FastRPC: Time Structures with RPCs in Contrast to Scintillators

Marco Szalay

CALICE collaboration meeting

Hamburg 20.03.2013

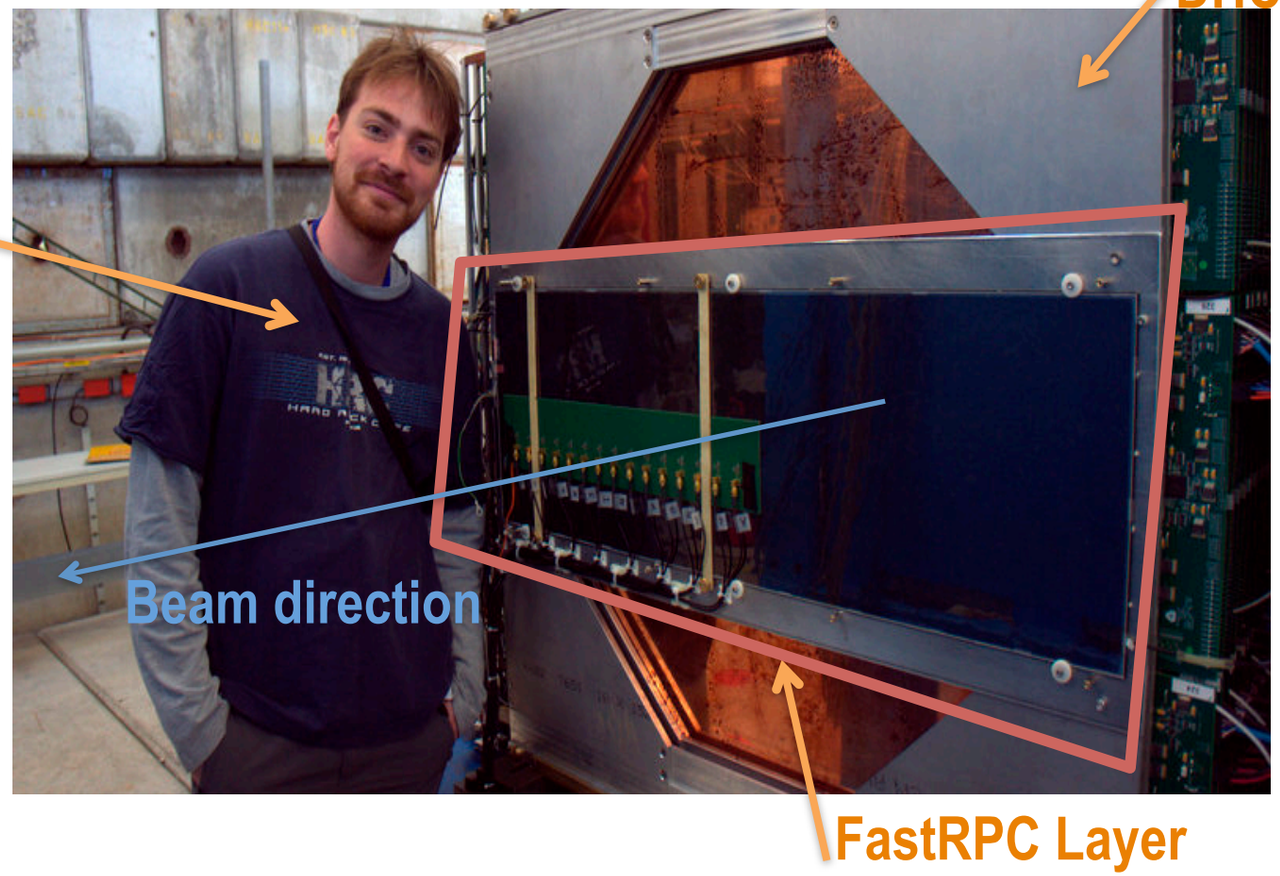
TECHNISCHE UNIVERSITÄT MÜNCHEN

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

Table Of Content

Overview

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

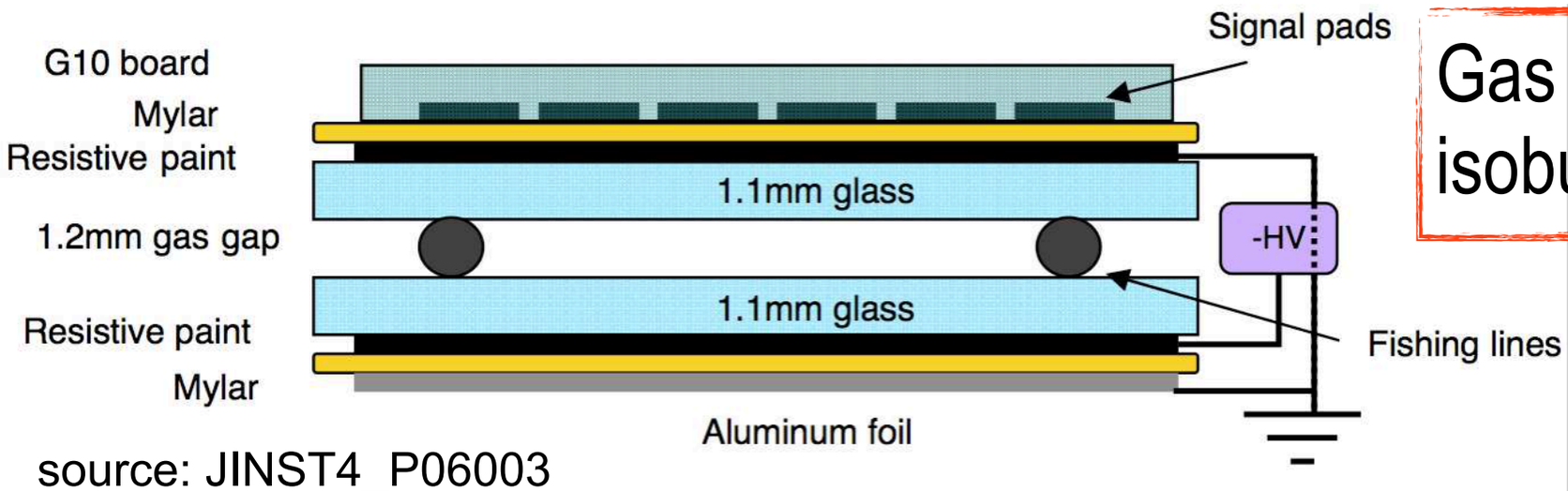


Understand the relevance of the time structure for Particle Flow Algorithms and background rejection

Input for detector simulations

Implementation - Active layer

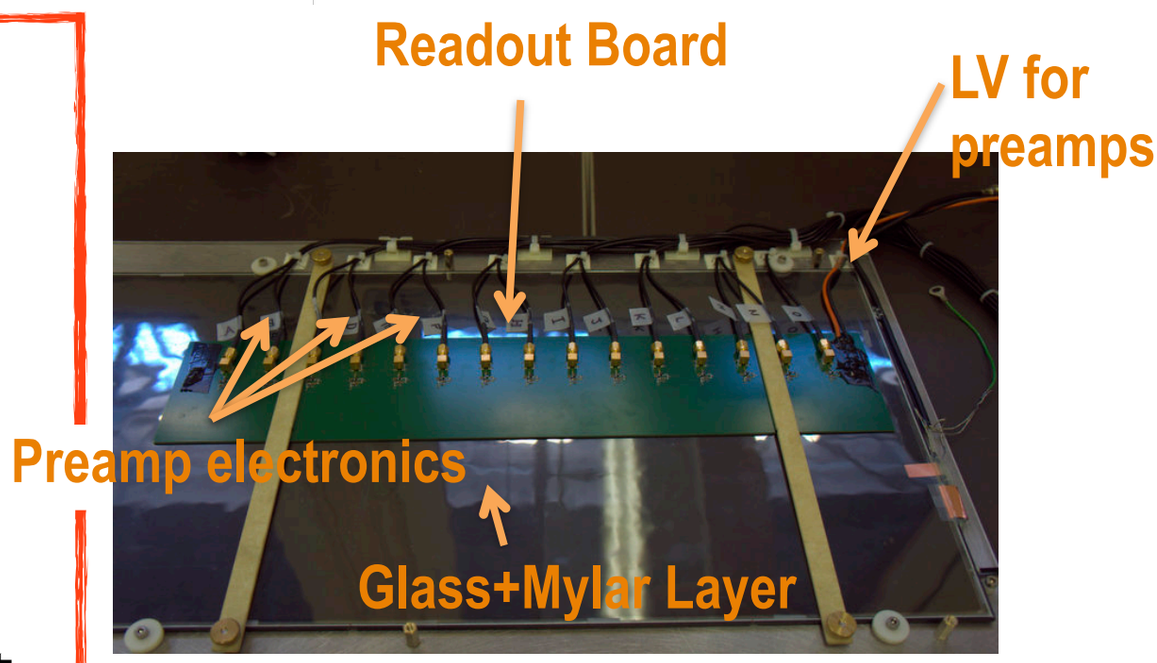
Resistive Plate Chamber



source: JINST4 P06003

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

- High resistance of the electrodes (~10^{12} Ωcm)
- High Voltage (6.3 kV ➔ E ~ 57 kV/cm)
- Gas Amplification (Gain ~ 10^5)
- Highly quenching gas mixture to prevent streamers



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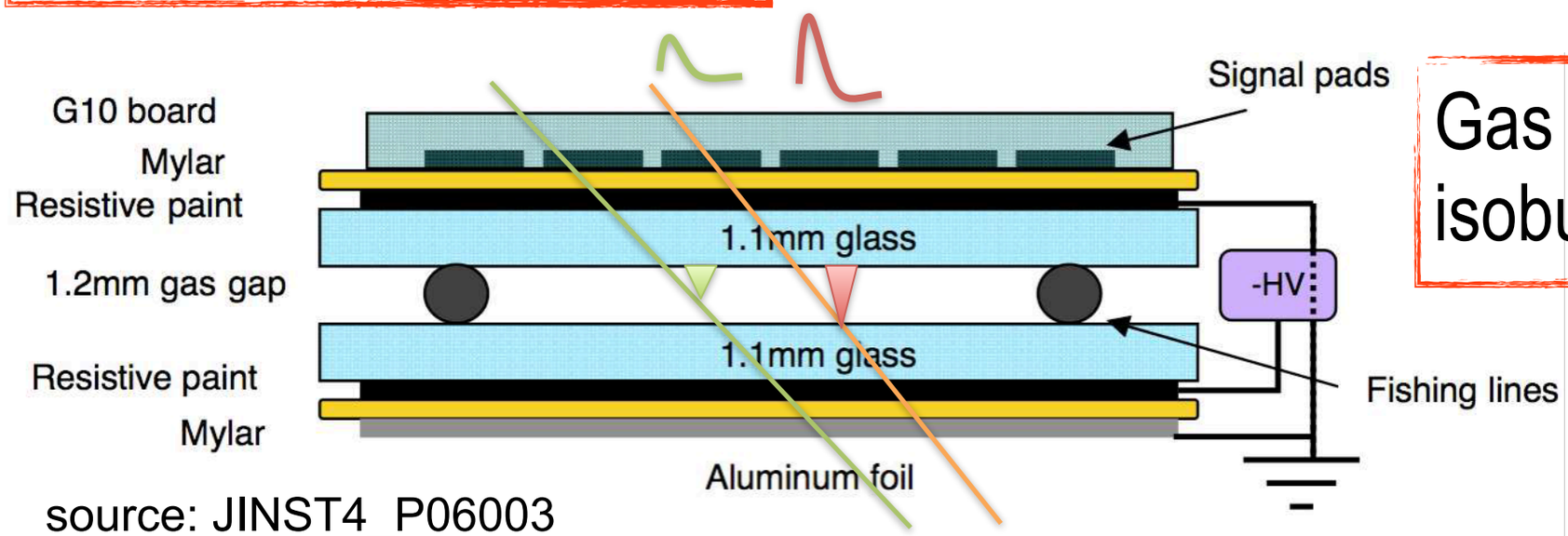

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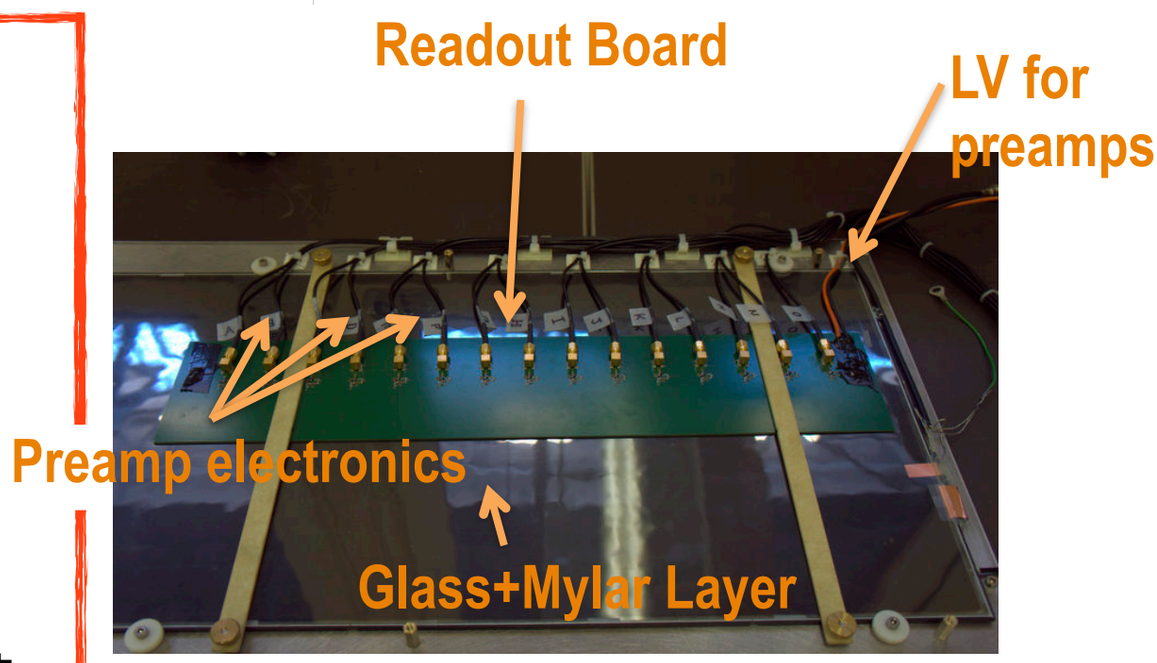
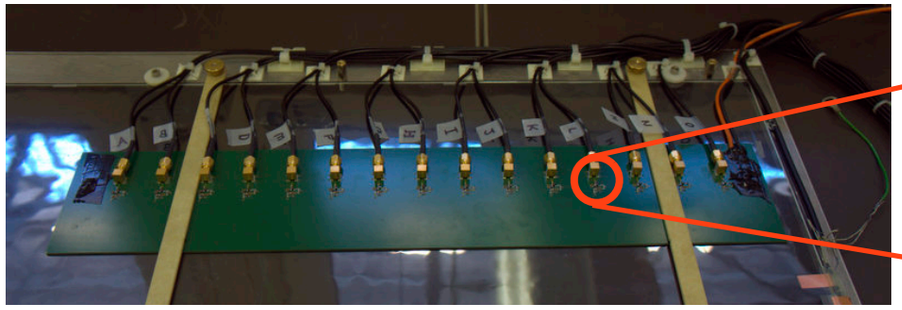


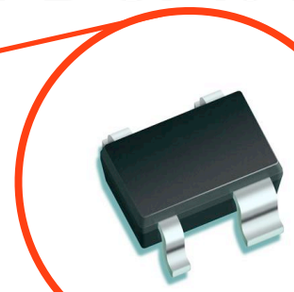
The FastRPC setup:

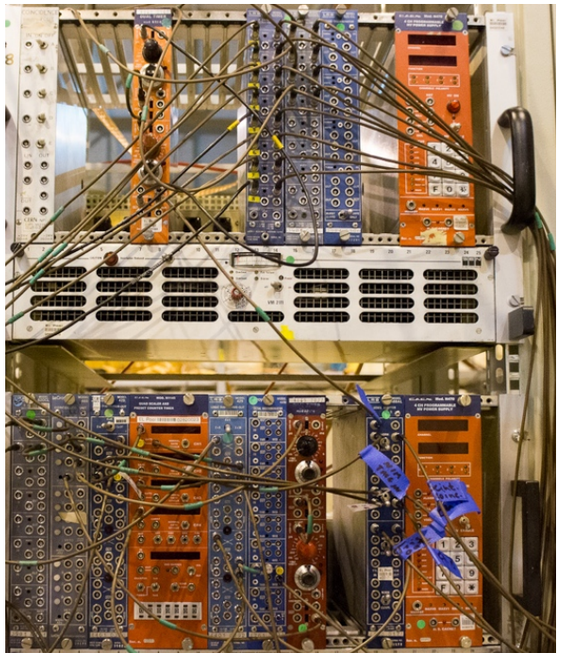
Implementation - readout

15 x 3x3 cm^2 pads



Infineon BGA614 preamp





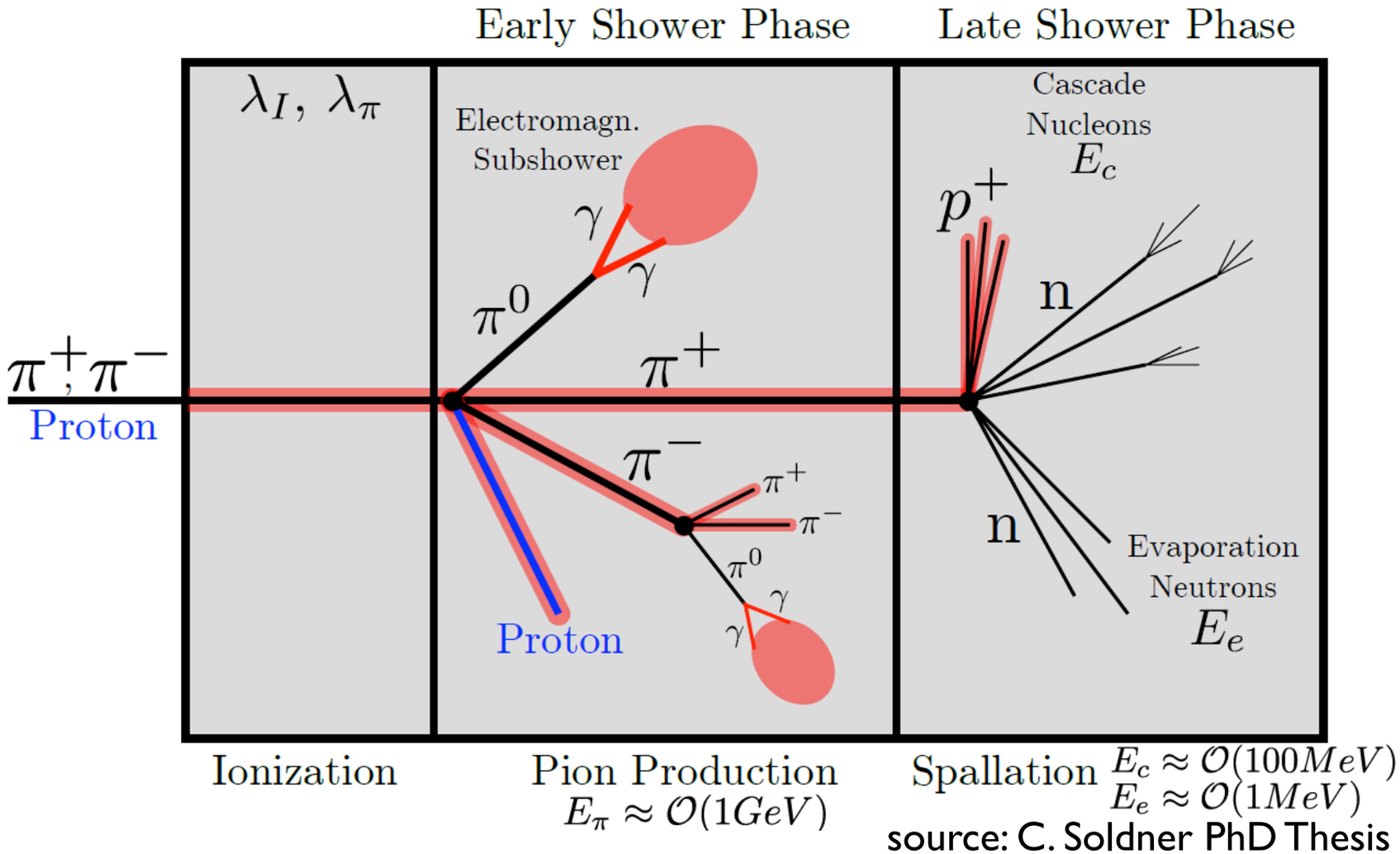
USB

spill info
scintillator triggers
DHCAL synchronization

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

Hadronic Showers:

