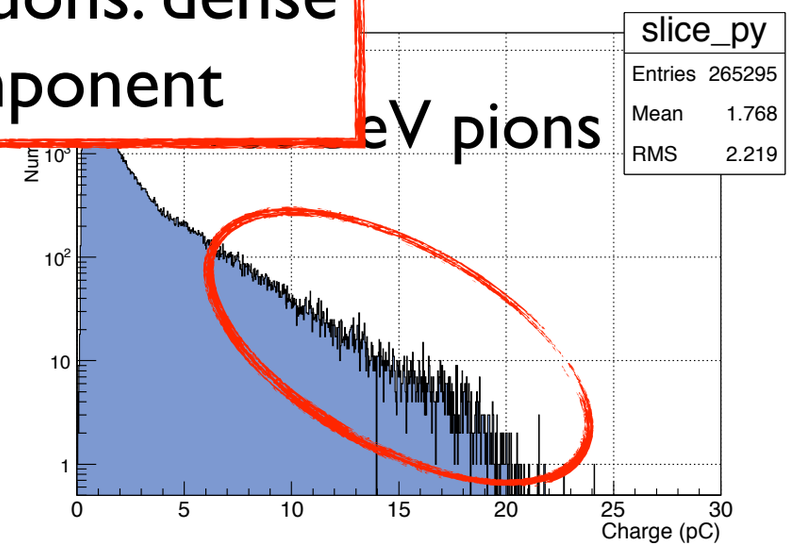




Higher Amplitudes compared to muons: dense shower component

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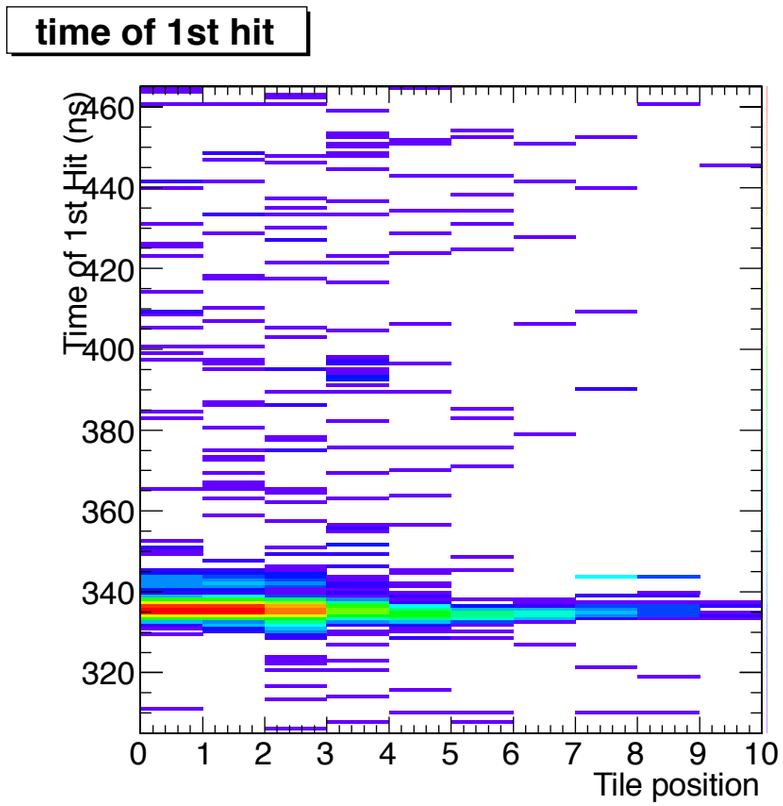
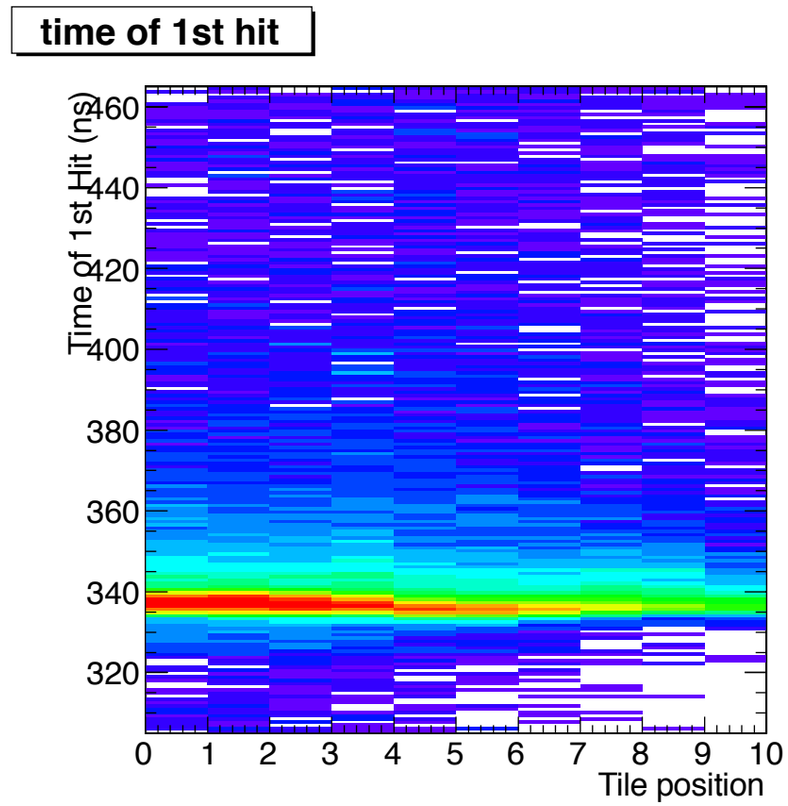
# Data Analysis - Time of 1st Hit

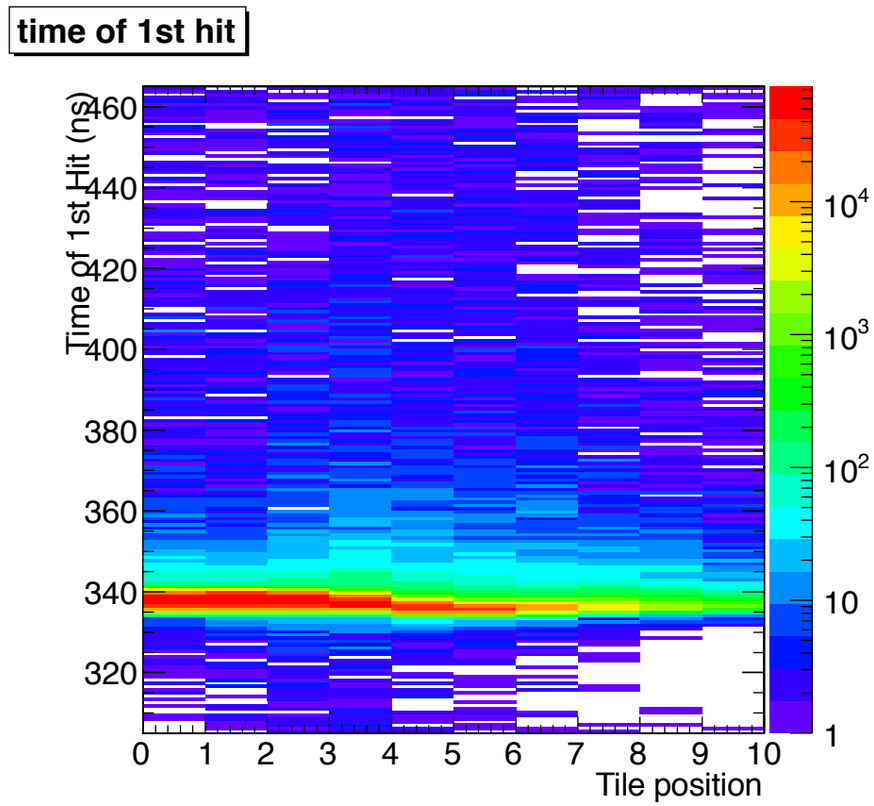
Muons




80GeV pions

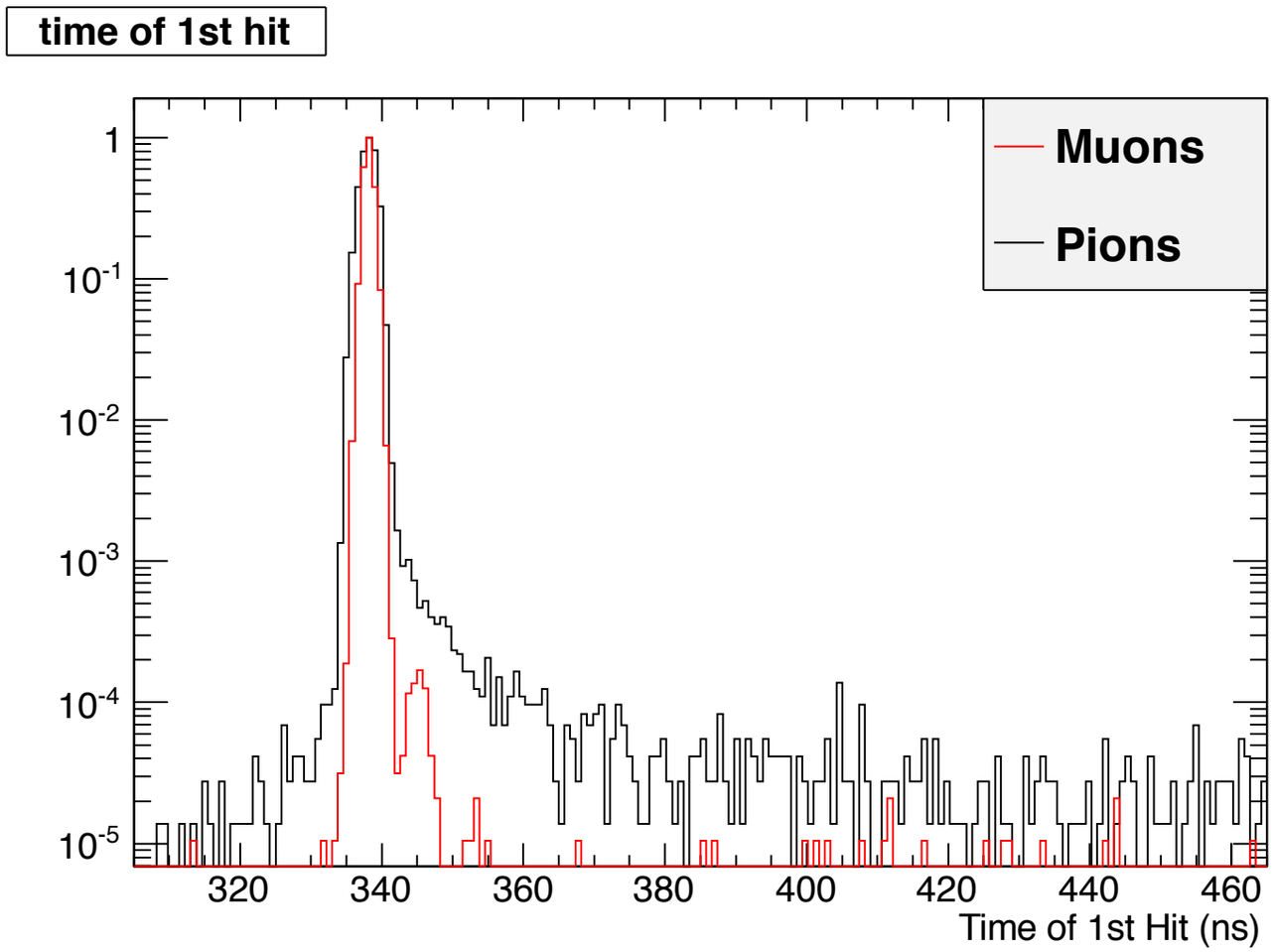



180GeV pions




- Muons are instantaneous
- Hadronic showers show substantial late contribution