Time development

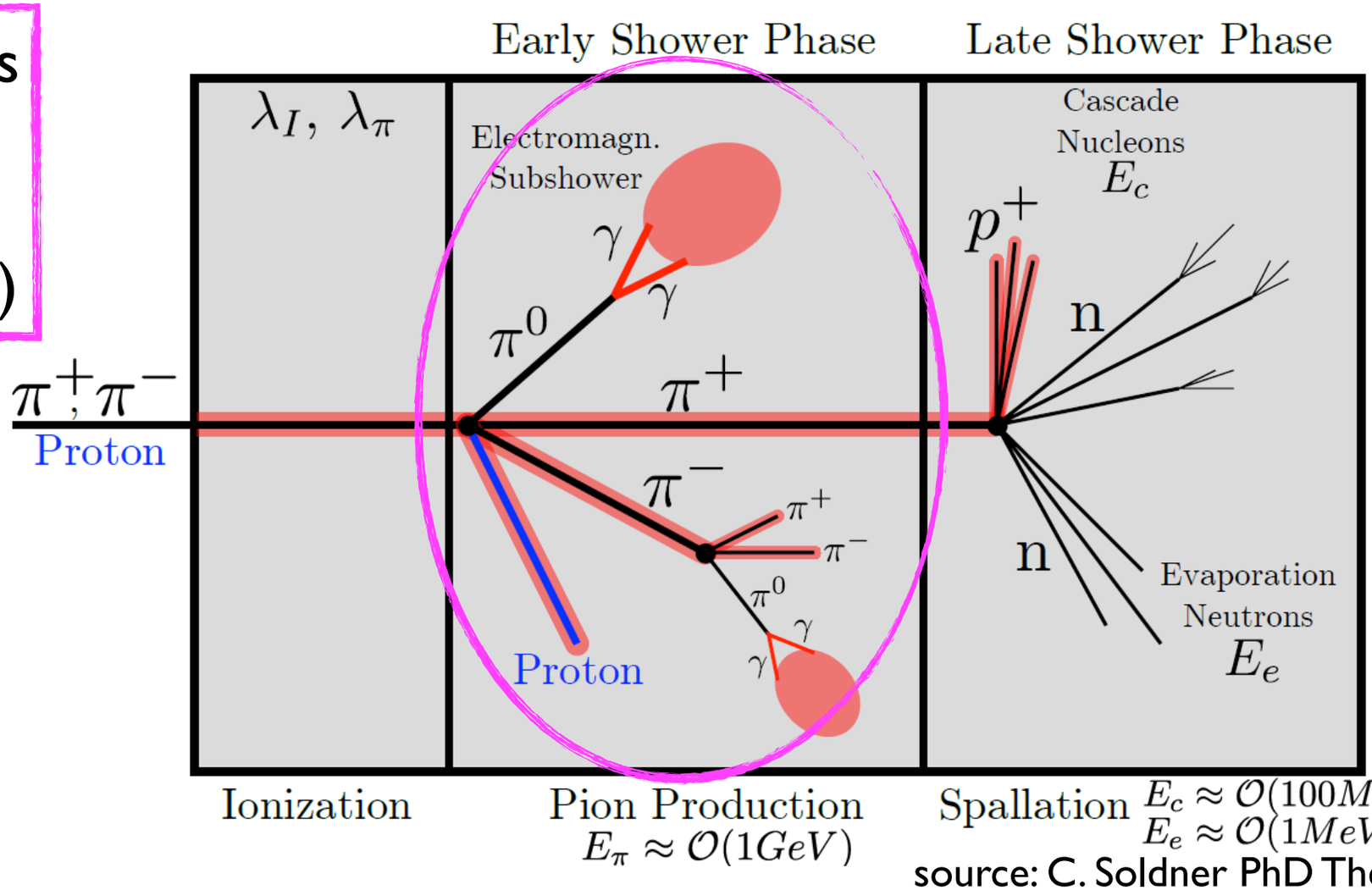


source: C. Soldner PhD Thesis

Hadronic Showers:

Time development

Early phase: instantaneous components (mainly relativistic hadrons and electromagnetic showers)



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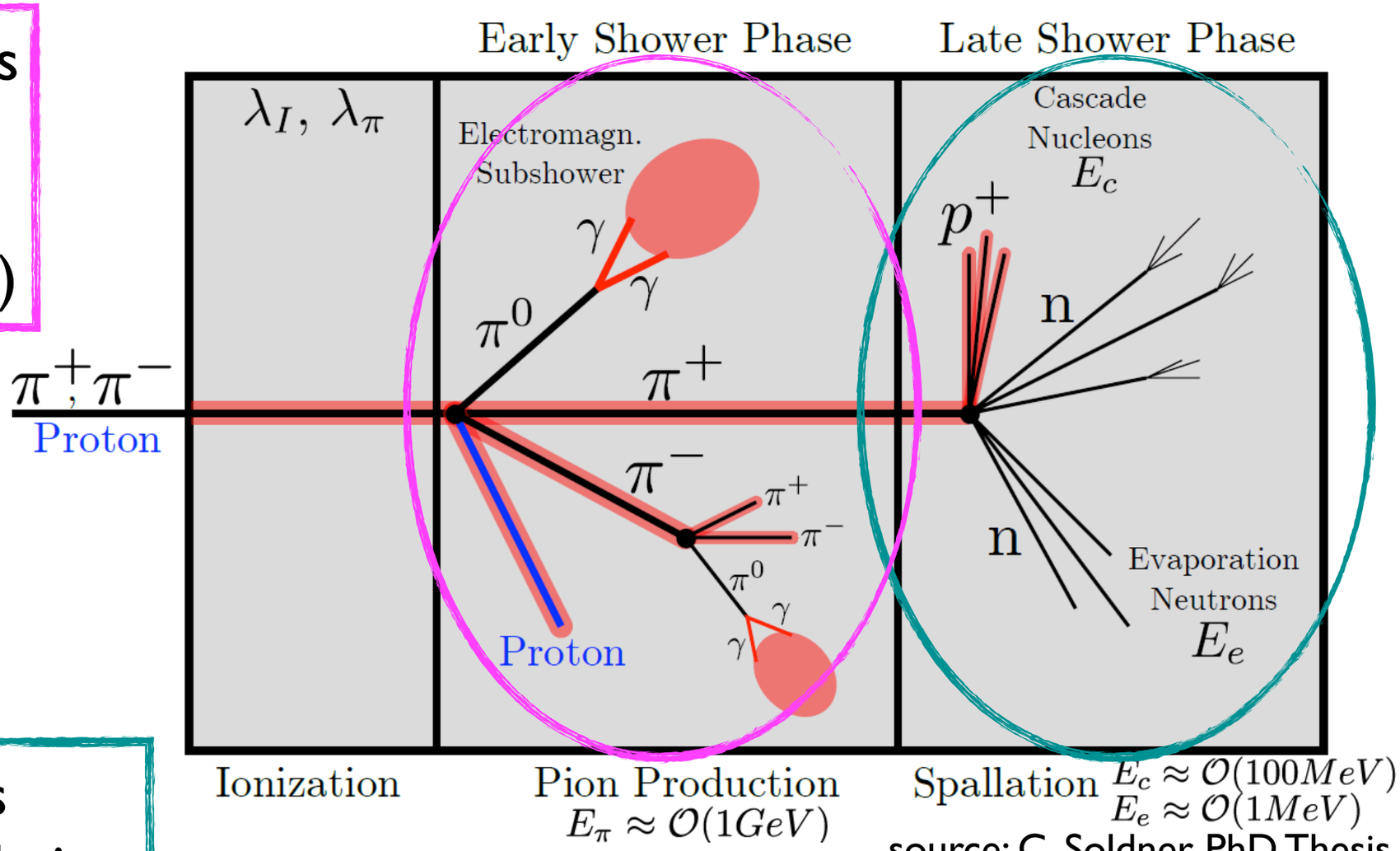

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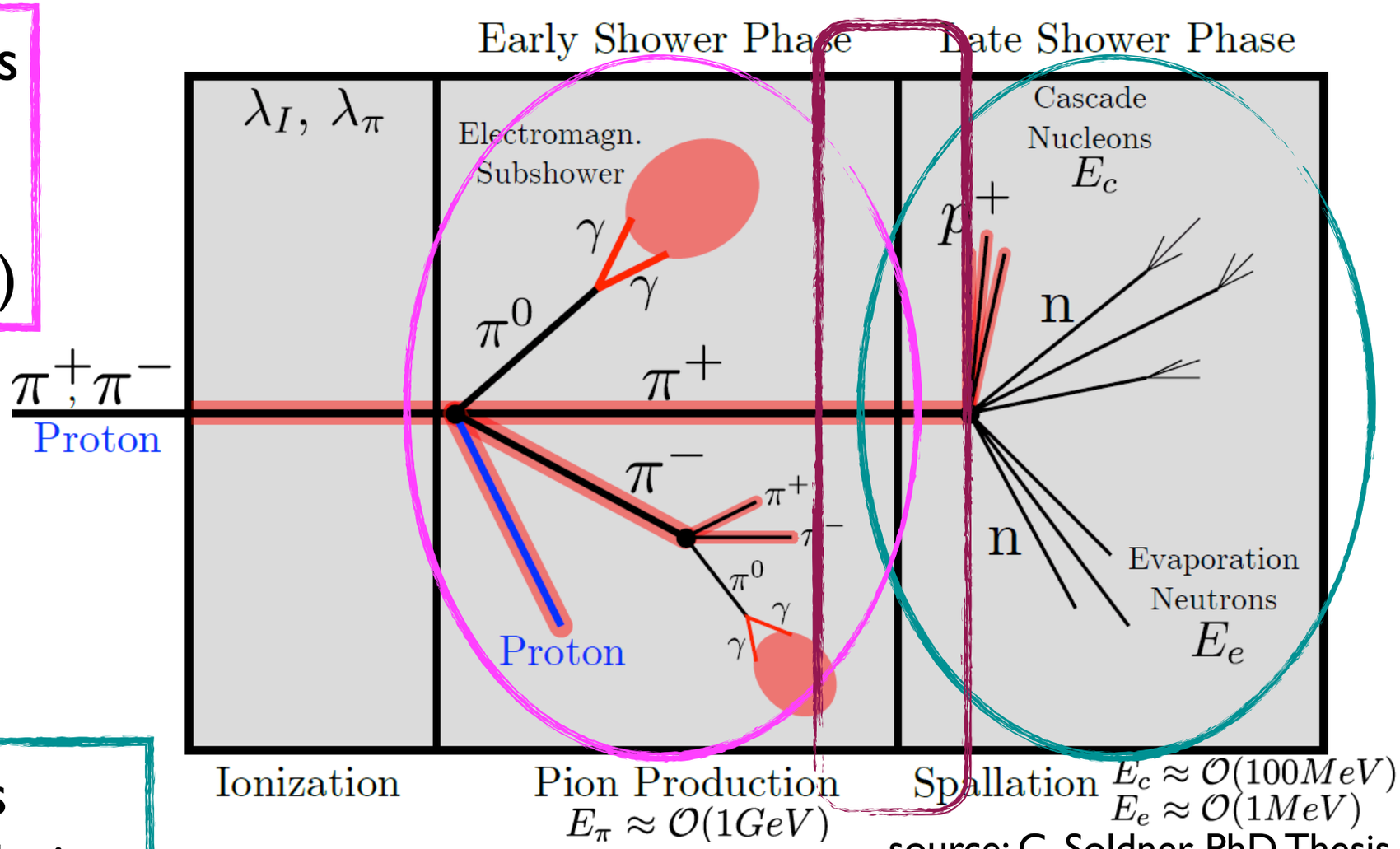
Late phase: slow neutrons capture, evaporation, spallation

Hadronic Showers:
Time development

Early phase: instantaneous components (mainly relativistic hadrons and electromagnetic showers)

Intermediate phase: neutron scattering

Late phase: slow neutrons capture, evaporation, spallation



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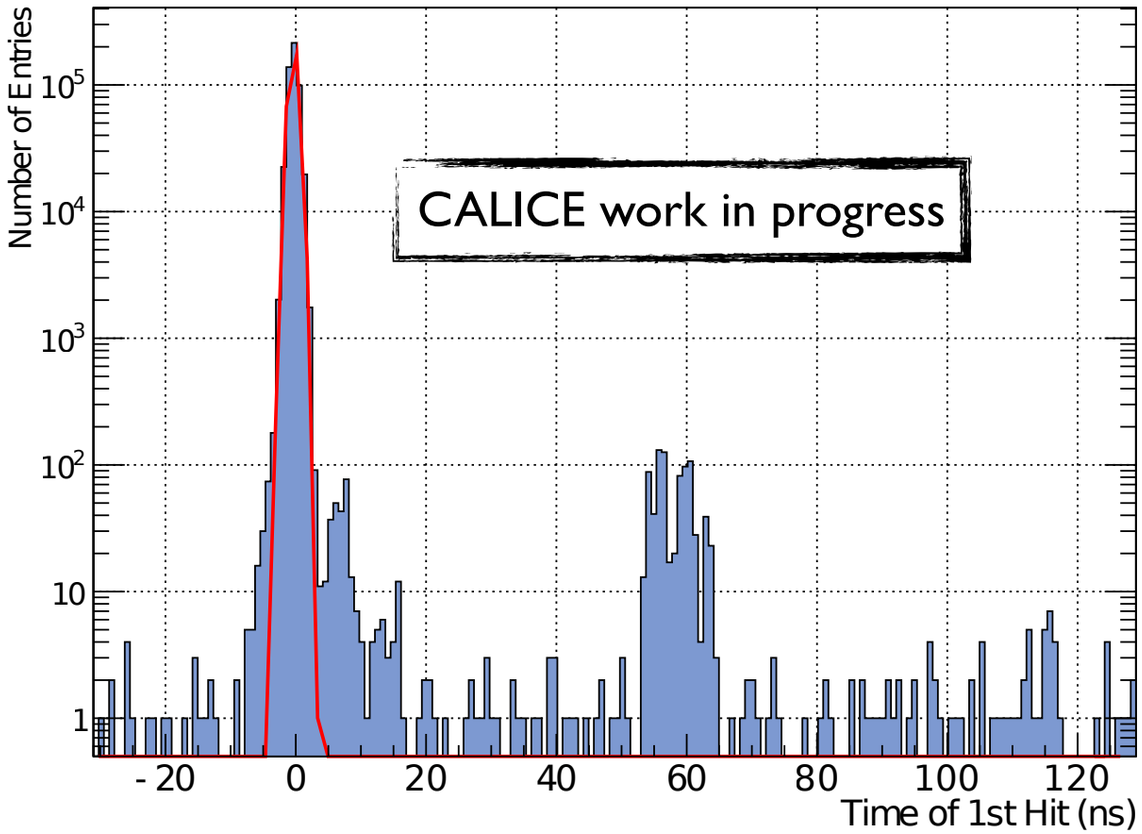
Hydrogen content in a gaseous detector is much lower than in plastic scintillators ➔ less sensitive to neutron elastic scattering

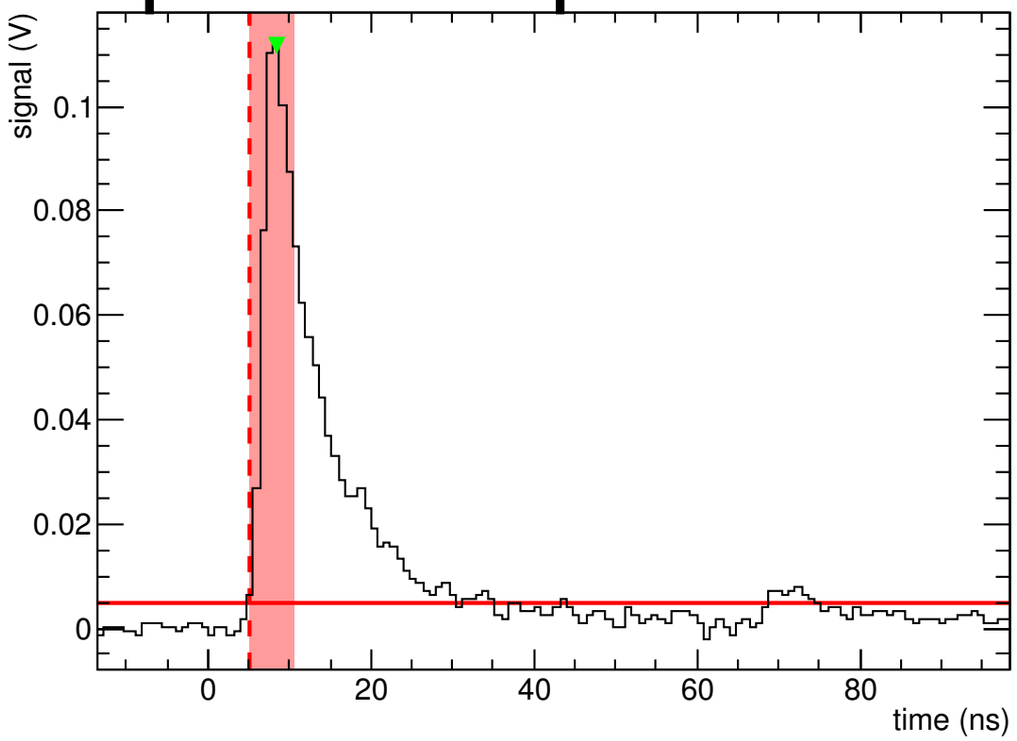
Calibration and Benchmark

Signal should form Gaussian for muons

Benchmark calibration by comparing with Gaussian fit



TSpectrum - peak finder



10 mV threshold + 6 ns window

0.997 efficiency (compared to 5 mV threshold)

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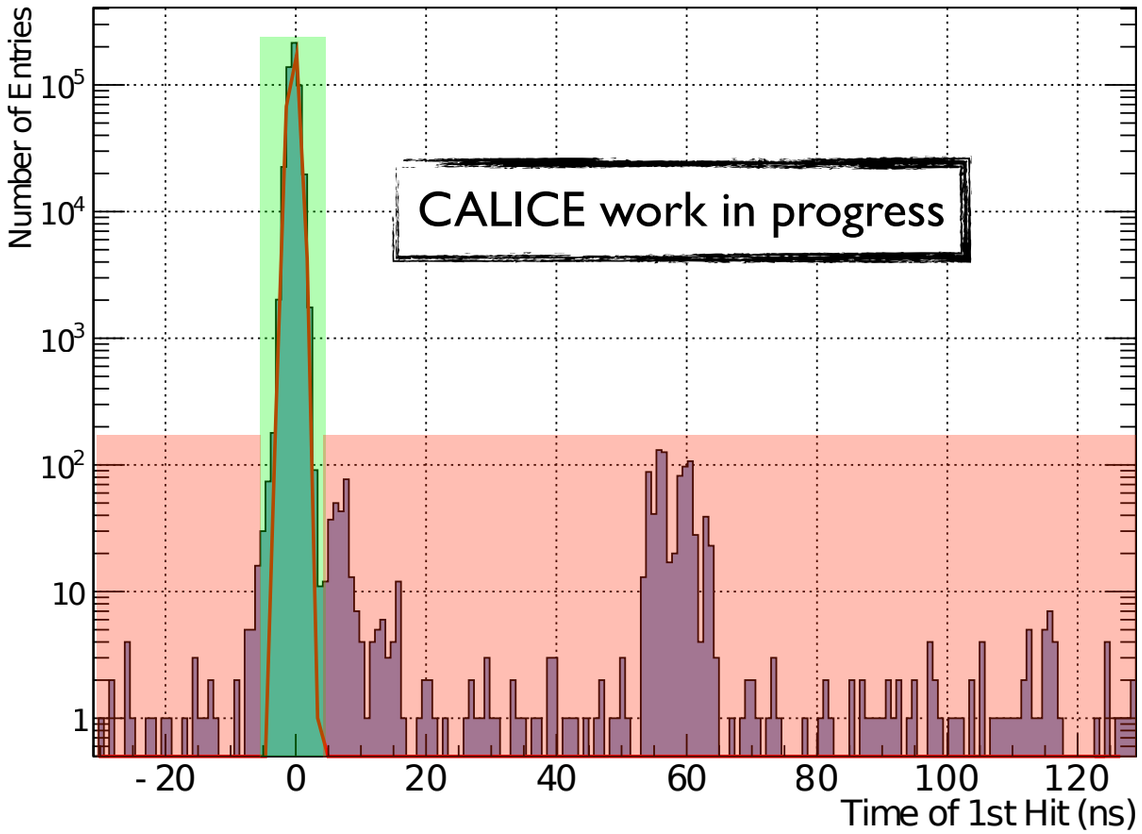

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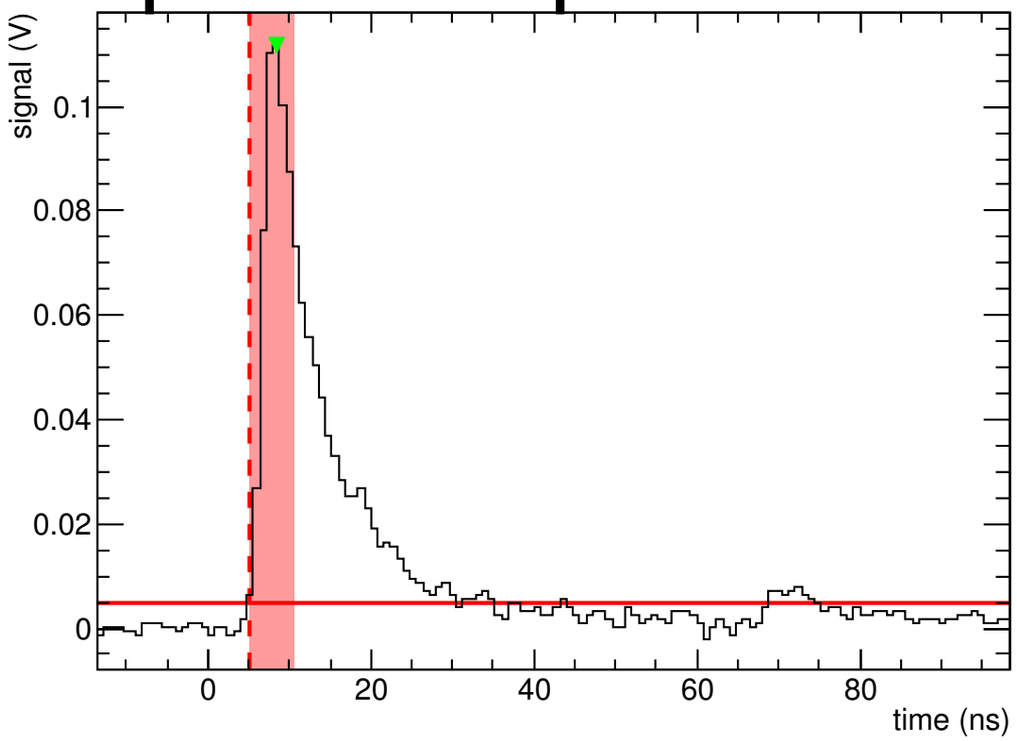