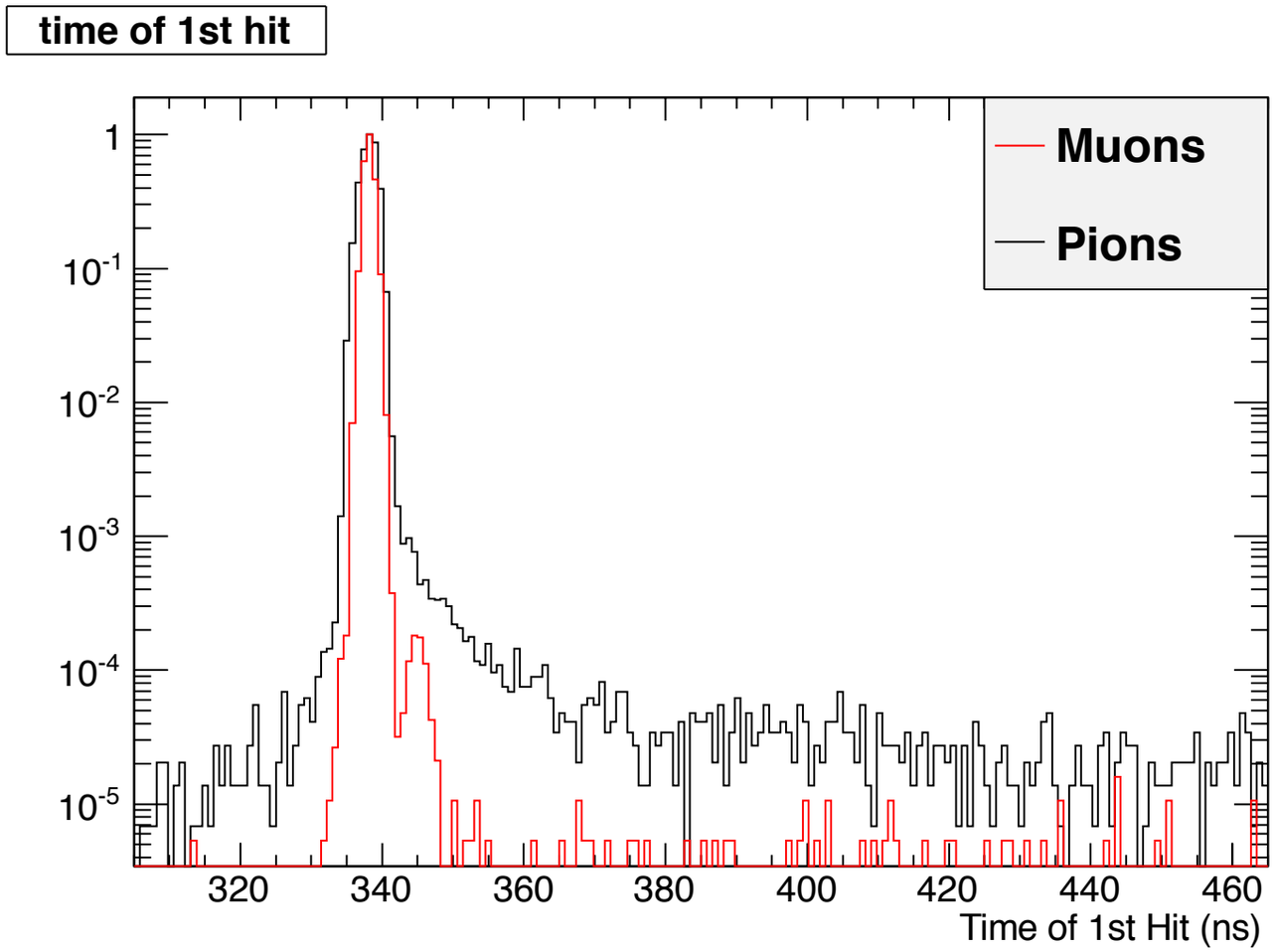
# Data Analysis - Time of 1st Hit




Center of the shower: Dominated by instantaneous contribution from relativistic particles, including muons and punch-through pions

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

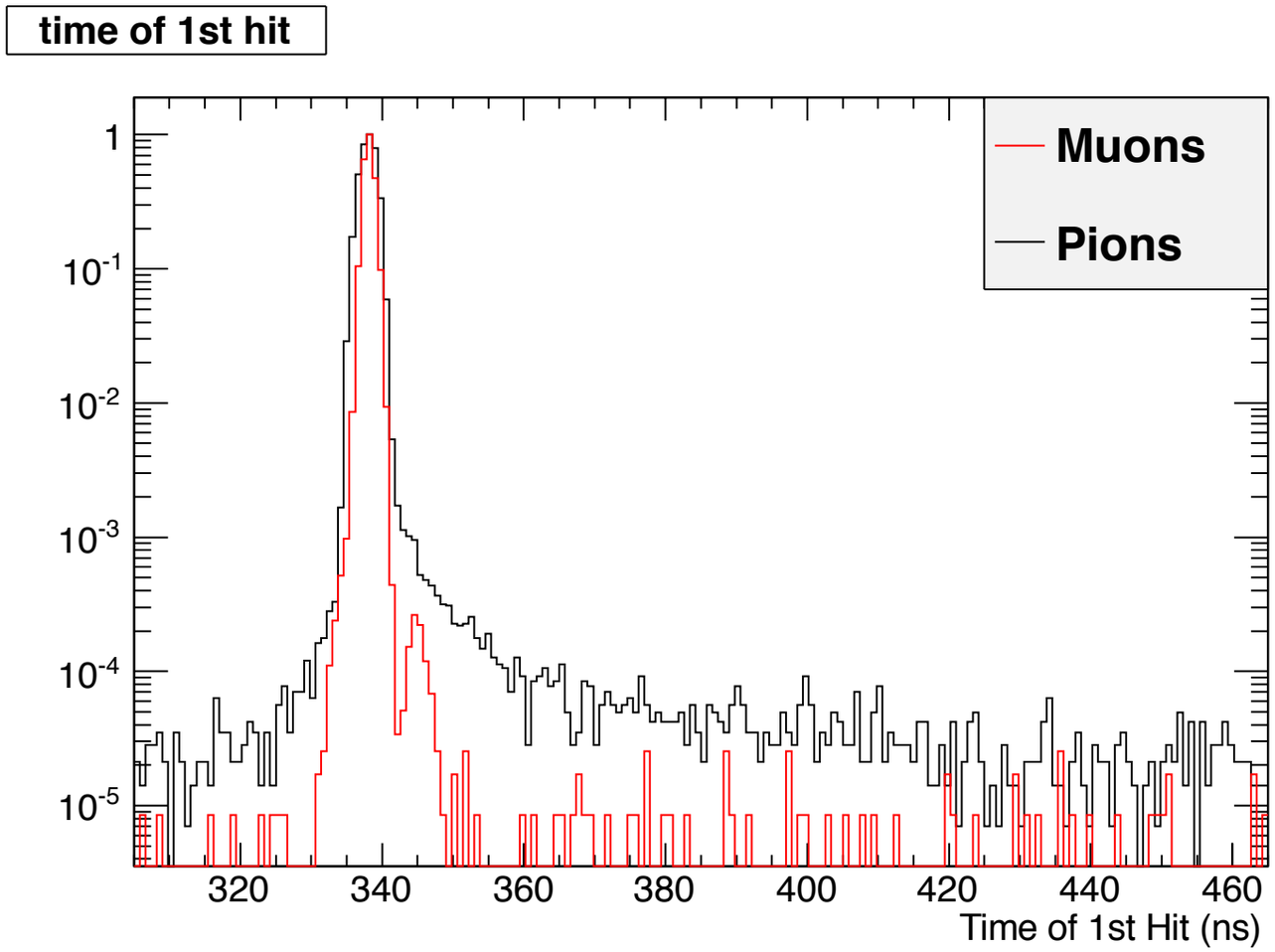
# Data Analysis - Time of 1st Hit




3cm from center:
still lot dominated by
instantaneous components

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

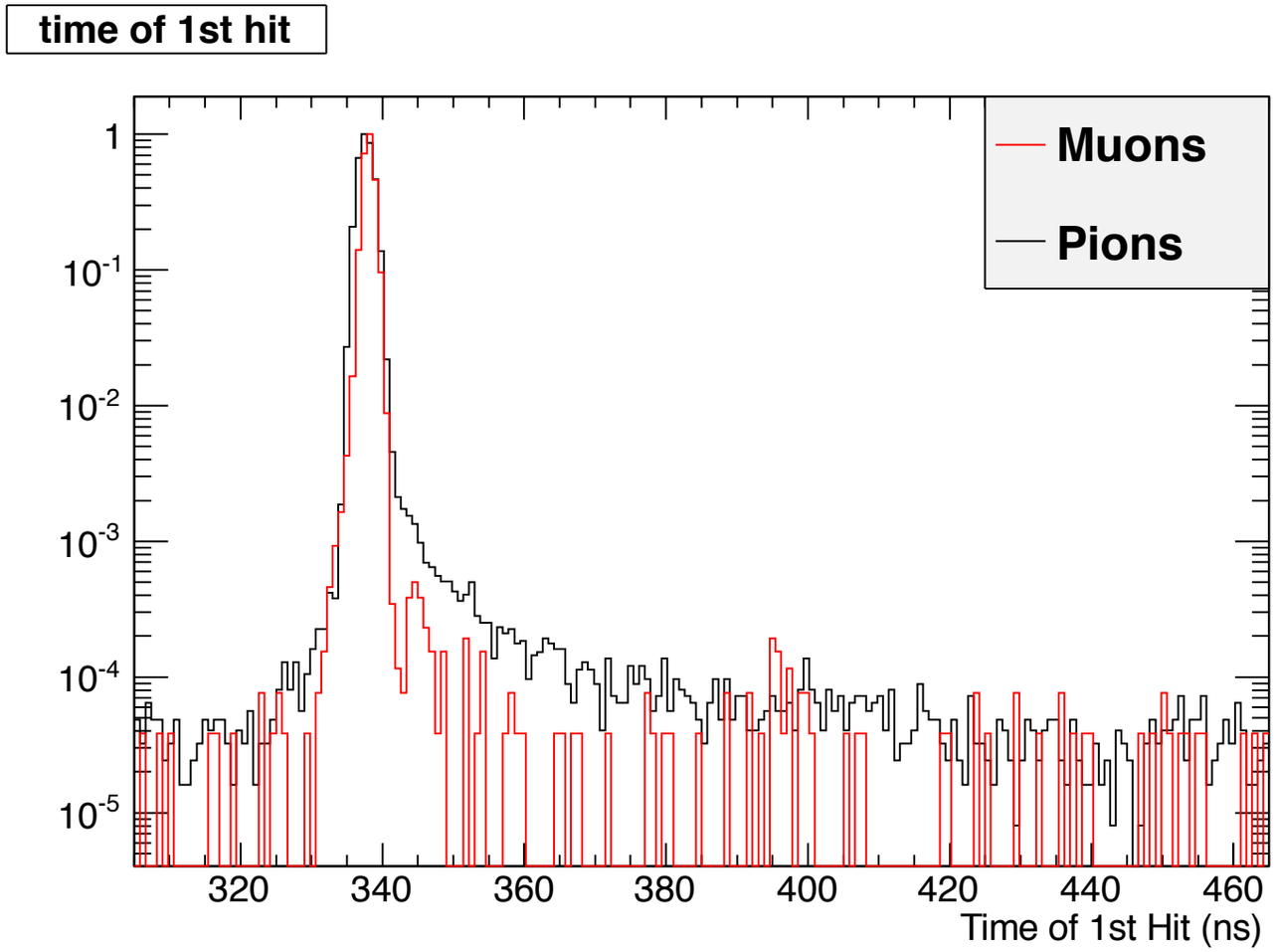
# Data Analysis - Time of 1st Hit




6cm from center

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