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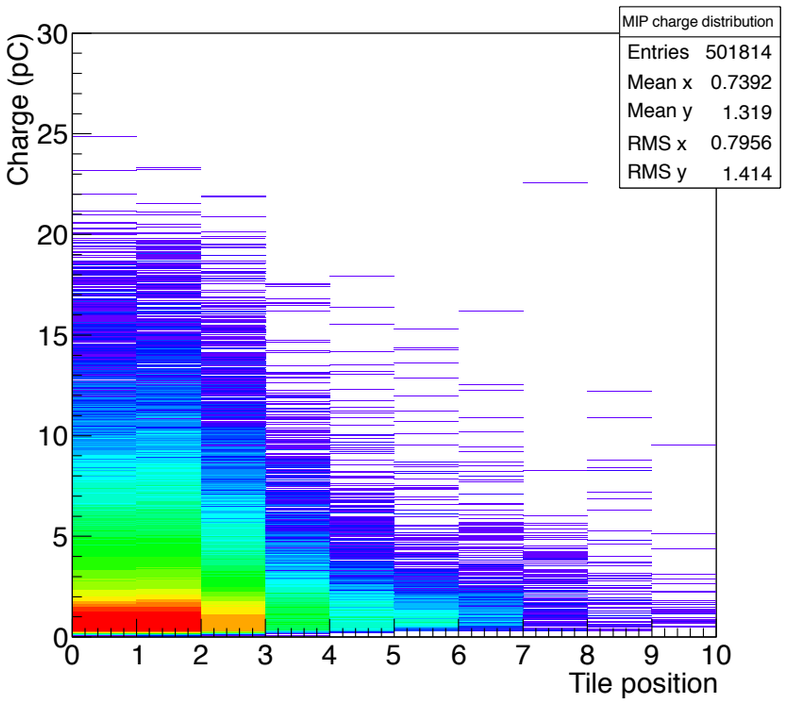
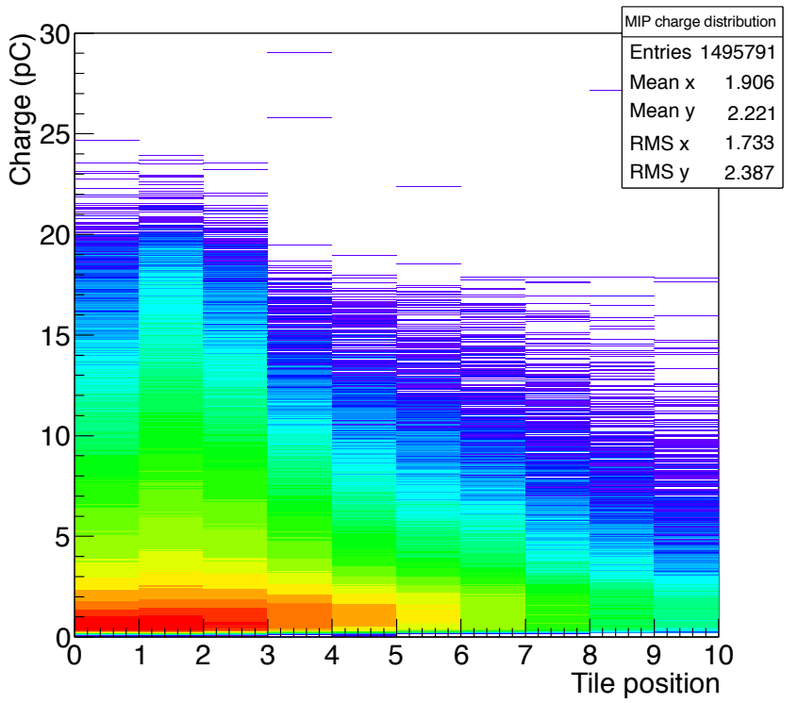
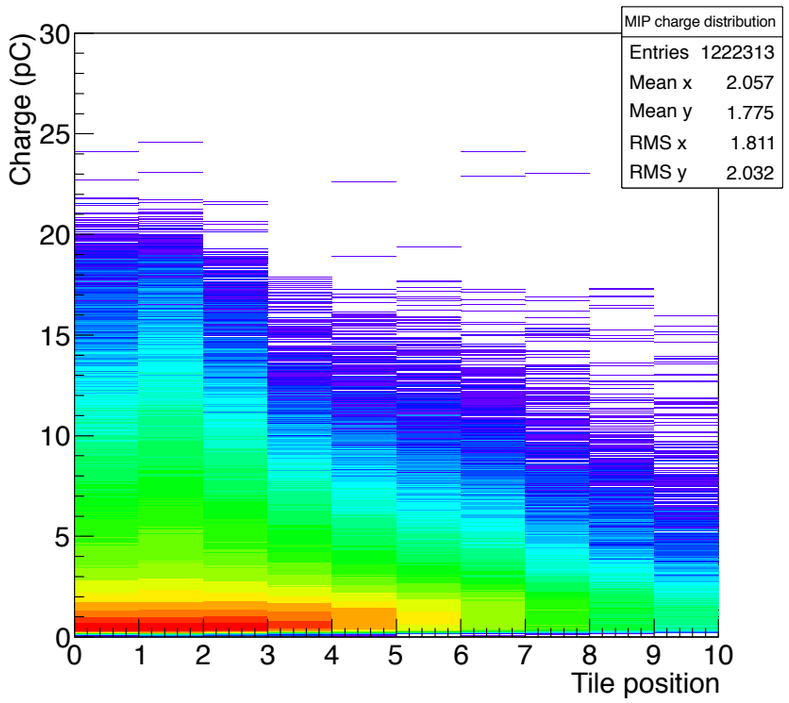
Data Analysis:

Charge Distribution







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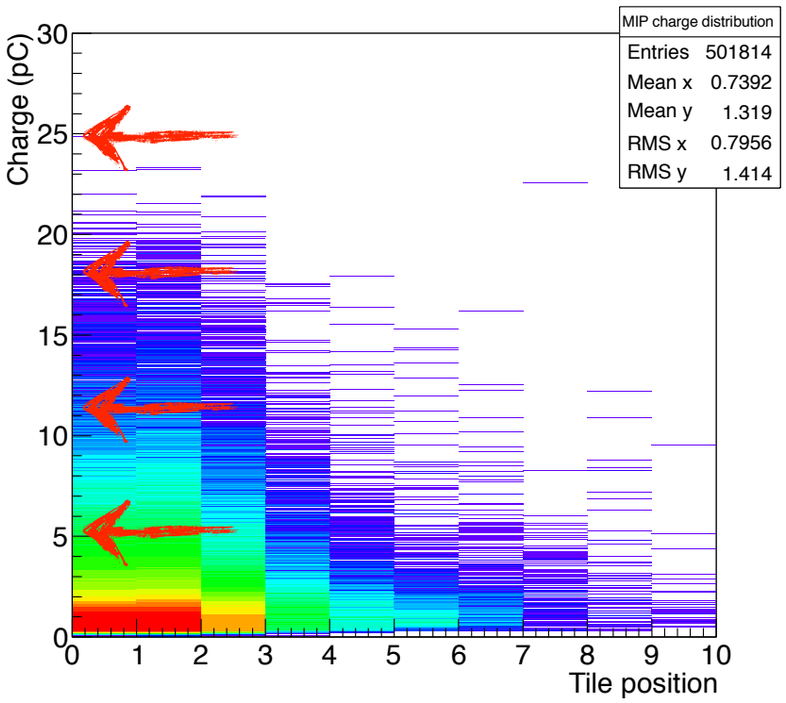

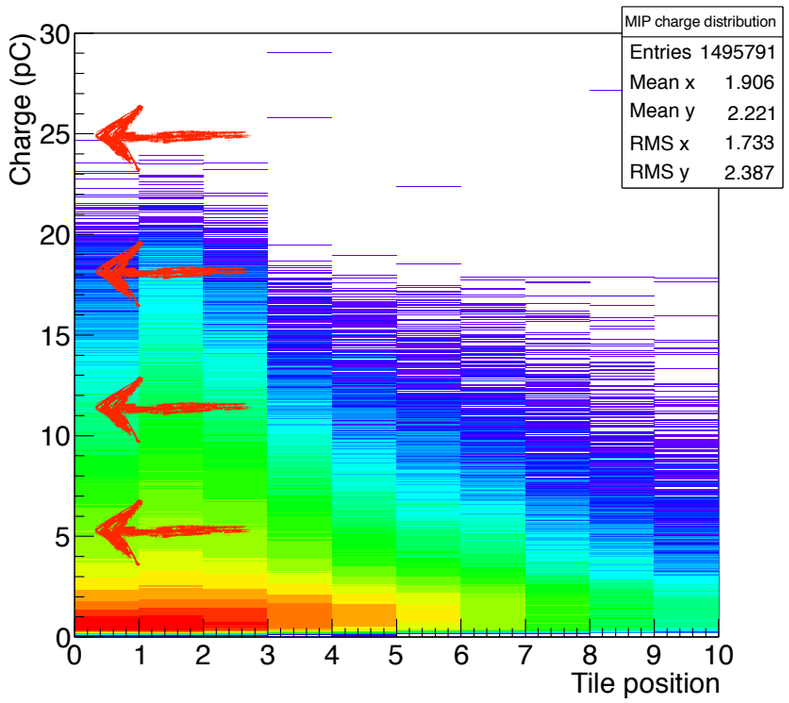

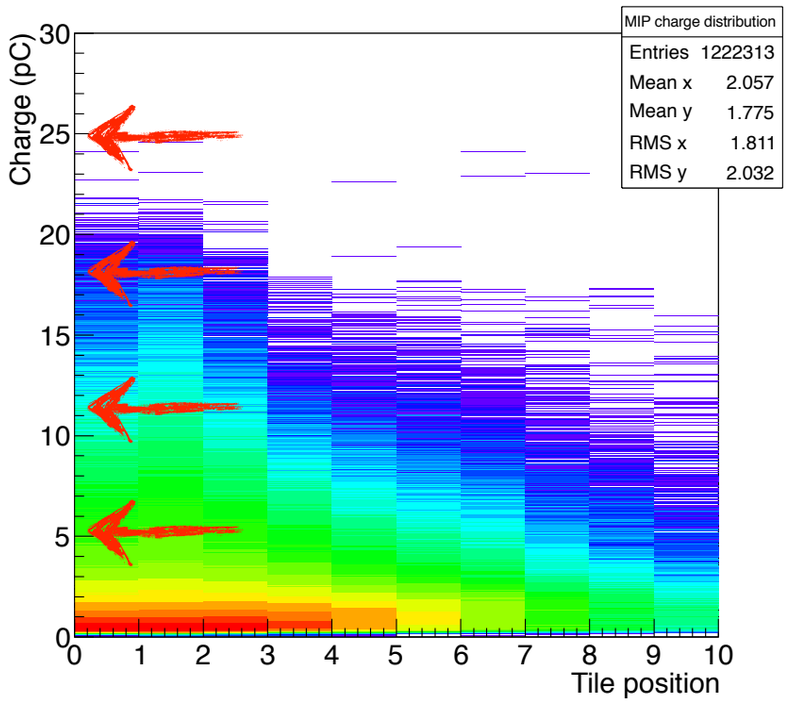

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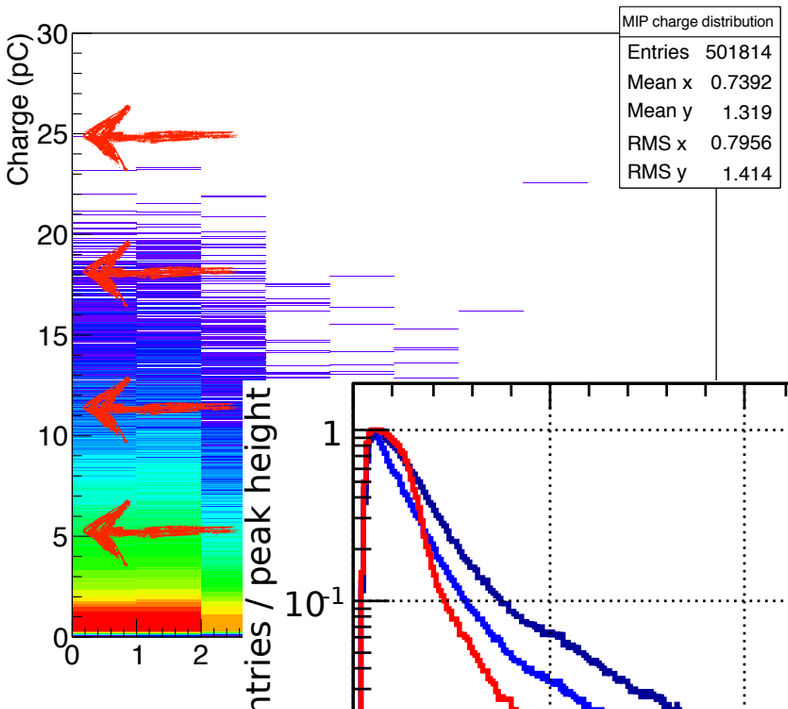
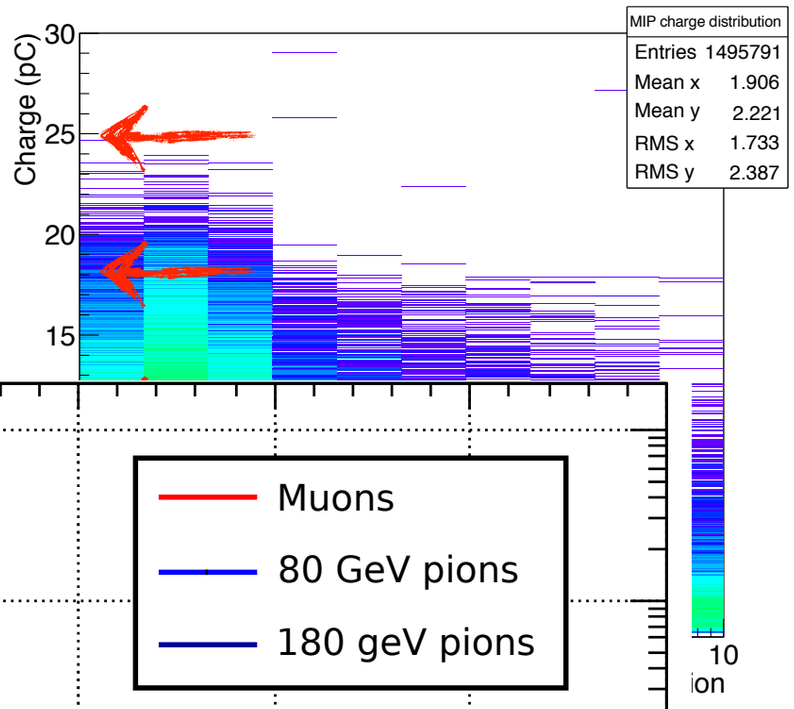
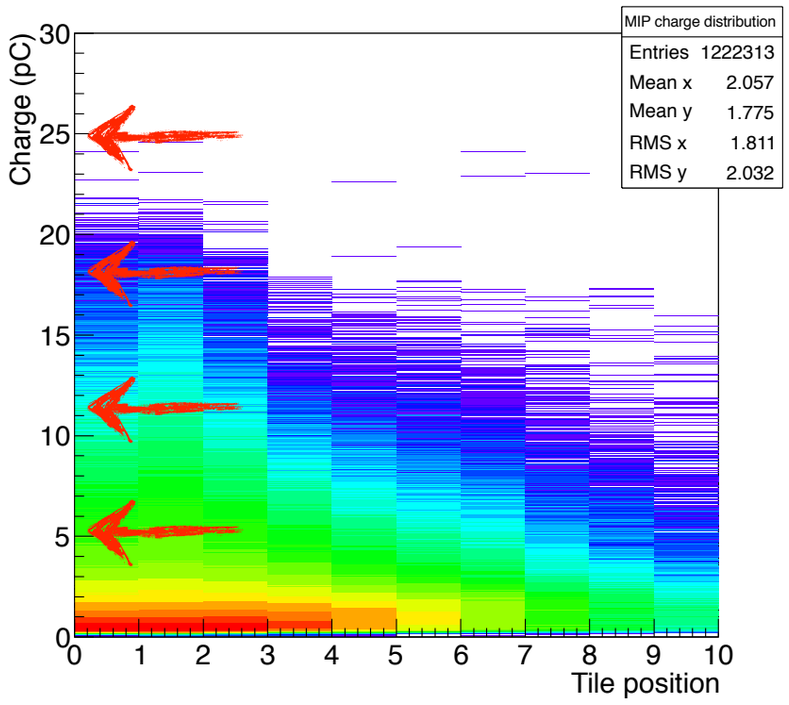
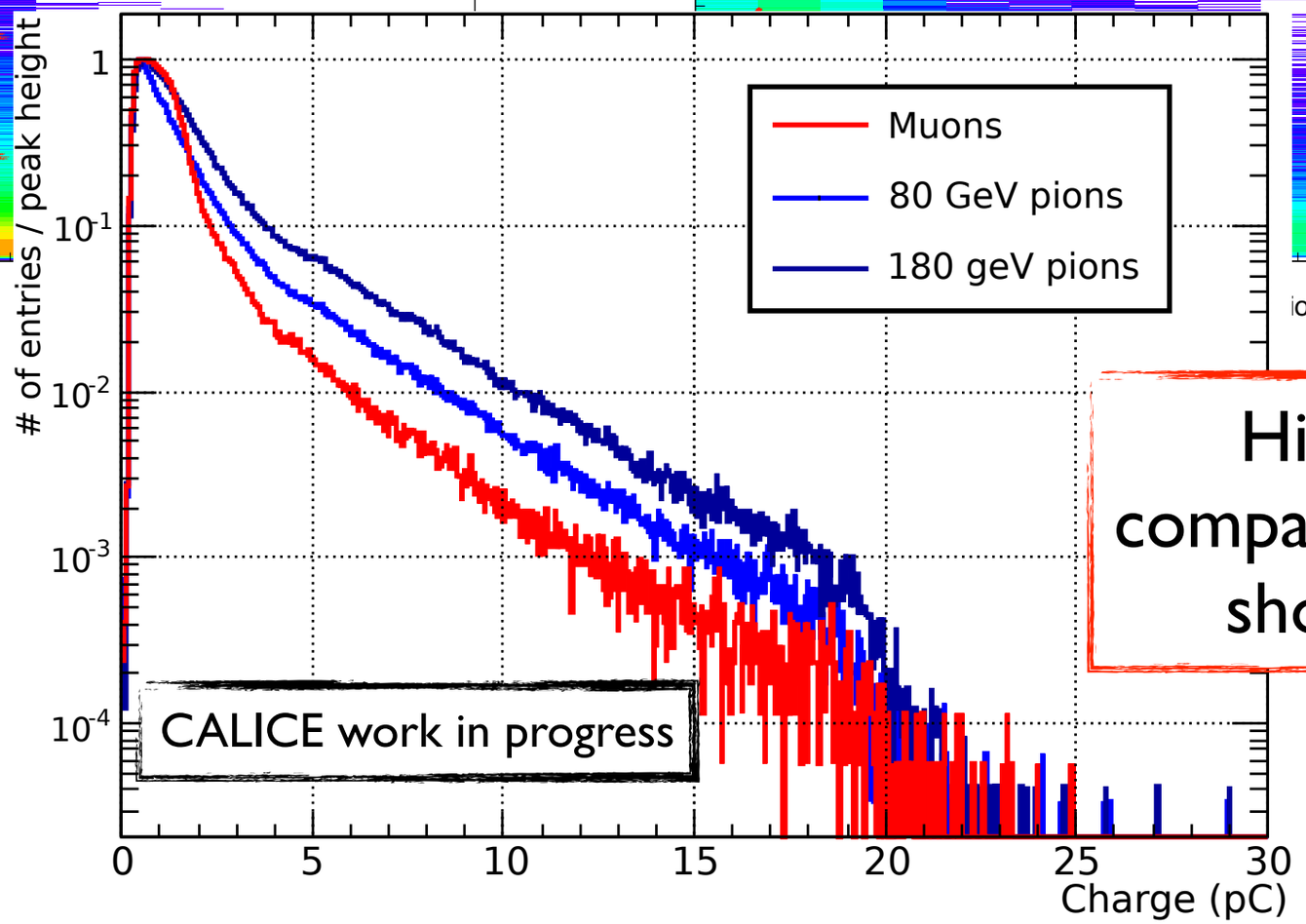








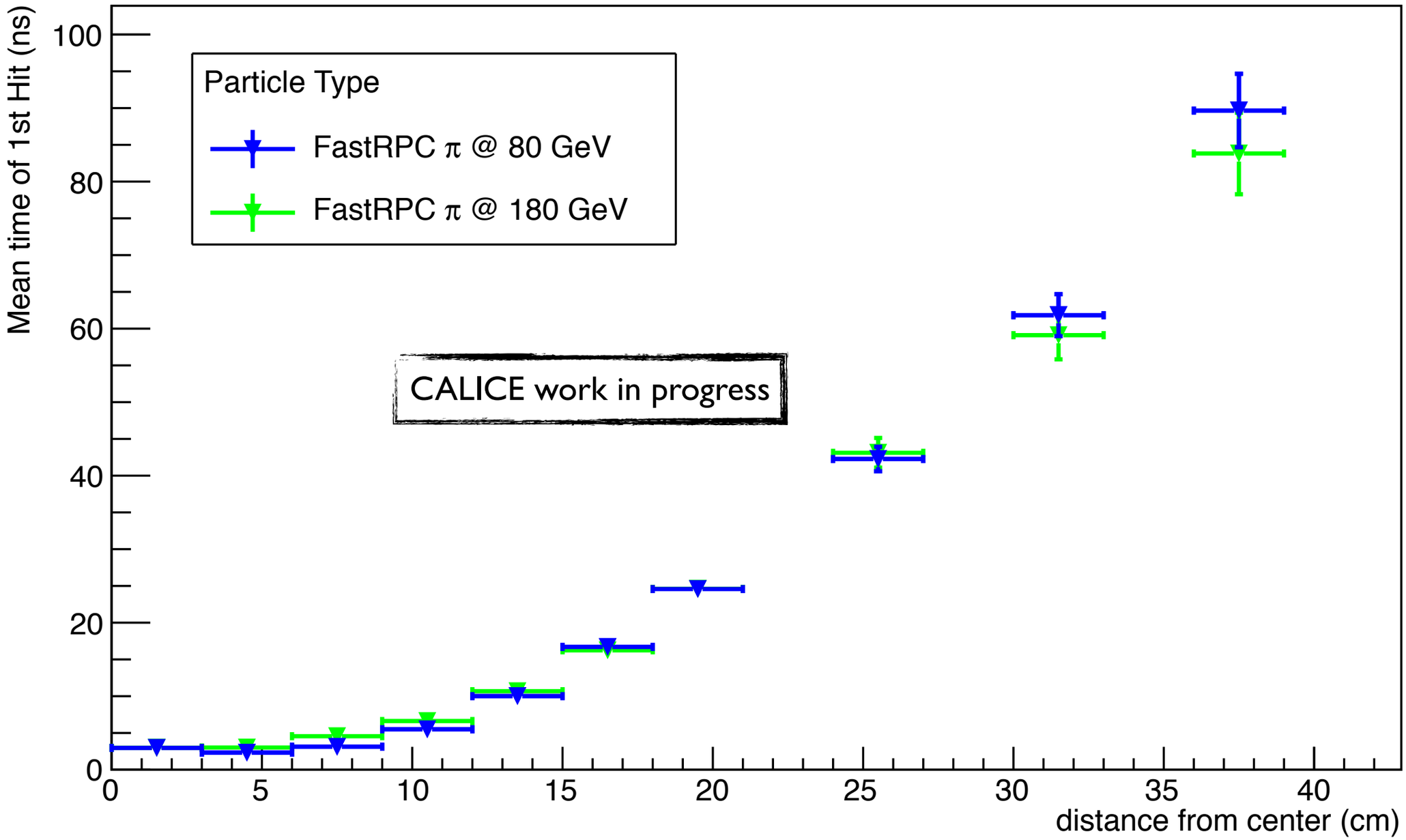
Higher Amplitudes compared to muons: dense shower component