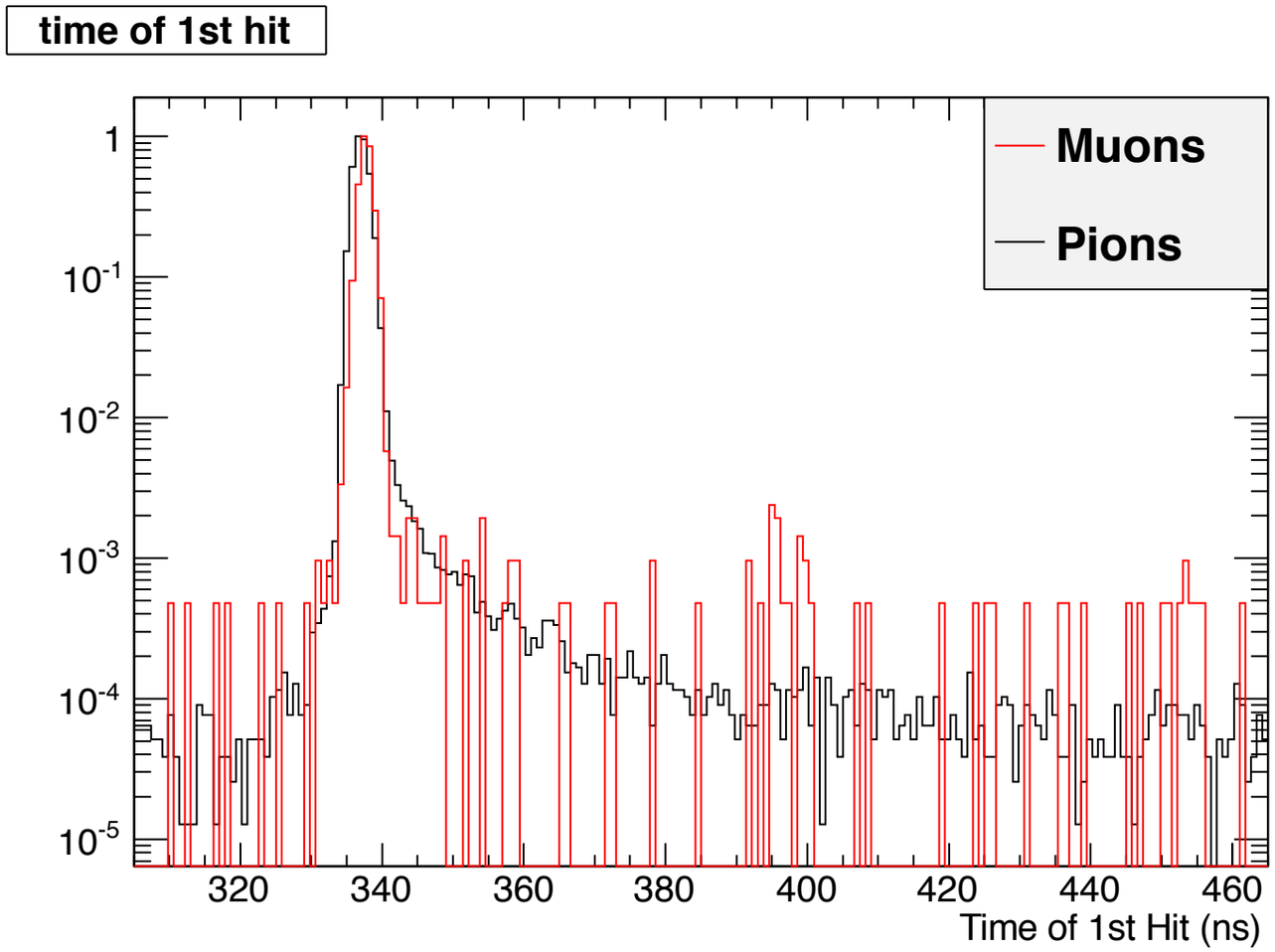
# Data Analysis - Time of 1st Hit




9cm from center

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

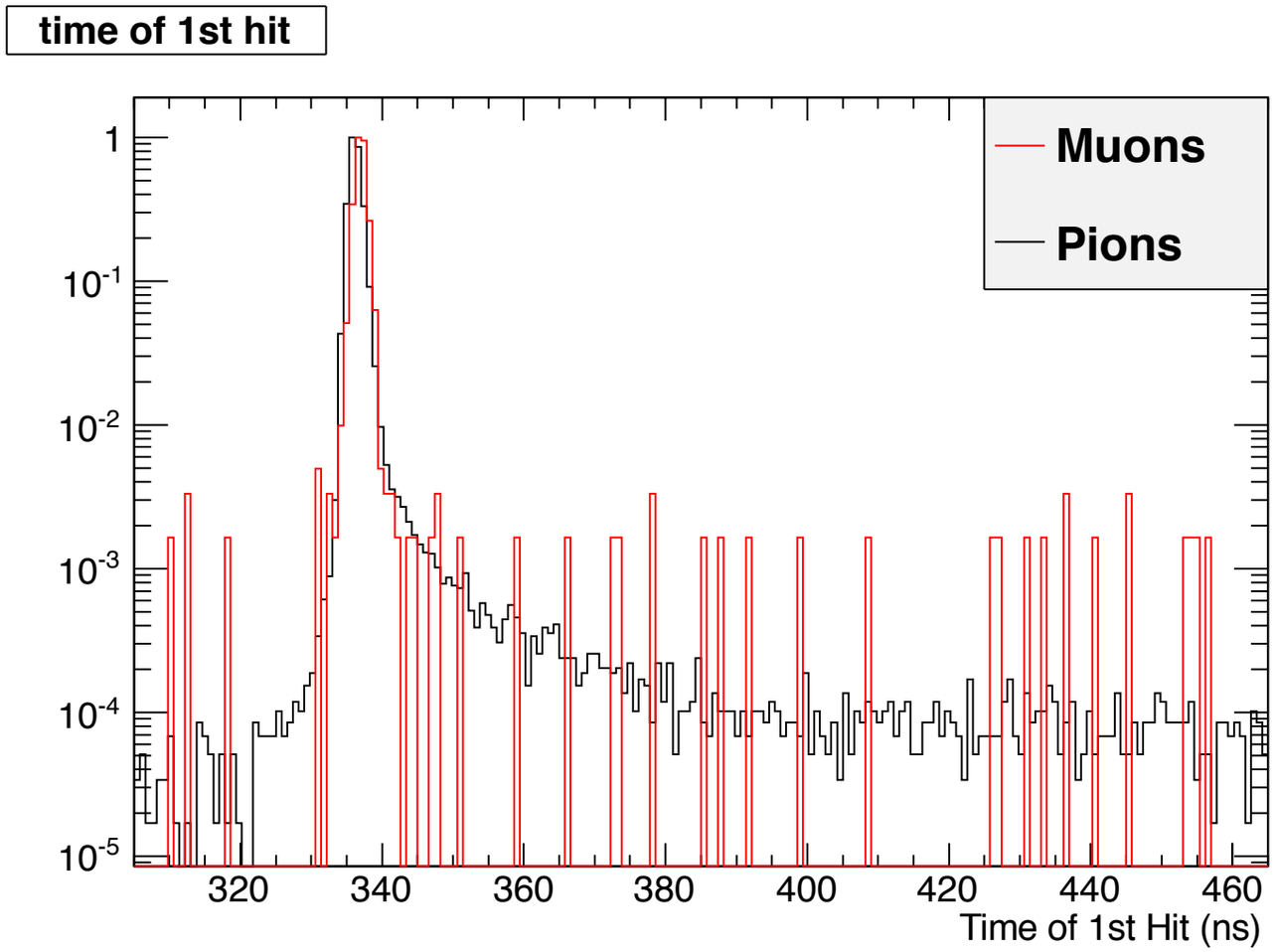
# Data Analysis - Time of 1st Hit




12cm from center

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

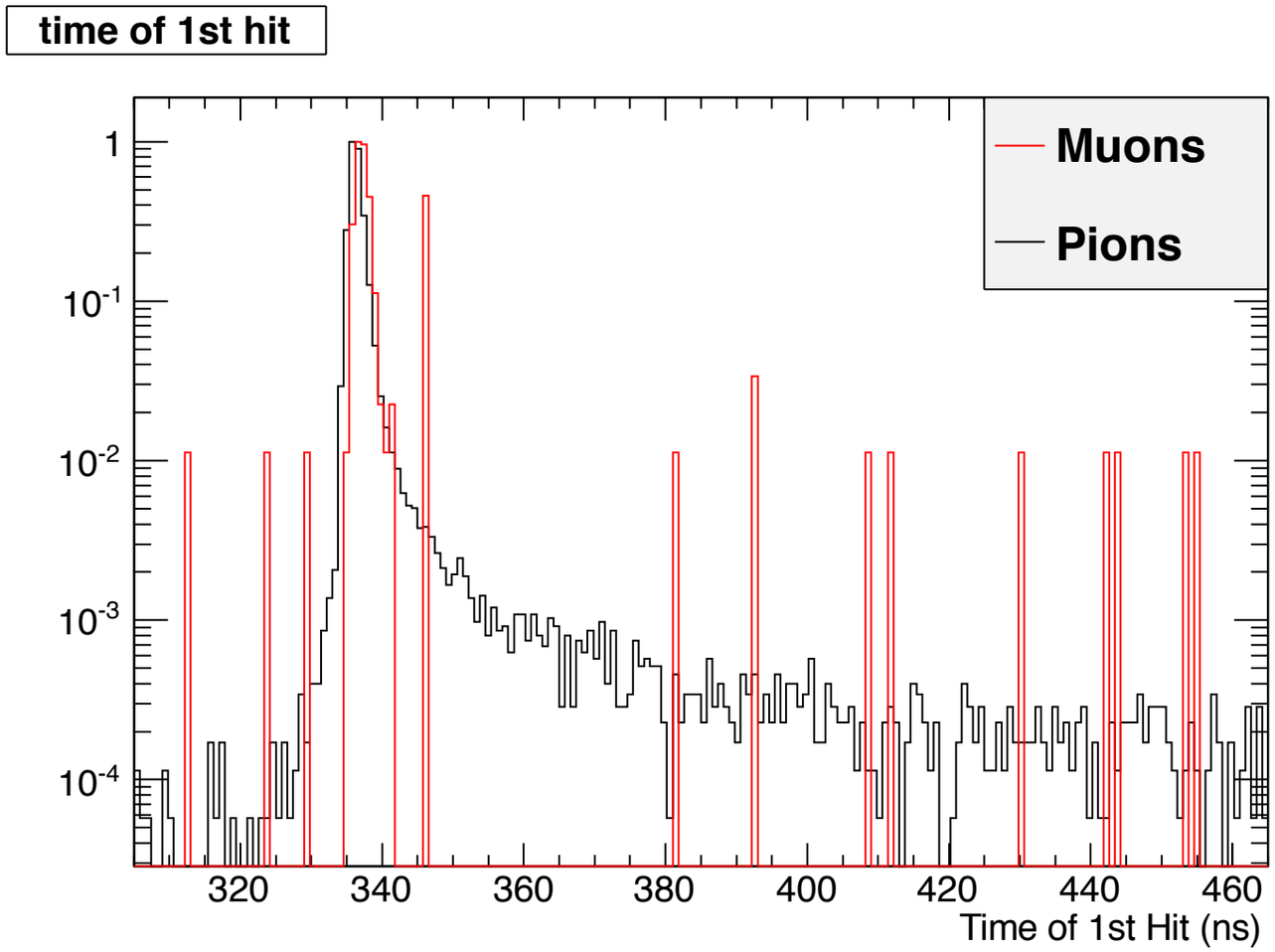
# Data Analysis - Time of 1st Hit




15cm from center

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

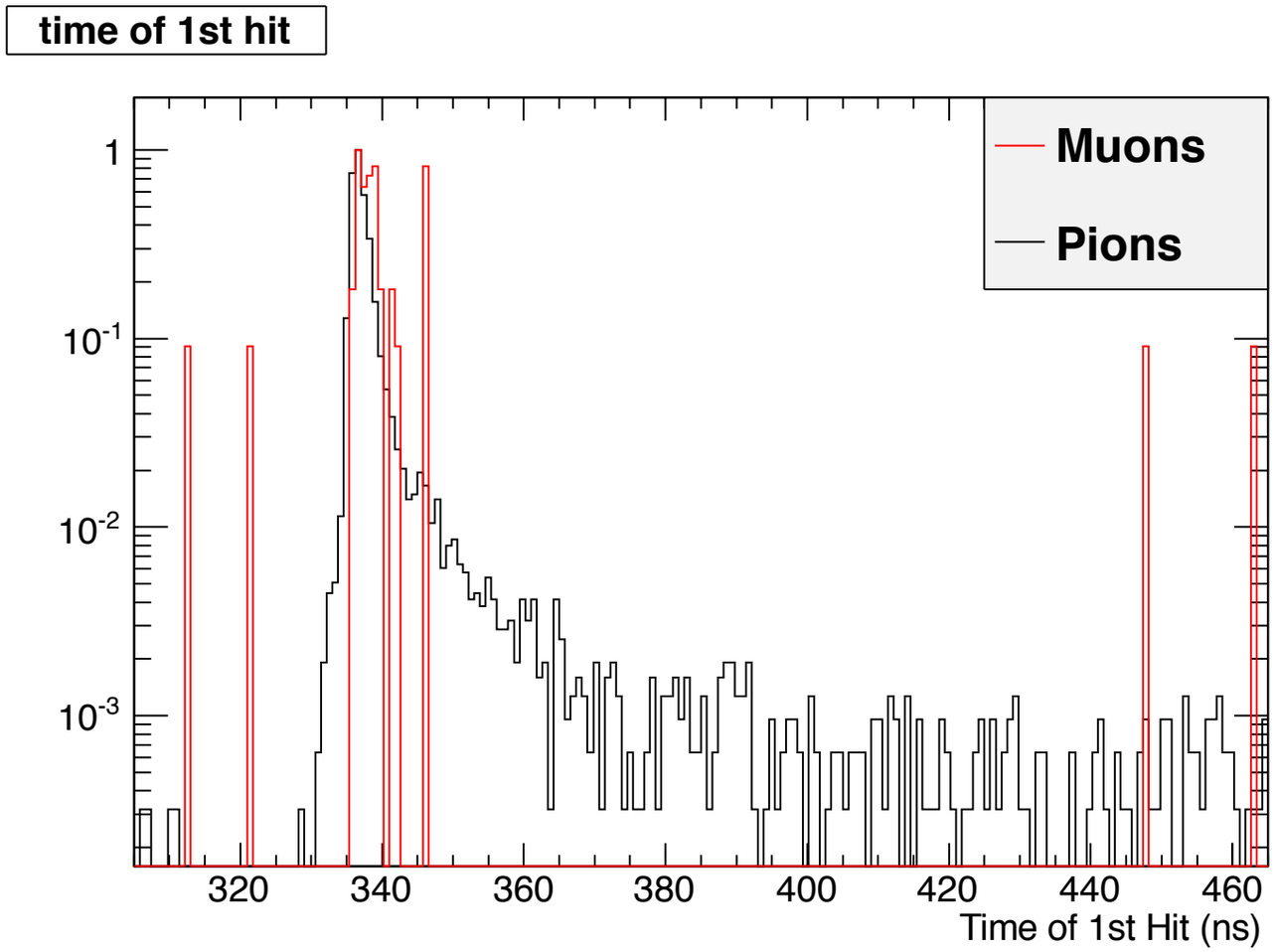
# Data Analysis - Time of 1st Hit




21cm from center

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

# Data Analysis - Time of 1st Hit




27cm from center

Toward the outside of the shower, the late energy deposition component fraction gets bigger and bigger

We can tune the radial extension of the shower by the choice of the time window
→ offers interesting possibilities for particle flow optimization and shower separation

# Conclusions

- Lepton colliders are a key tool to explore the higgs sector and physics at the TeV scale

- Construction and test of the FastRPC detector to study the time structure of hadronic showers in a tungsten HCAL
  - commissioning and data taking campaign at CERN in 2012

- Data Analysis
  - charge distribution shows a tail for pions: sensitivity to deposited energy also with RPCs
  - sensitive to late components on the showers, especially in the outer region

  - Comparison with T3B data
  - Full event synchronization with the DHCAL
  - Comparison with MC