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

Data Analysis:

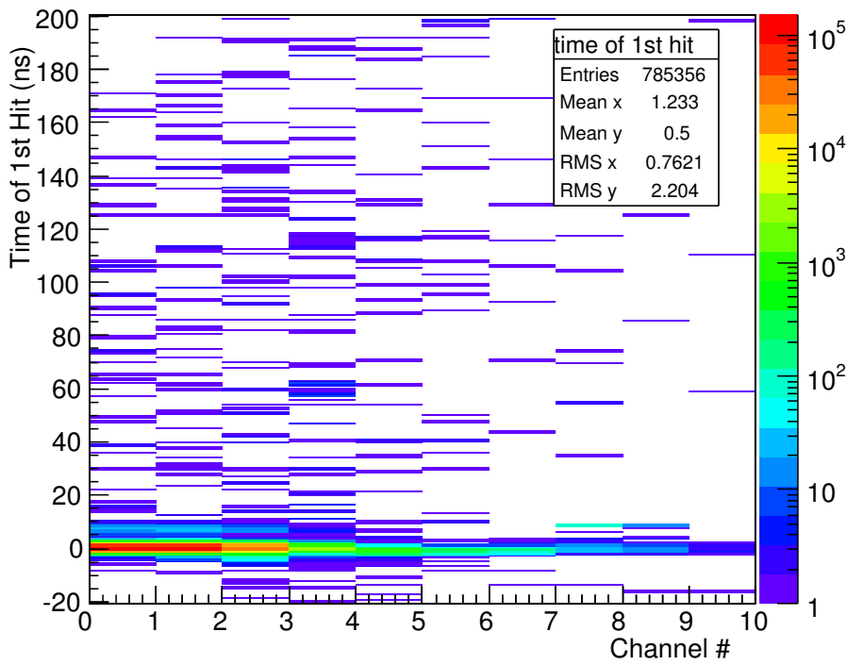
Radial Profile - Mean ToFH

Mean time calculated over 2μs window

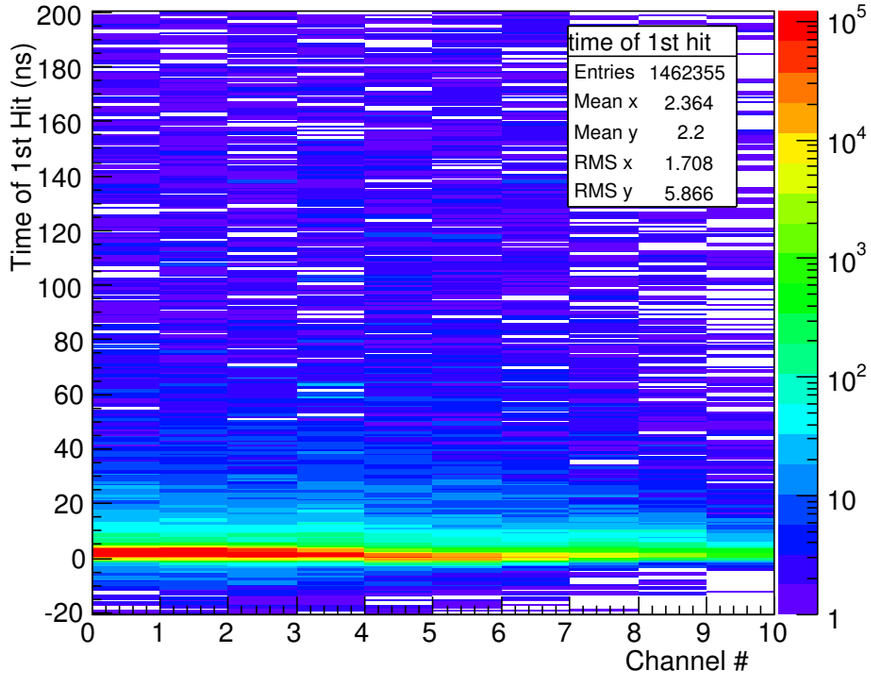


Data Analysis:
Time of 1st Hit

Muons



80GeV pions



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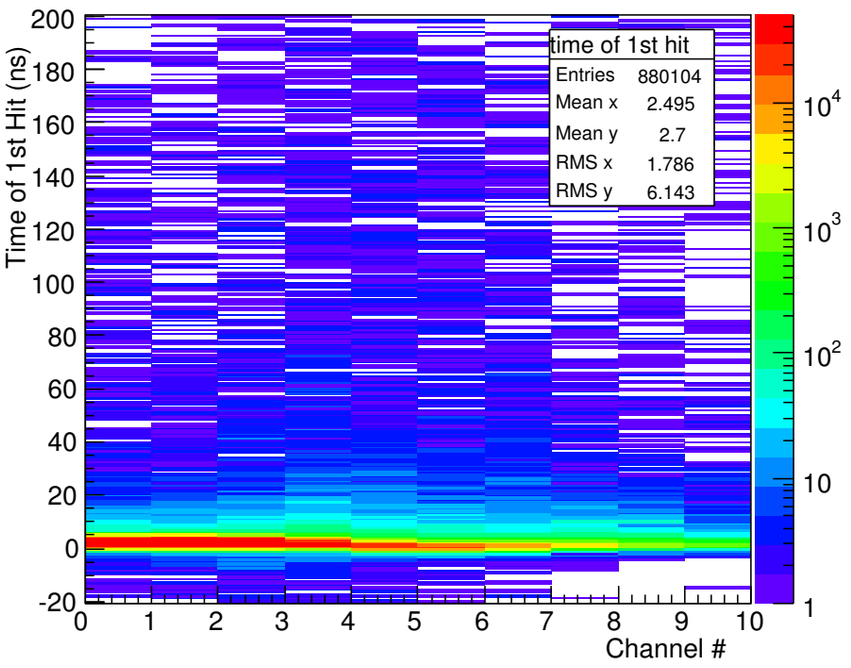
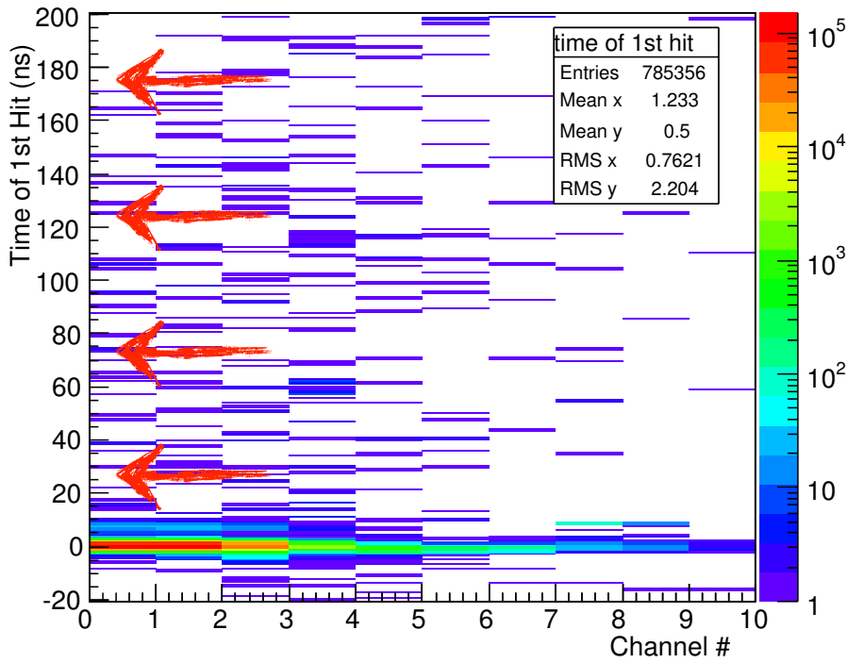


CALICE work in progress

- Muons are instantaneous
- Hadronic showers show substantial late contribution

Data Analysis:
Time of 1st Hit

Muons



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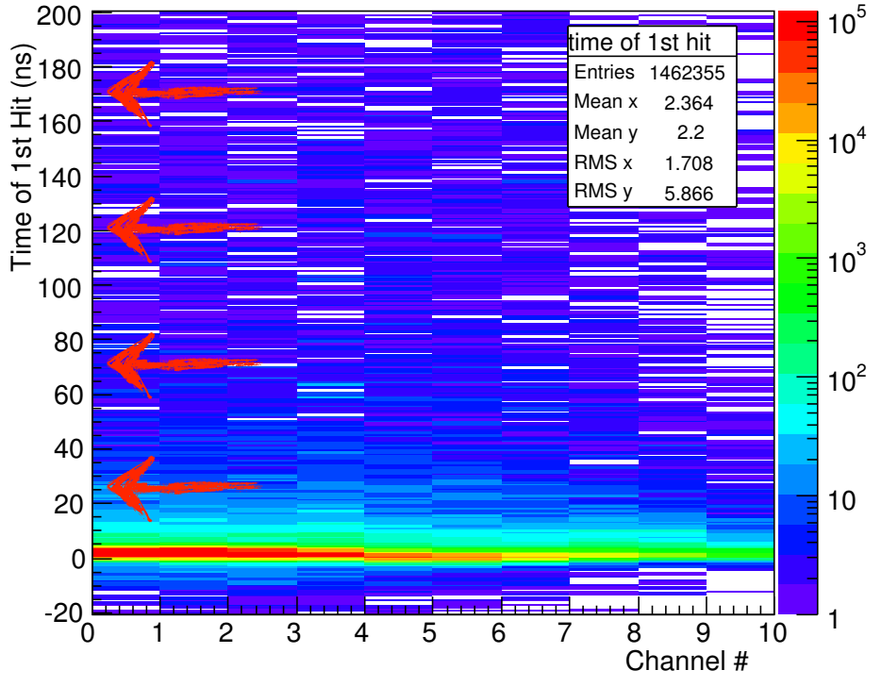

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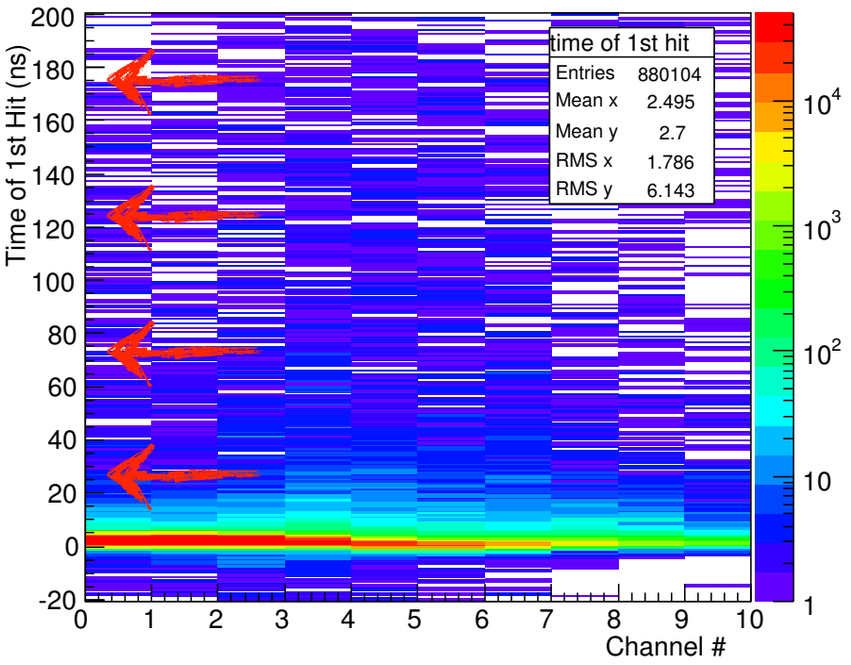

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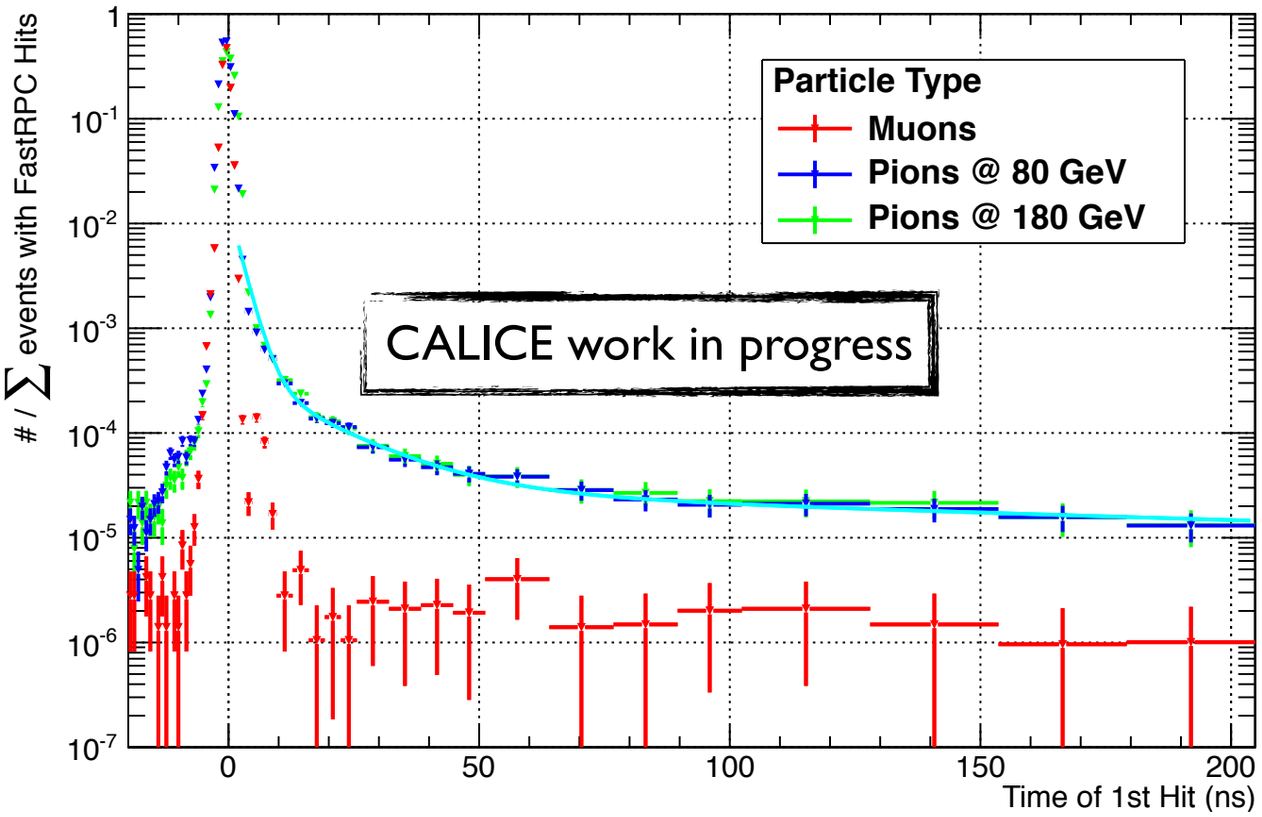
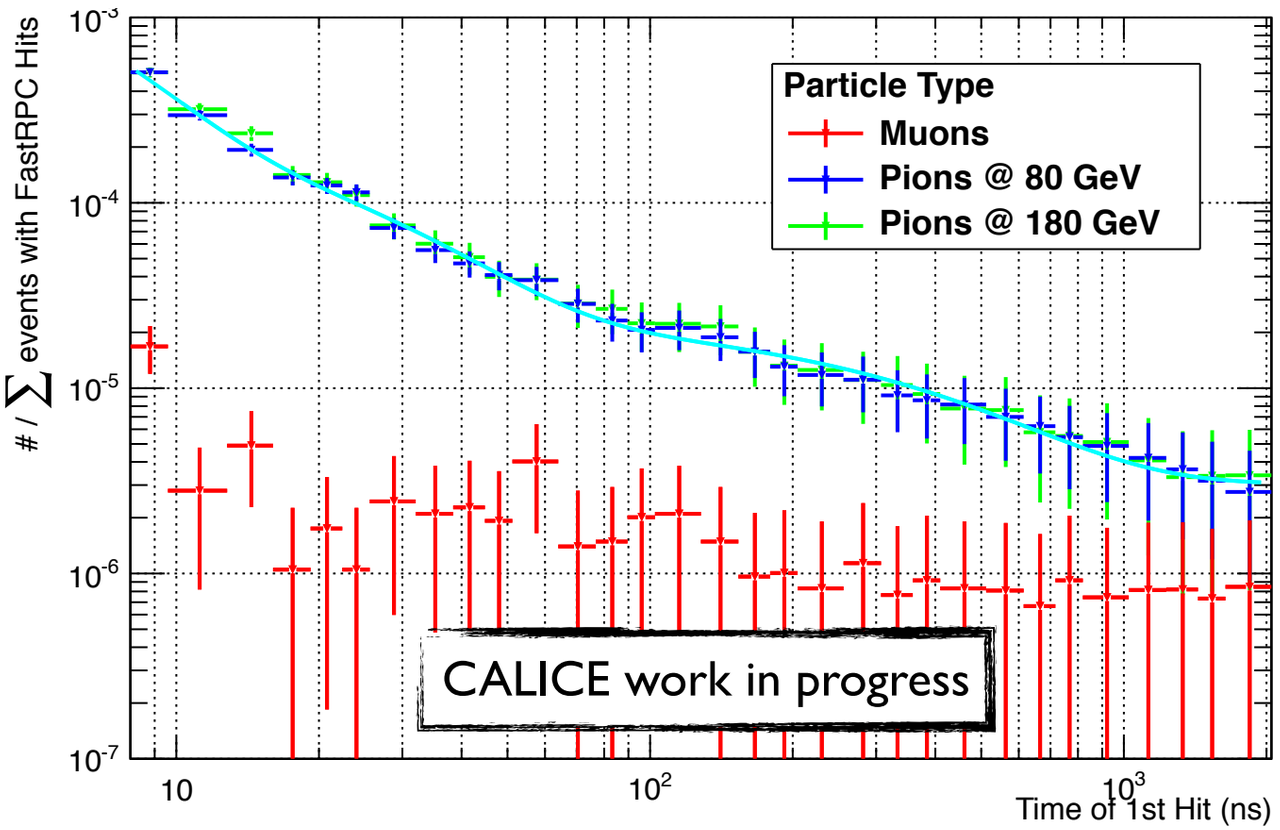
Data Analysis:

ToFH - Projection & Fit





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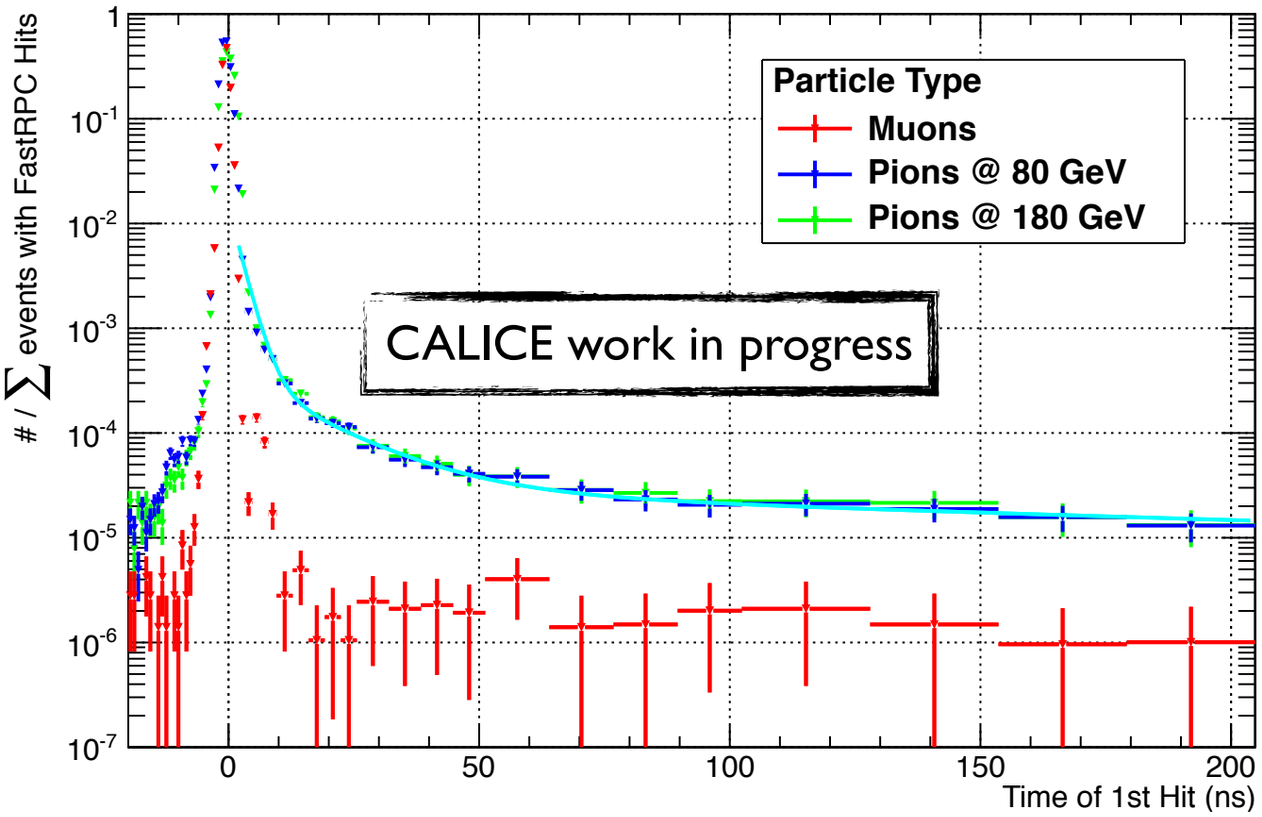
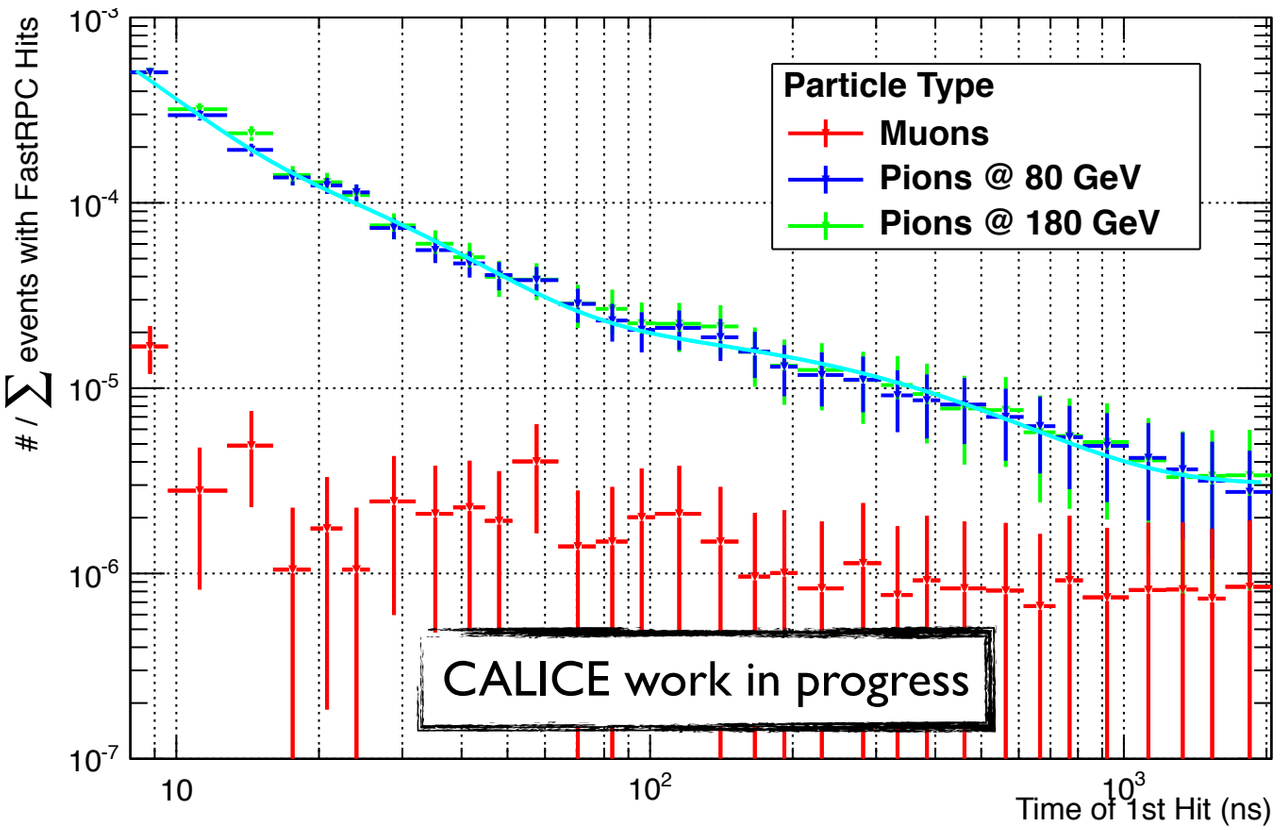
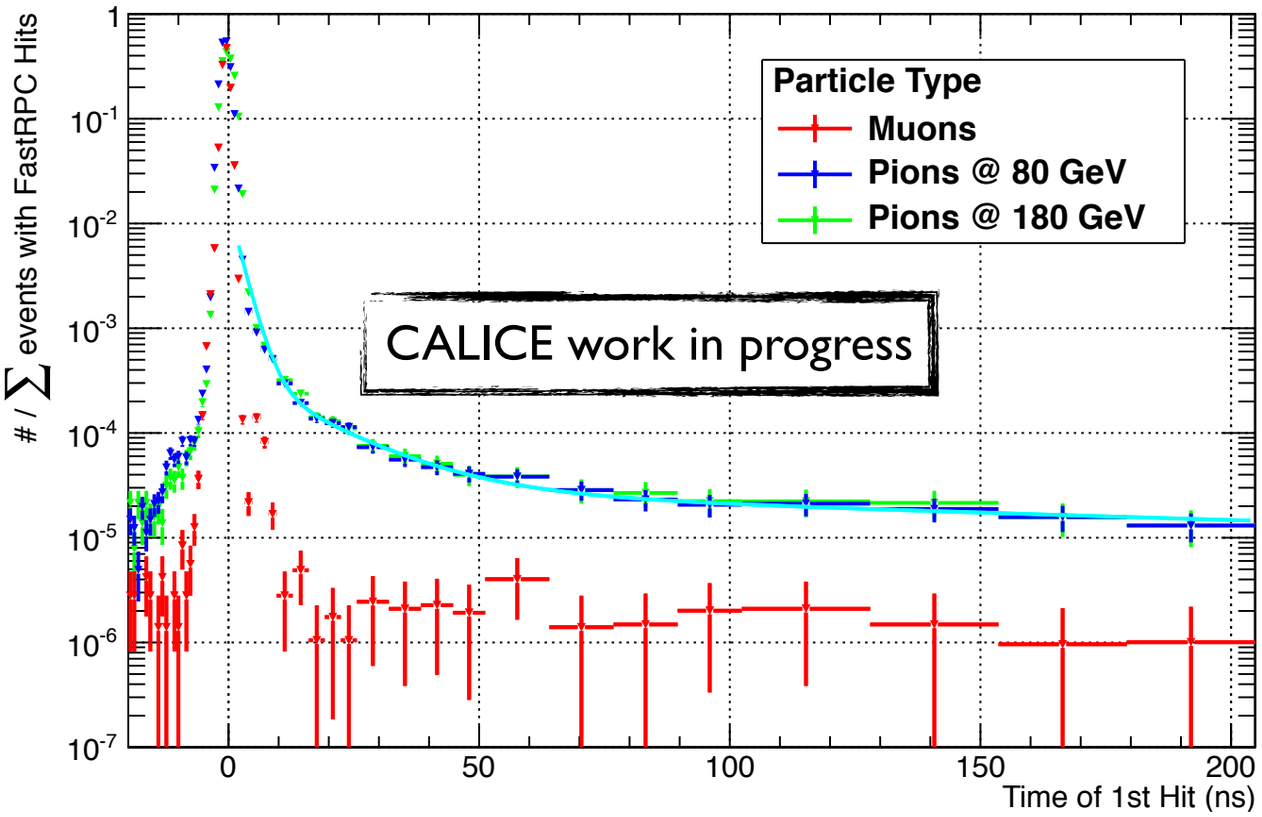


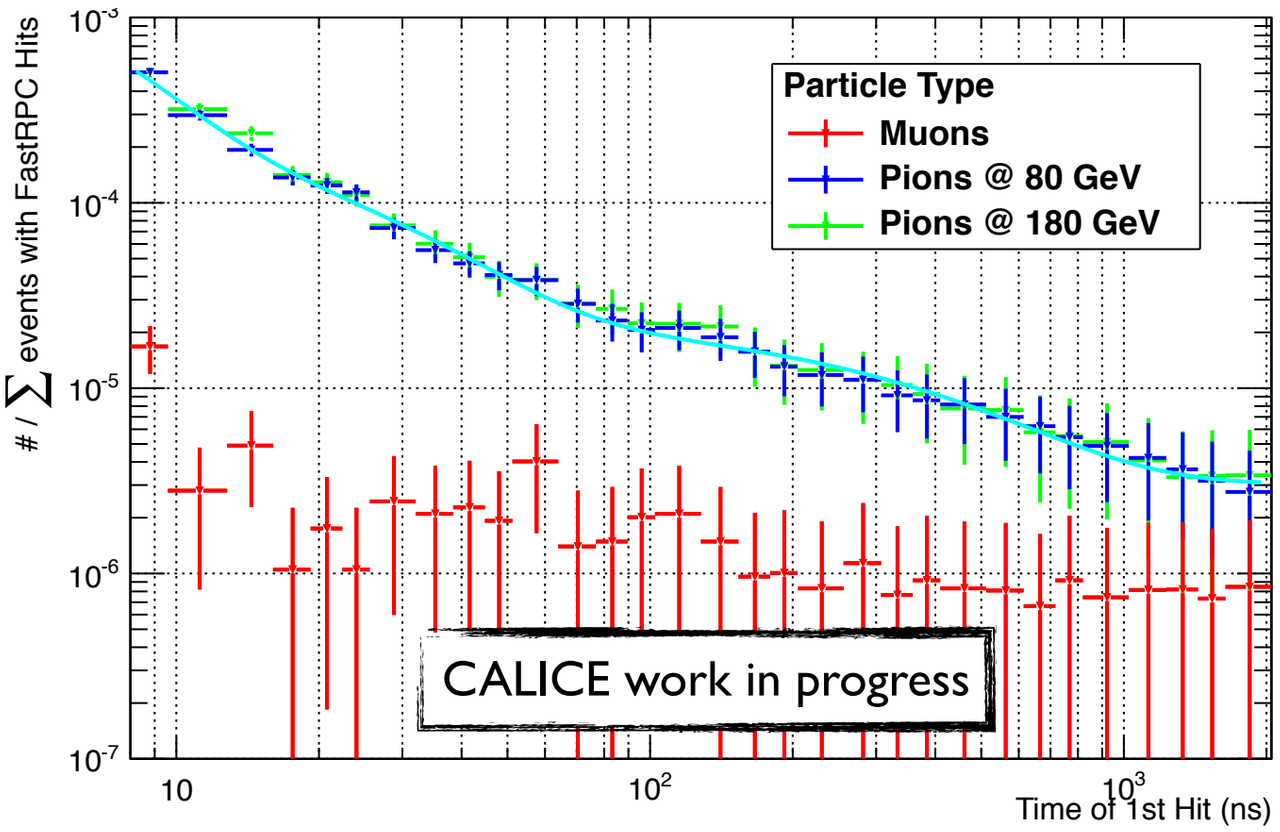


Time structure is independent from energy of the incoming particle

Data Analysis:

ToFH - Projection & Fit



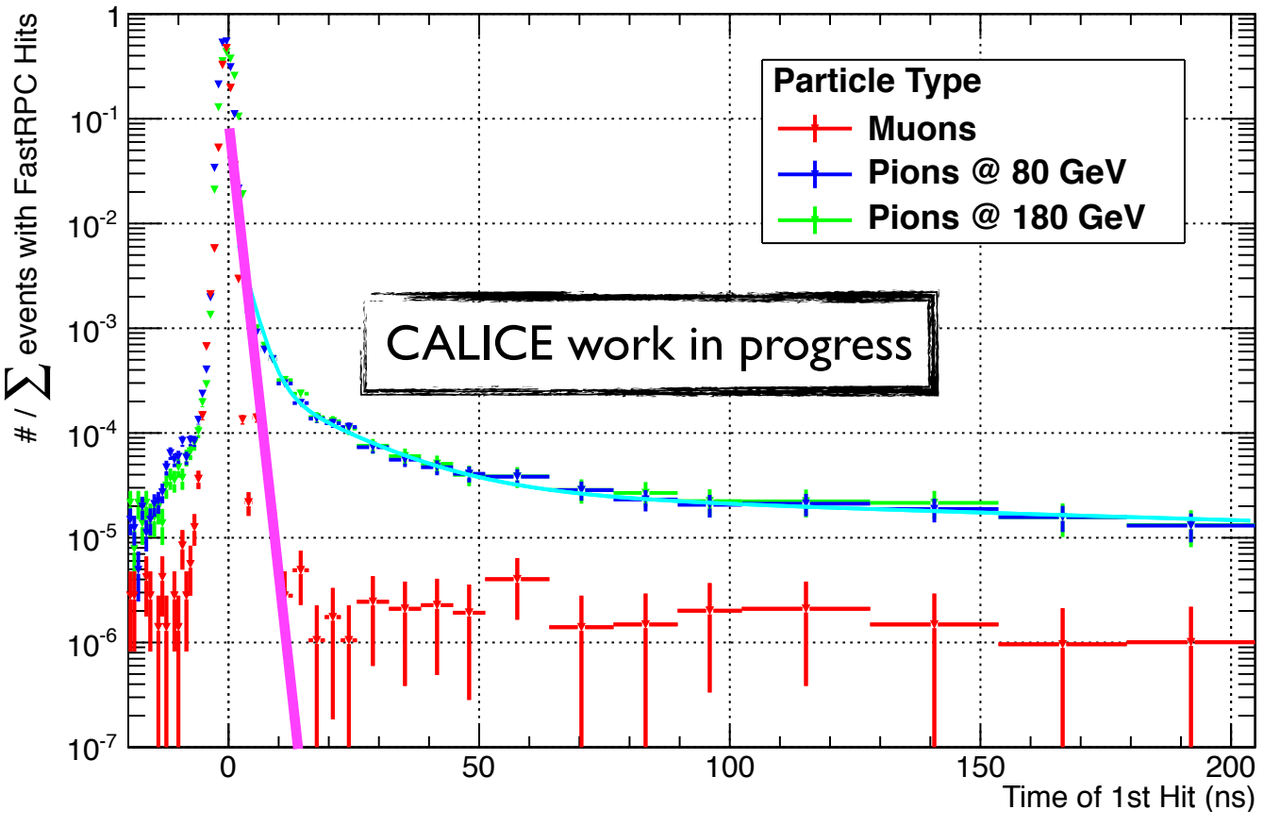


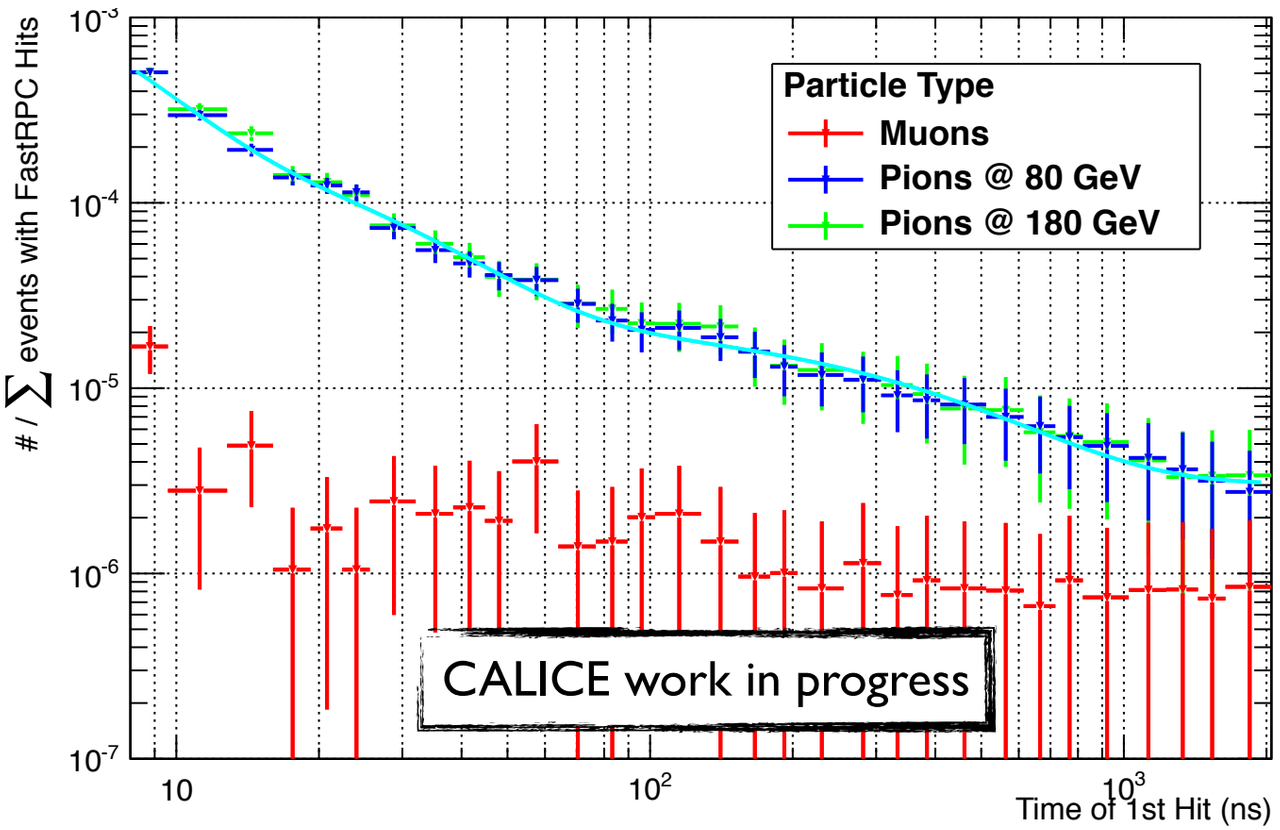
Time structure is independent from energy of the incoming particle

$$A_1 \cdot \exp\left(-\frac{t}{\tau_1}\right) + A_2 \cdot \exp\left(-\frac{t}{\tau_2}\right) + A_3 \cdot \exp\left(-\frac{t}{\tau_3}\right) + c$$

Data Analysis:

ToFH - Projection & Fit





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$A_1 = 4.2 \times 10^{-3}$ $\tau_1 = 3.2$ ns

Data Analysis:

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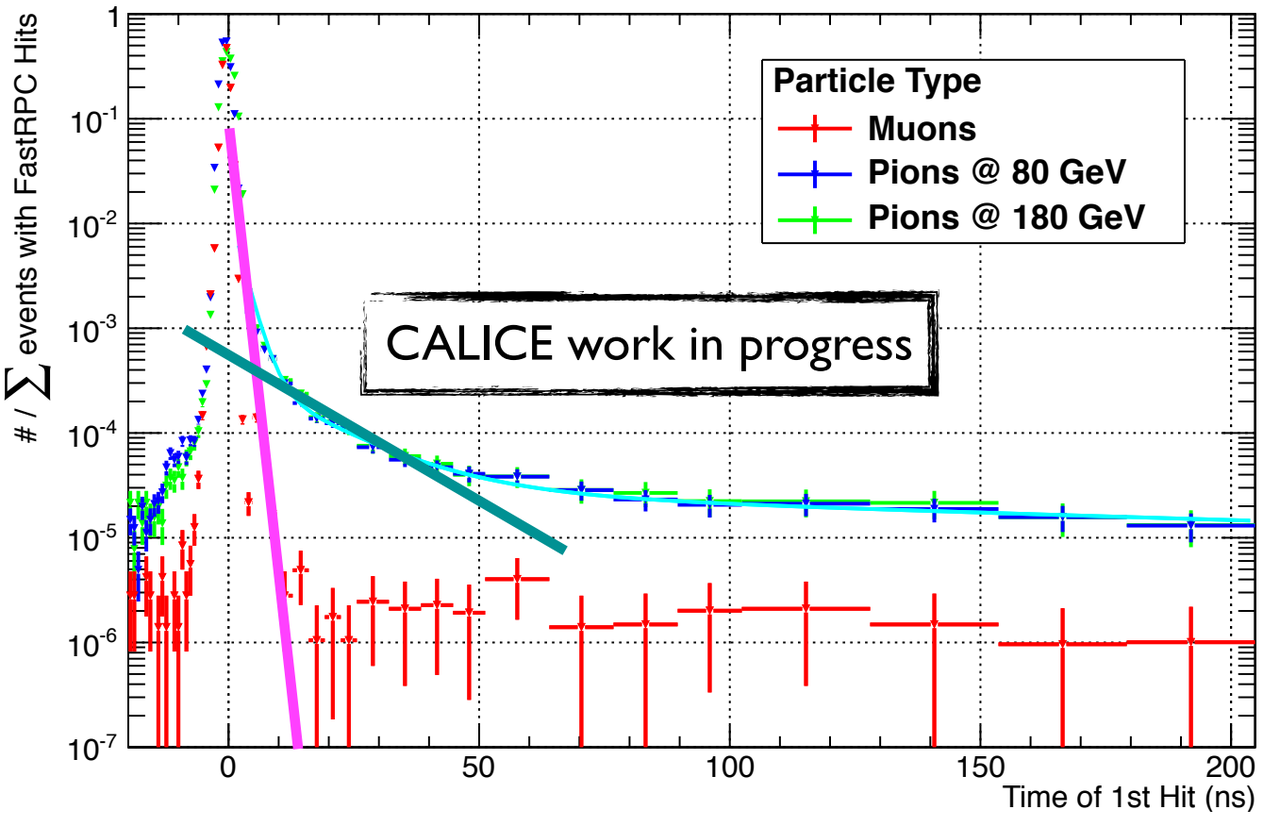

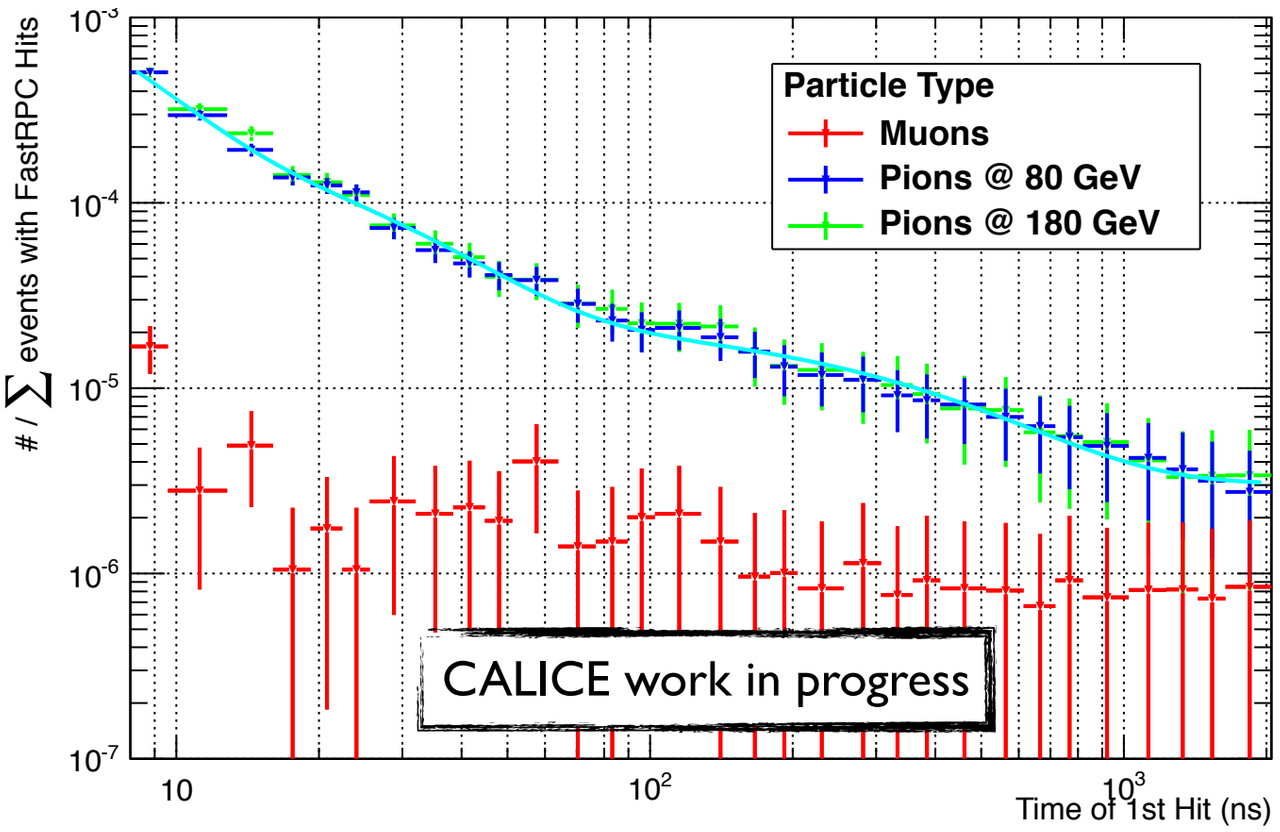

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$A_1 = 4.2 \times 10^{-3}$ $\tau_1 = 3.2$ ns

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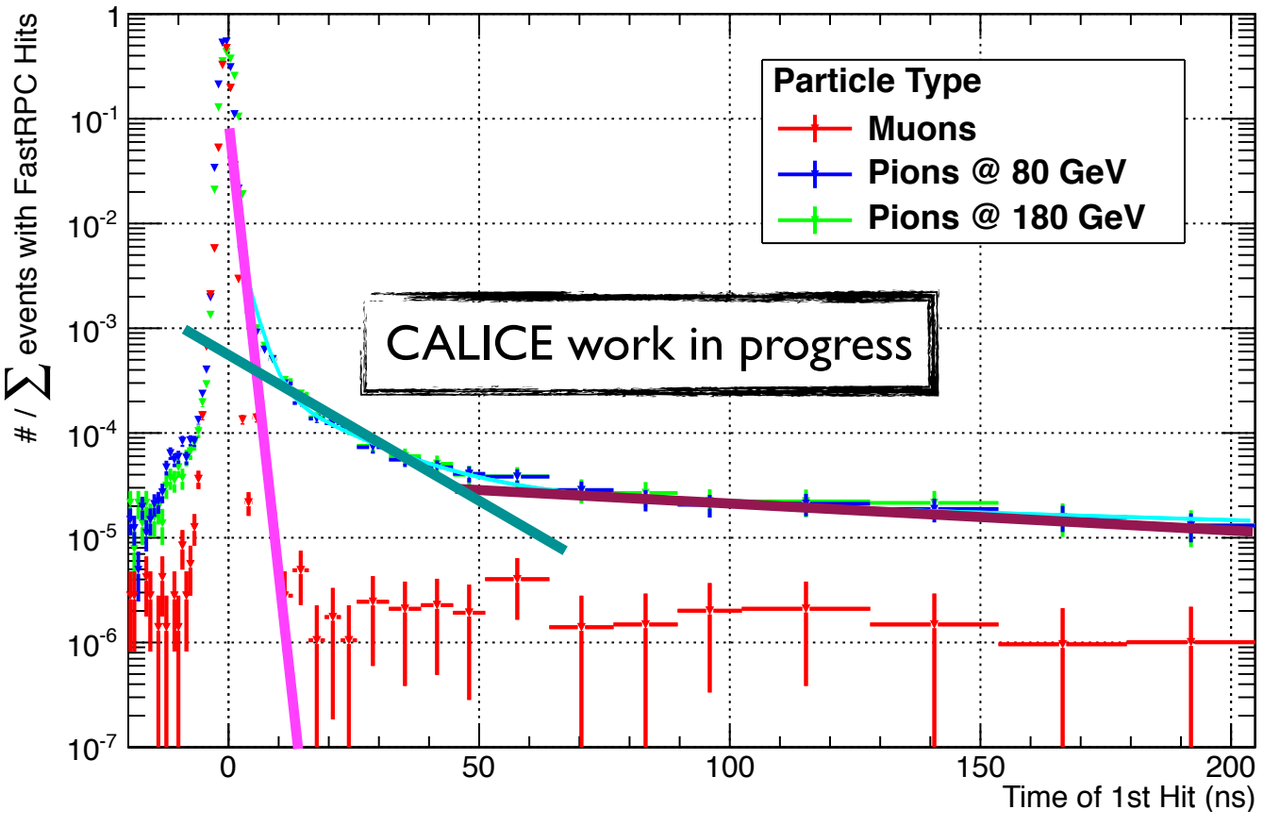

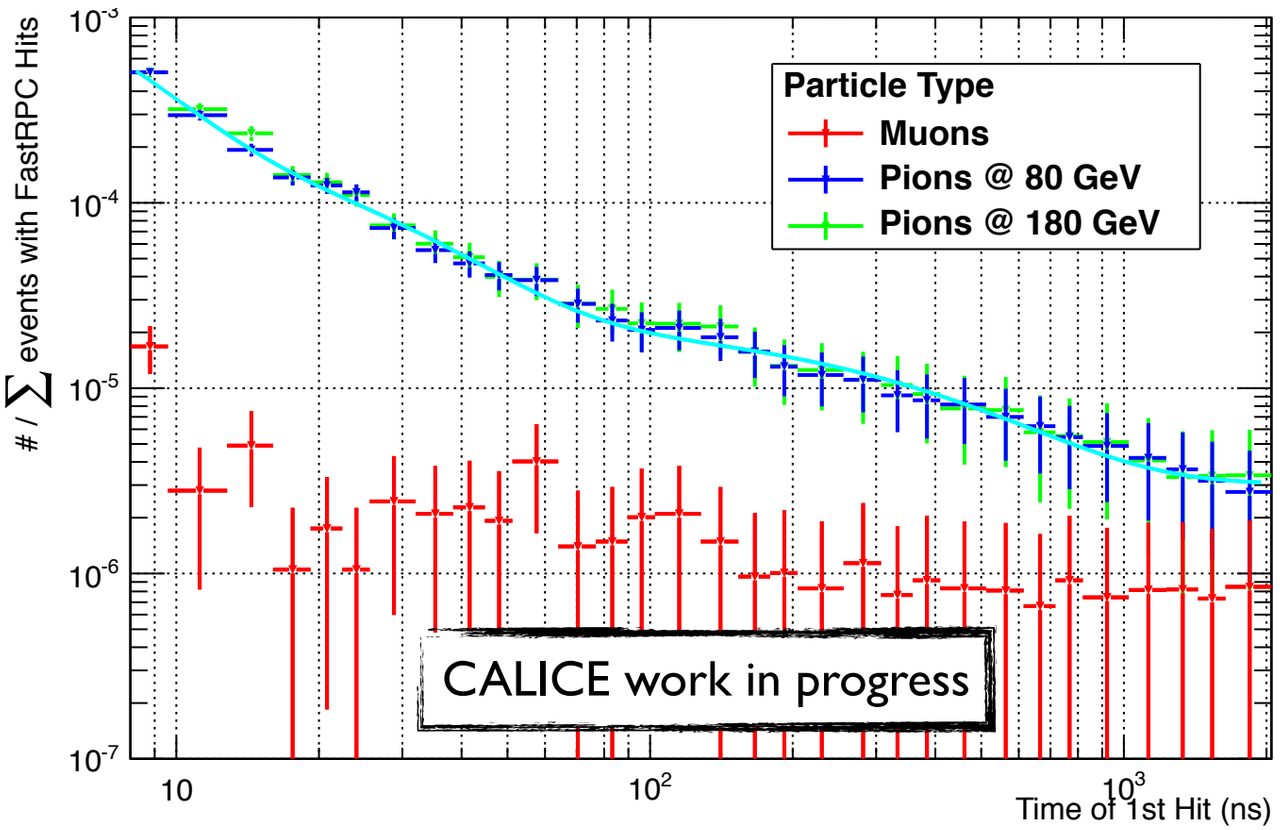

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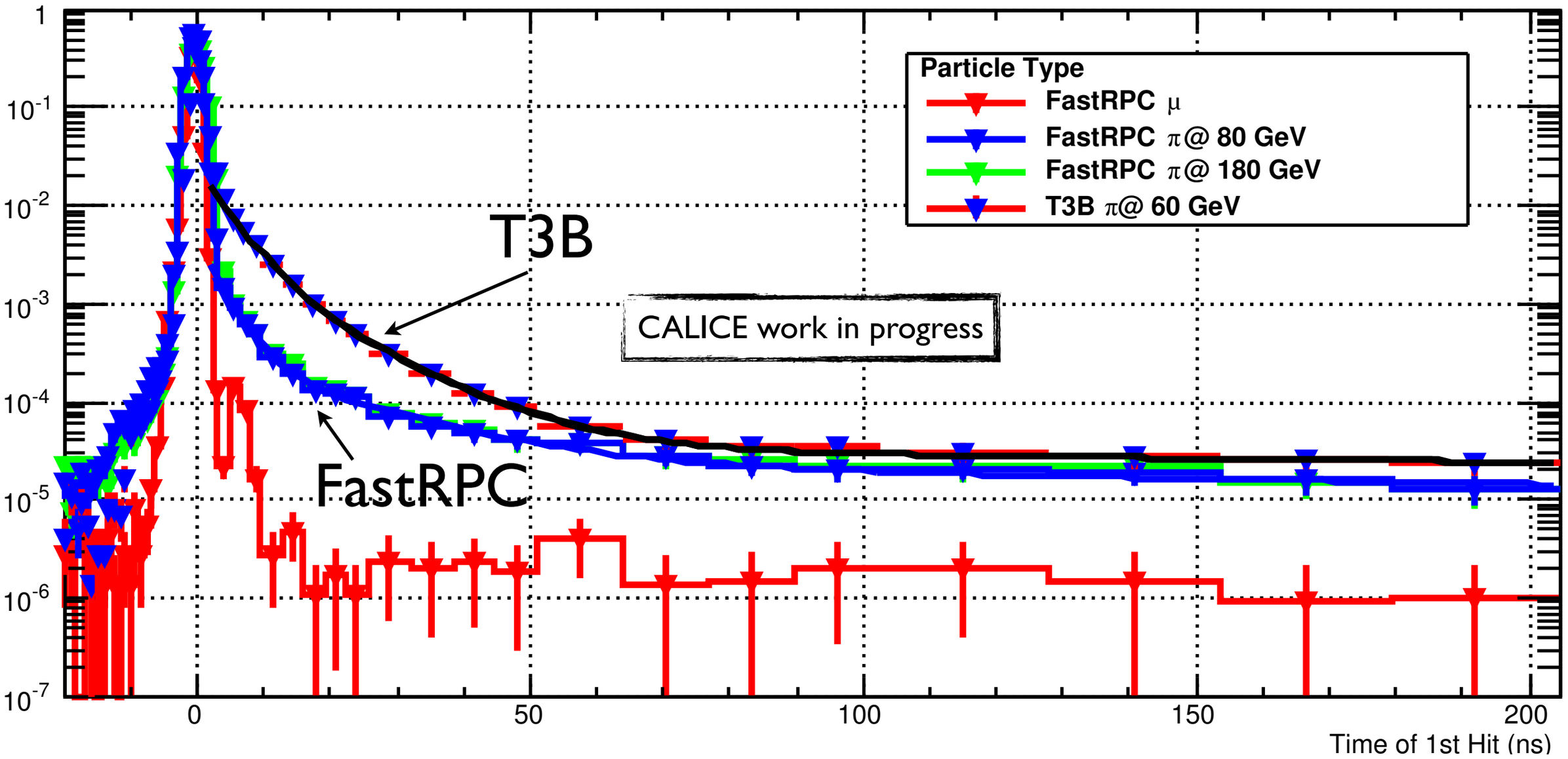
$A_2 = 2.8 \times 10^{-4}$ $\tau_2 = 18$ ns

$A_3 = 2.1 \times 10^{-5}$ $\tau_3 = 320$ ns

Data Analysis:

Comparison with Plastic Scintillators

Similar experiment T3B = same readout and absorber BUT plastic scintillators as active layer



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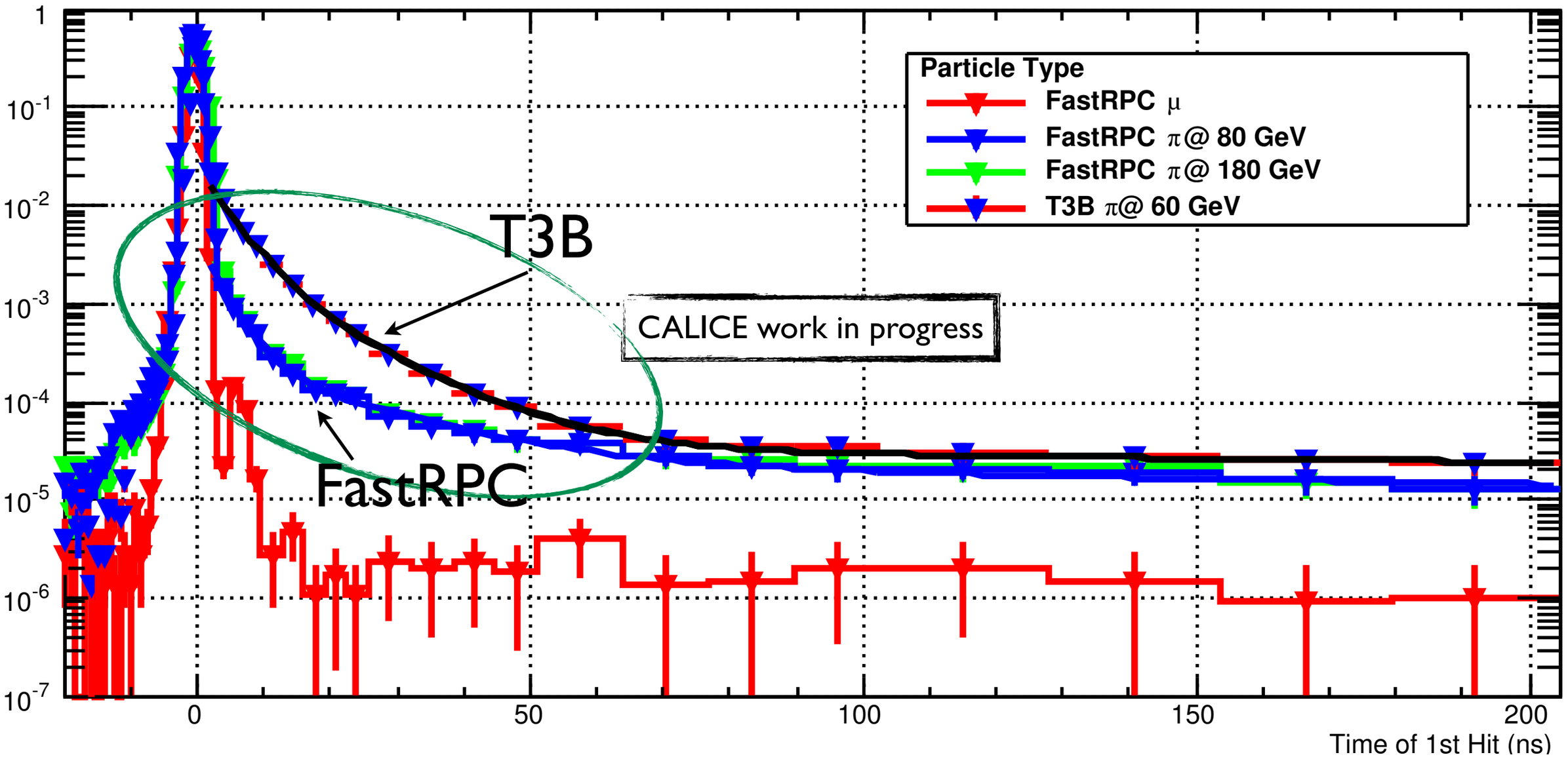
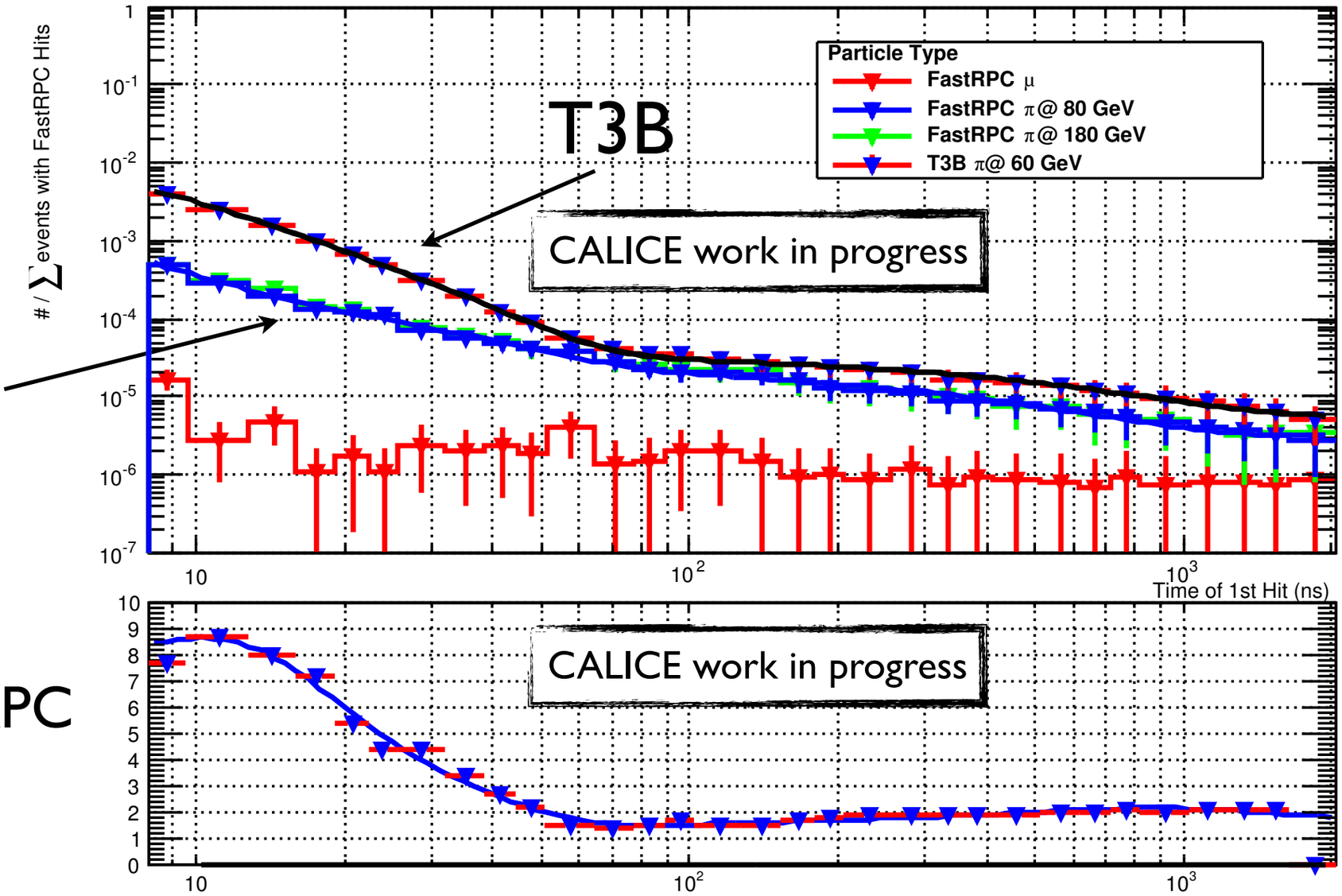


Data Analysis:
Comparison with Plastic Scintillators

FastRPC

T3B/FastRPC ratio



RPC suppress intermediate components [10,100] ns from neutron elastic scattering

Conclusions

- Development of the FastRPC detector to study the time structure of hadronic showers in a tungsten HCAL
  - Data taken with WDHCAL up to 180 GeV

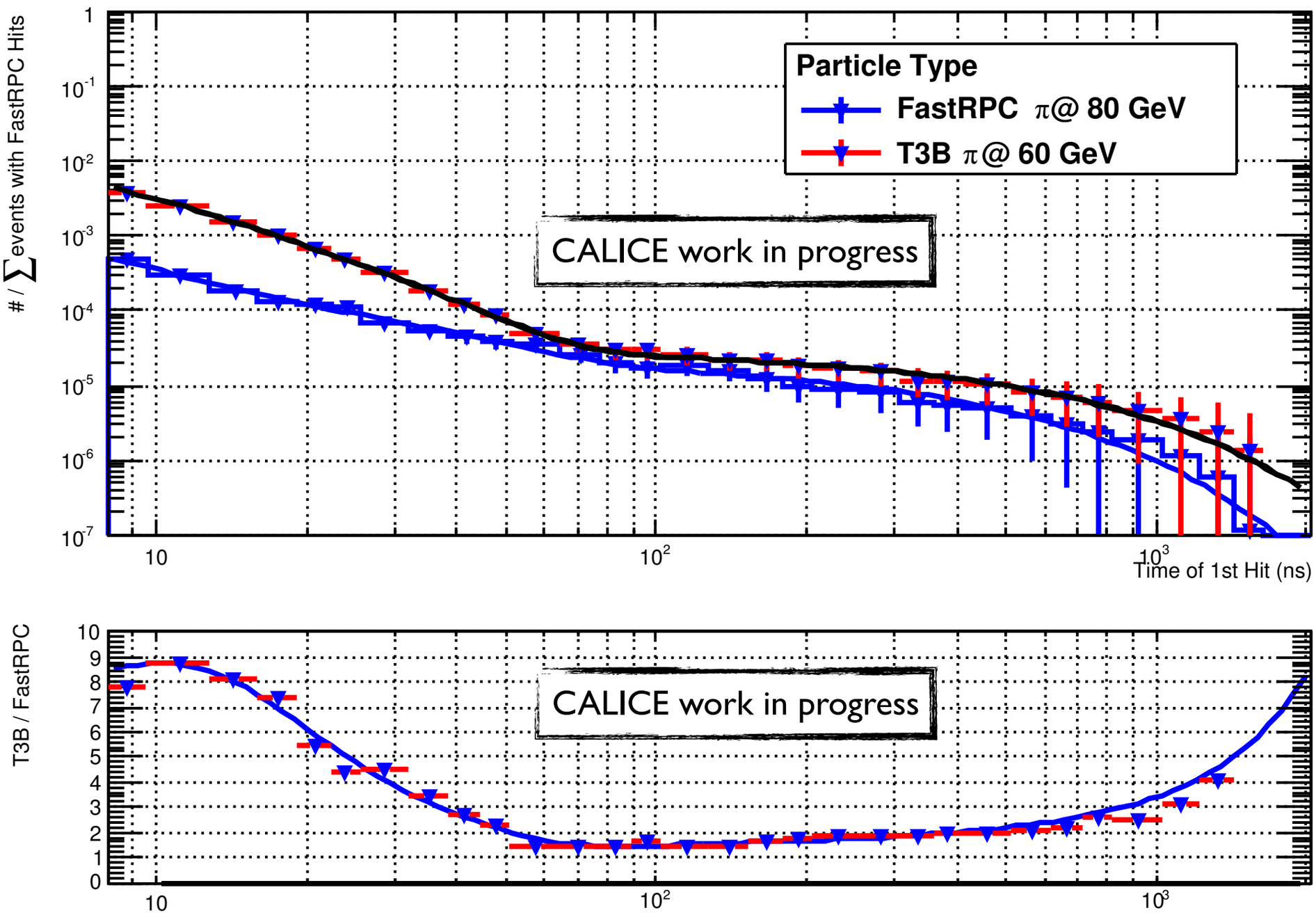
- Data Analysis
  - charge dependent to particle type and energy
  - sensitive to late components of the showers, 3 time components from different underlying processes in the shower
  - comparison with plastic scintillators shows suppression of intermediate components from neutron elastic scattering on H nuclei

- Full event synchronization with the DHCAL
- Comparison with MC

Backup

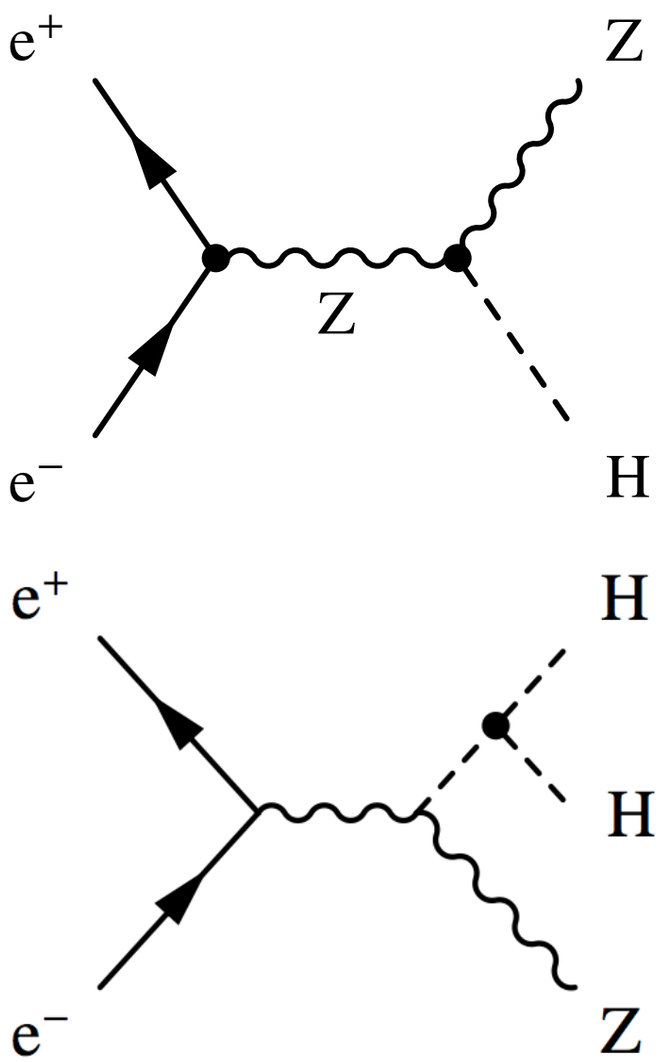
Backup:

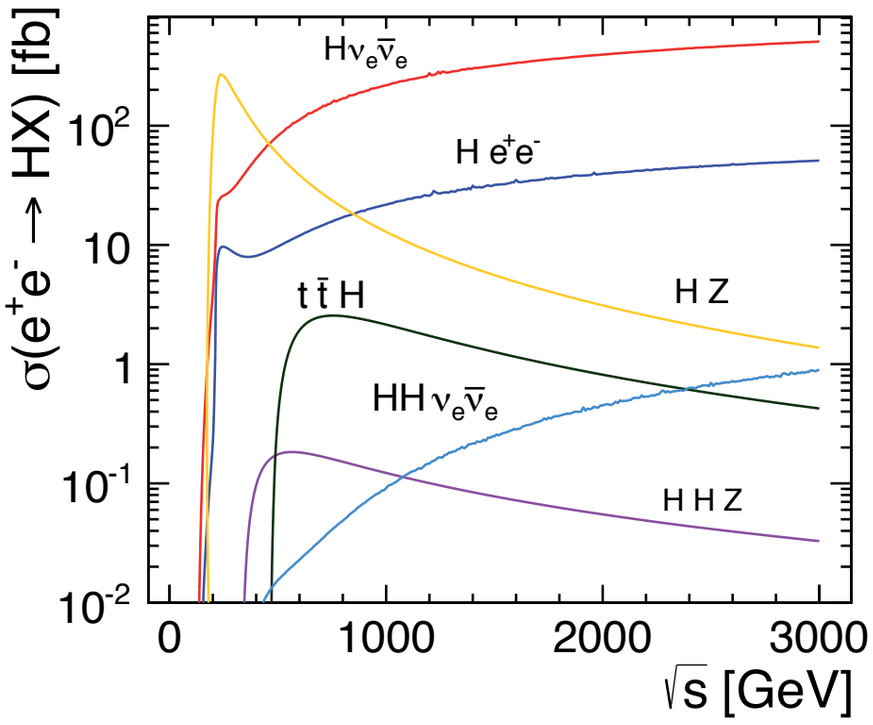
pedestal subtracted comparison



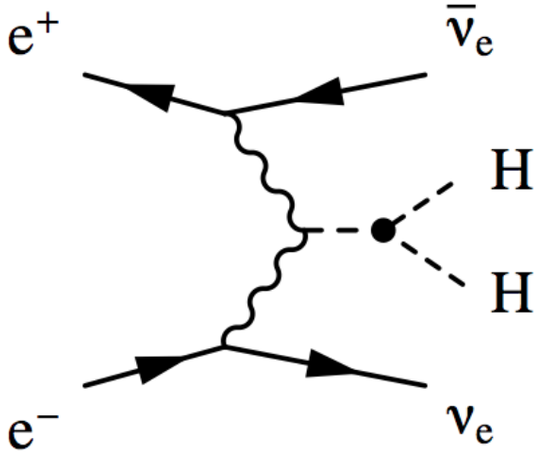
Backup:

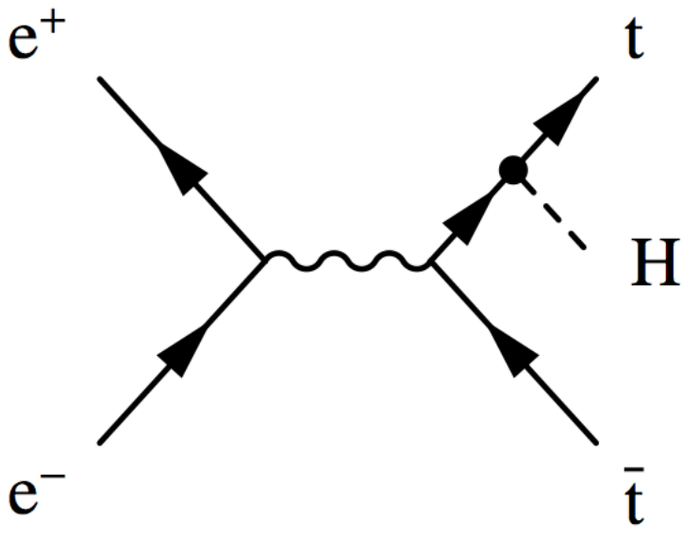
Physics processes LC

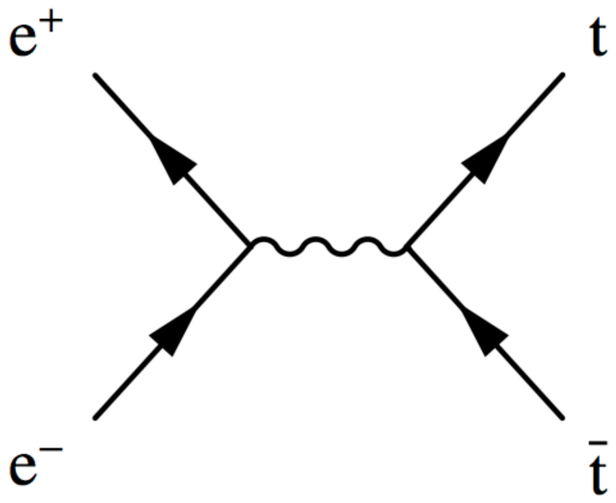




source: Frank Simon - arXiv:1211.7242

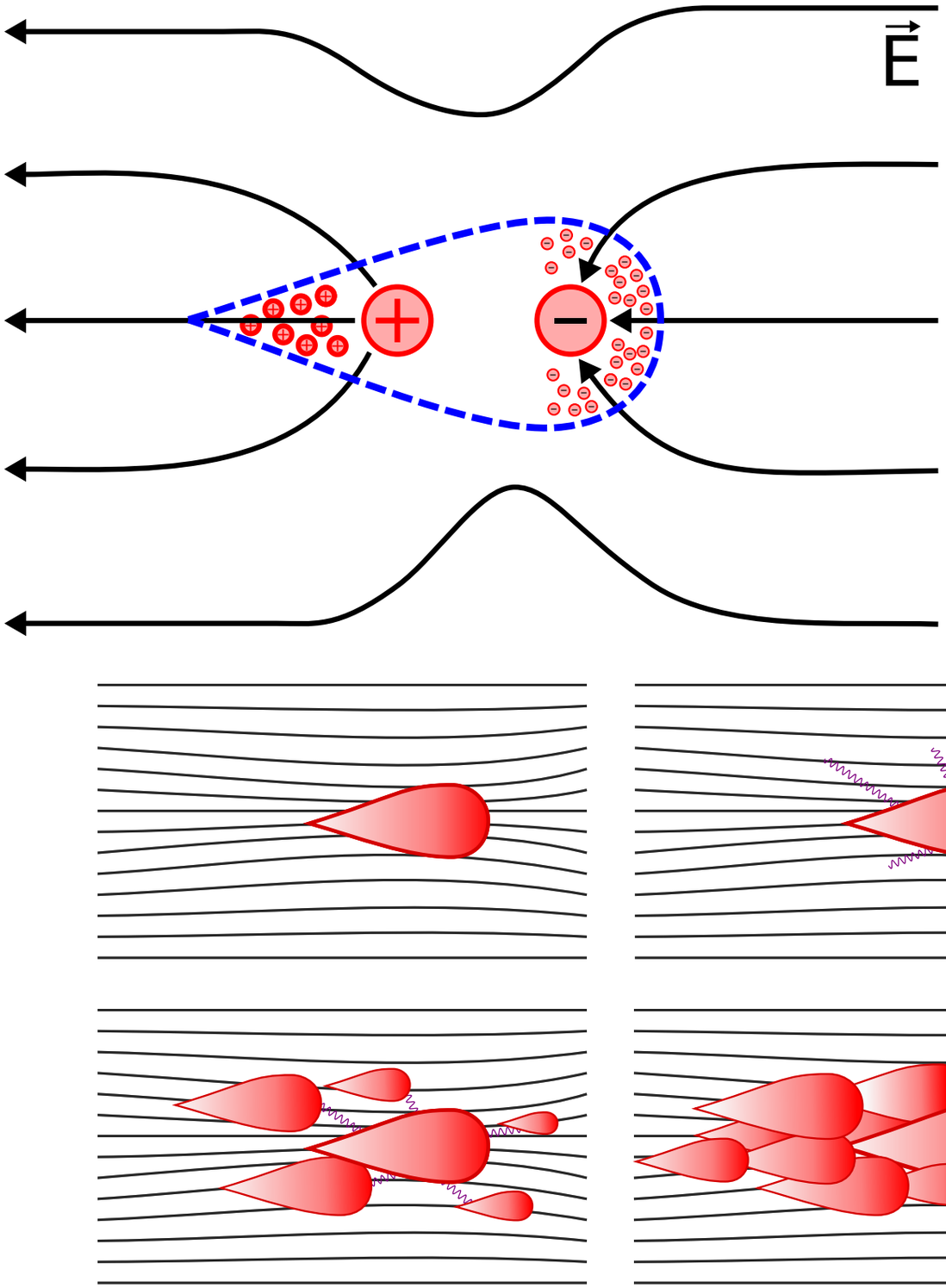


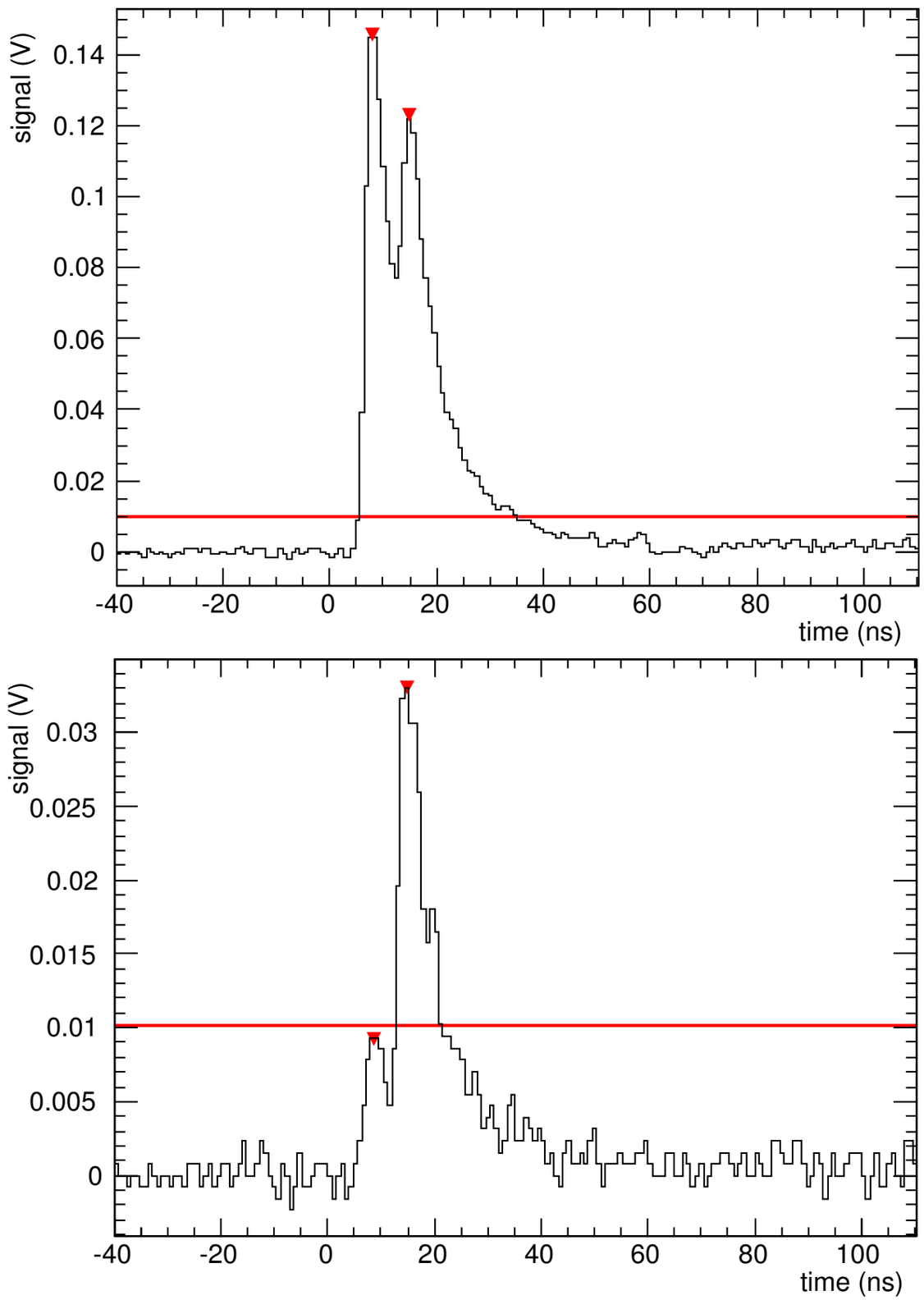




Backup:

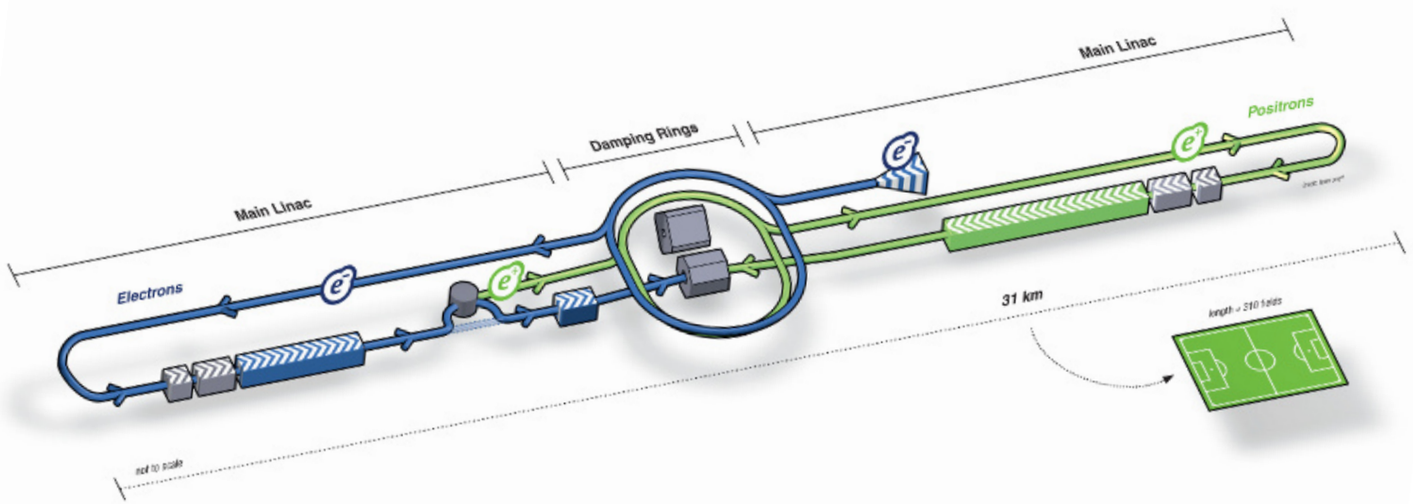
Streamers



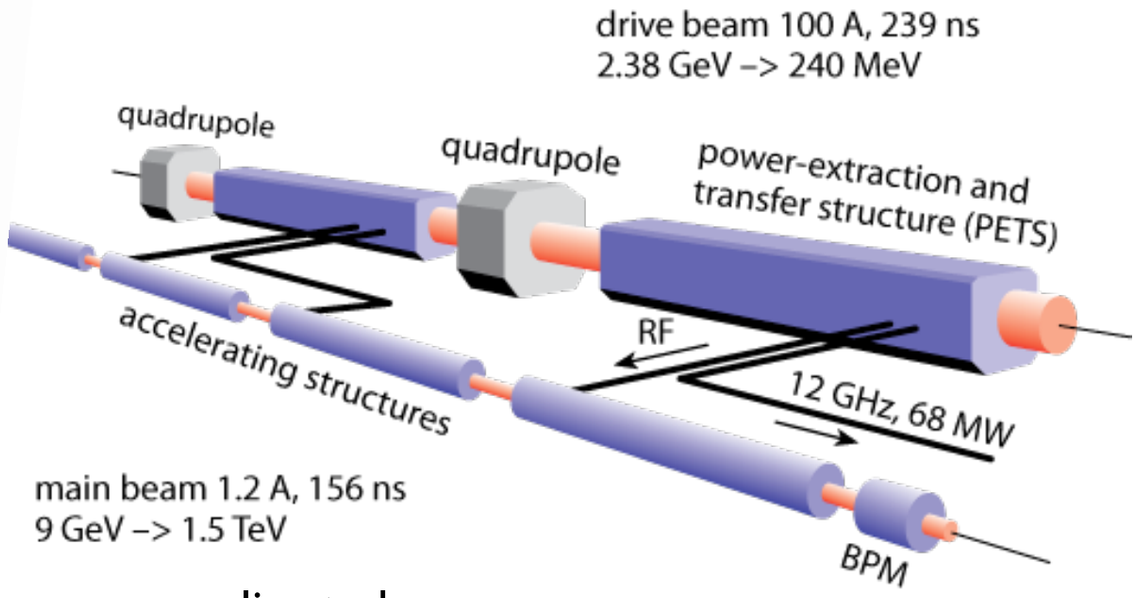


Physics at e+/e- LC

- 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



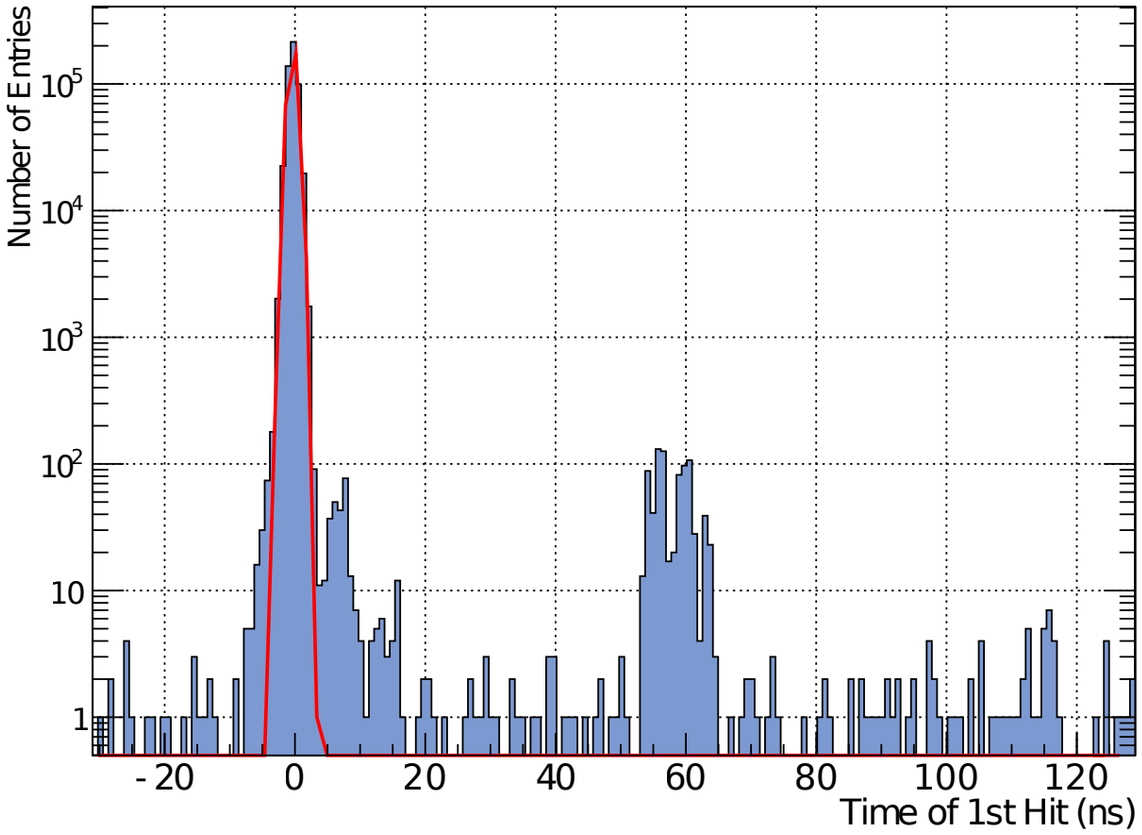
source: linearcollider.org



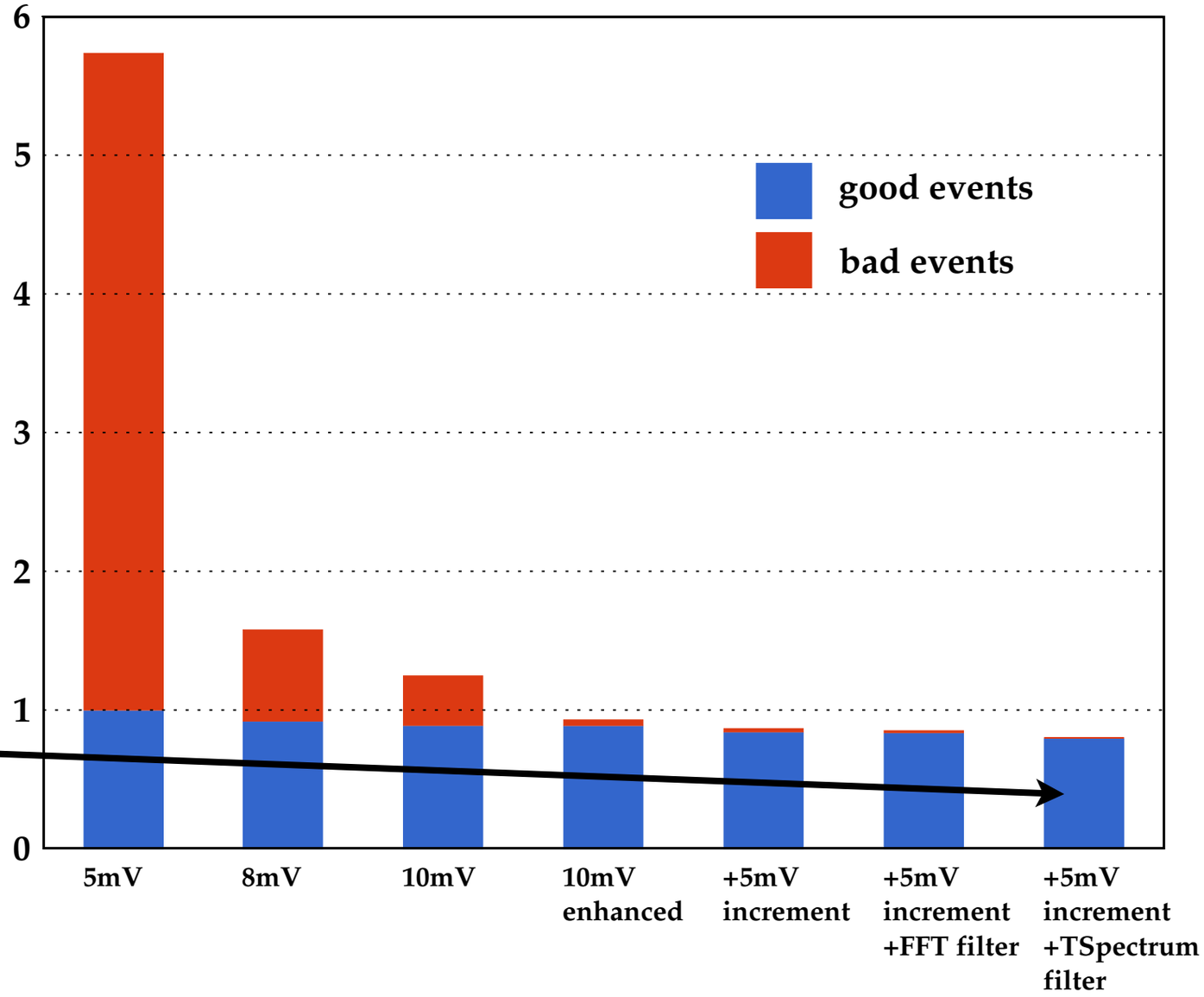
source: clic-study.org

Backup:

Calibration Benchmark

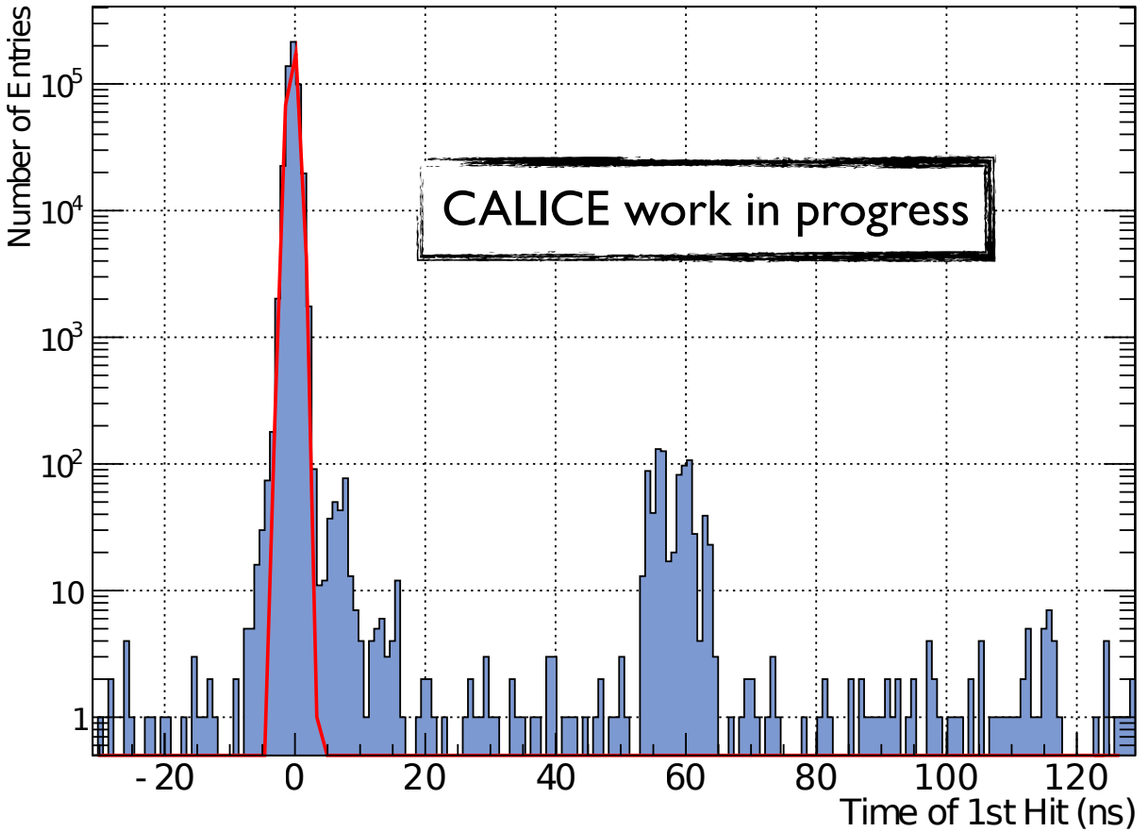


0.997 efficiency

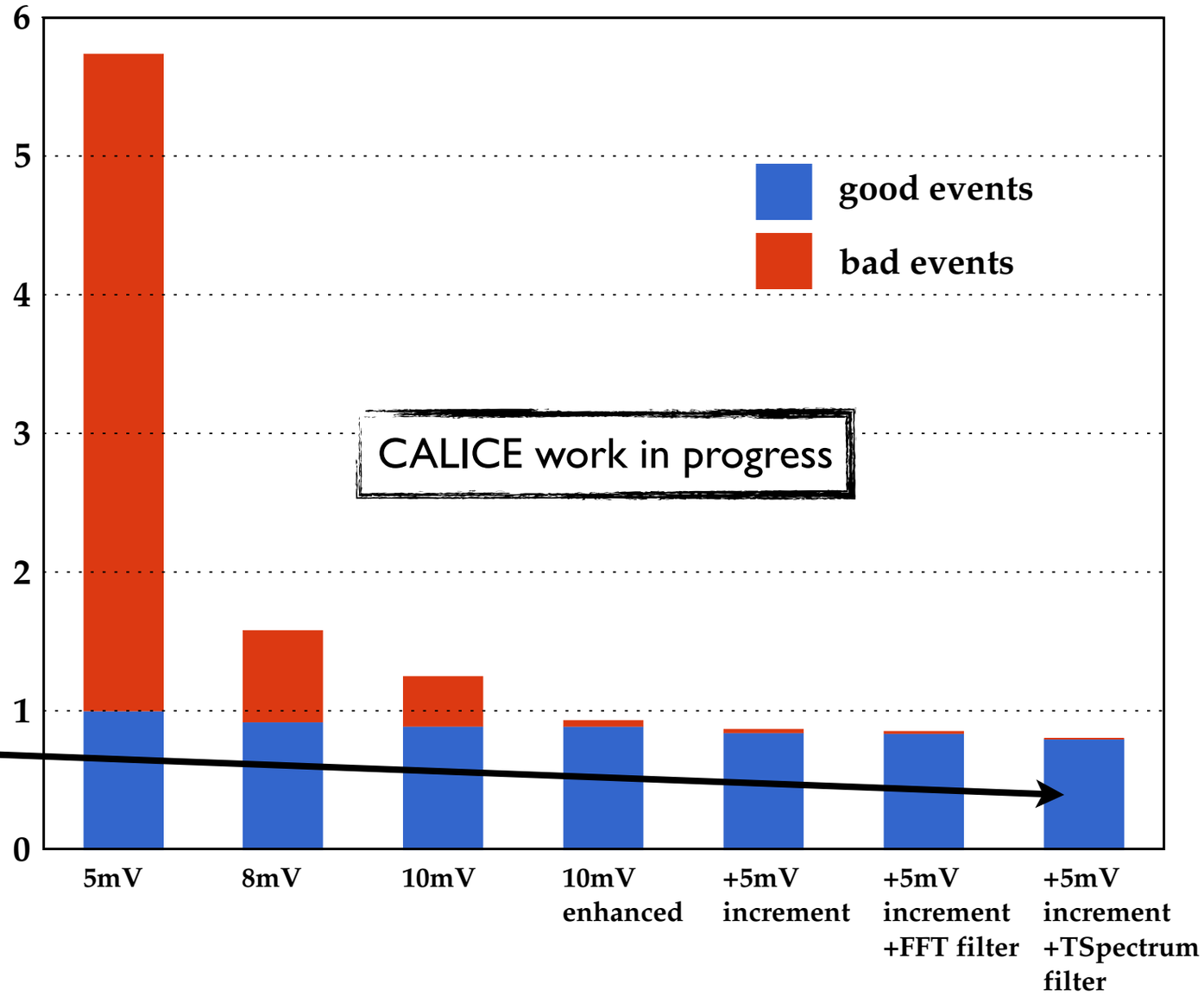


Backup:

Calibration Benchmark



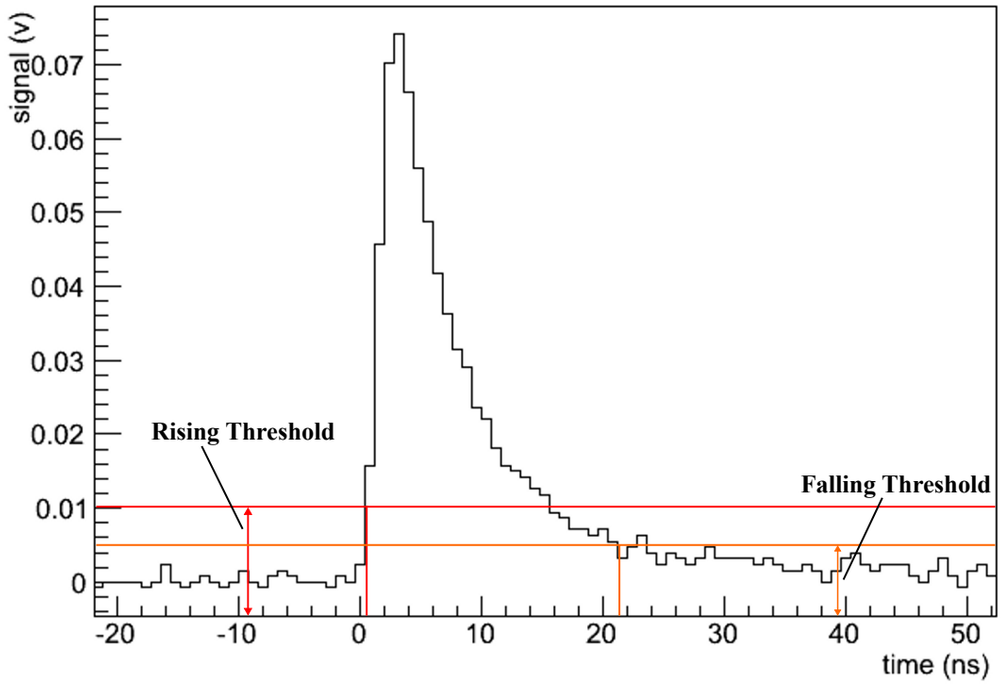
0.997 efficiency



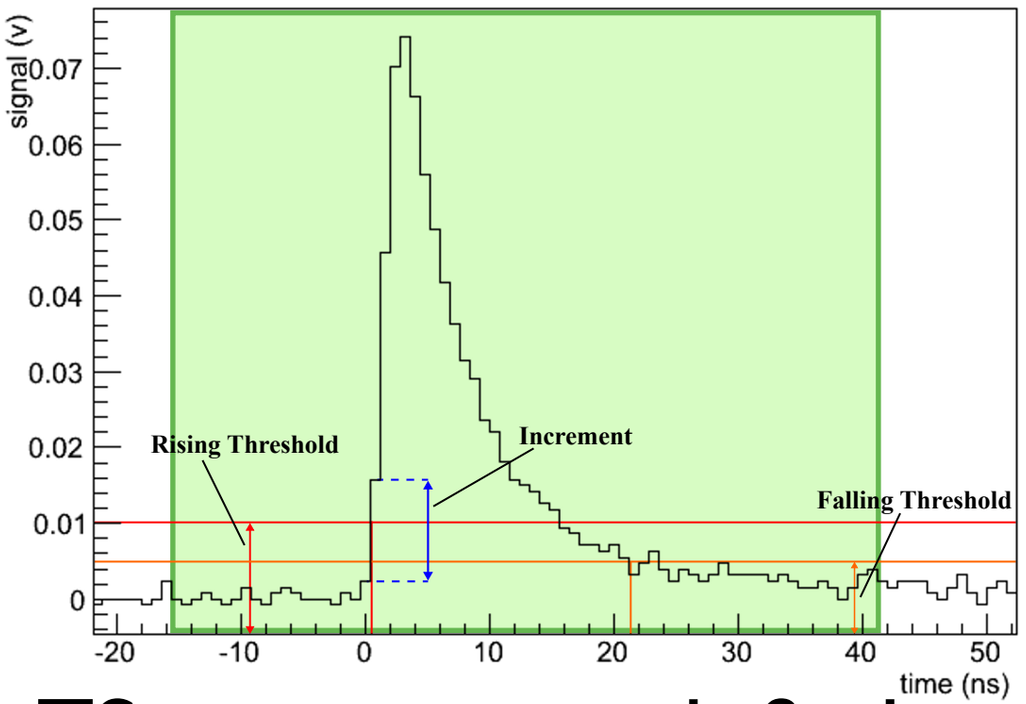
Backup:

Calibration

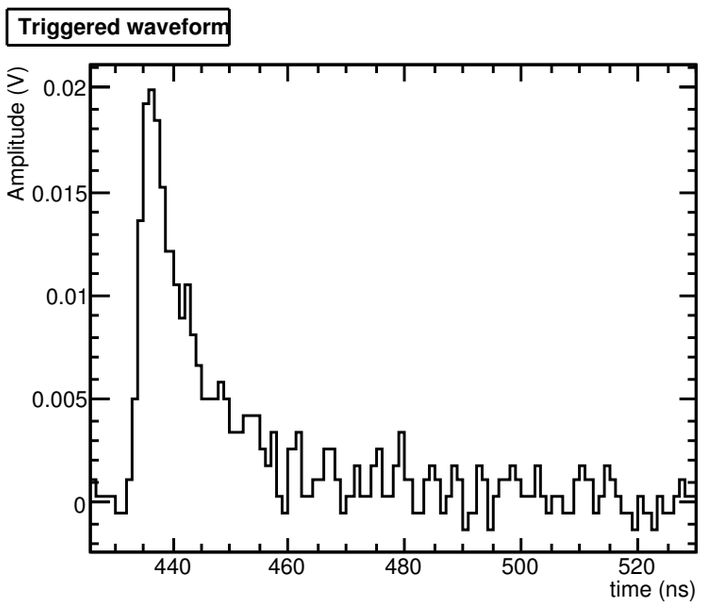
Threshold cut

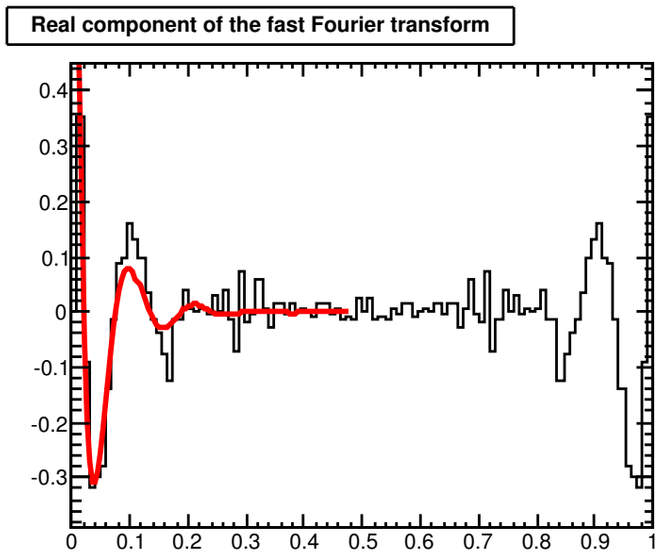


Threshold cut + derivative

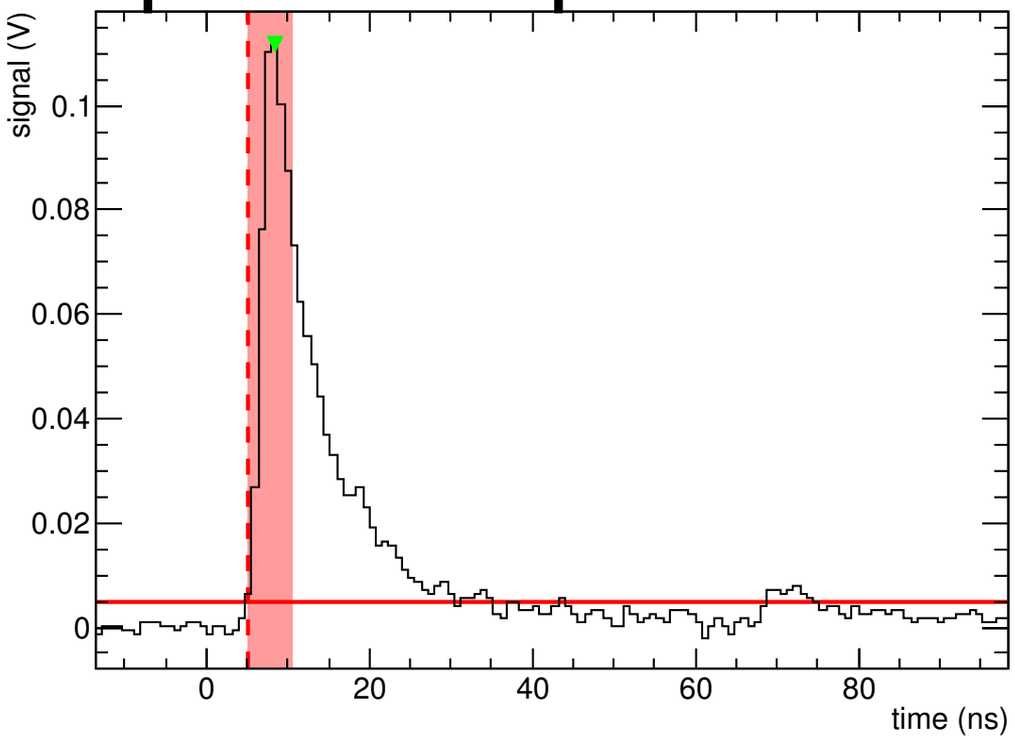


FFT + fit



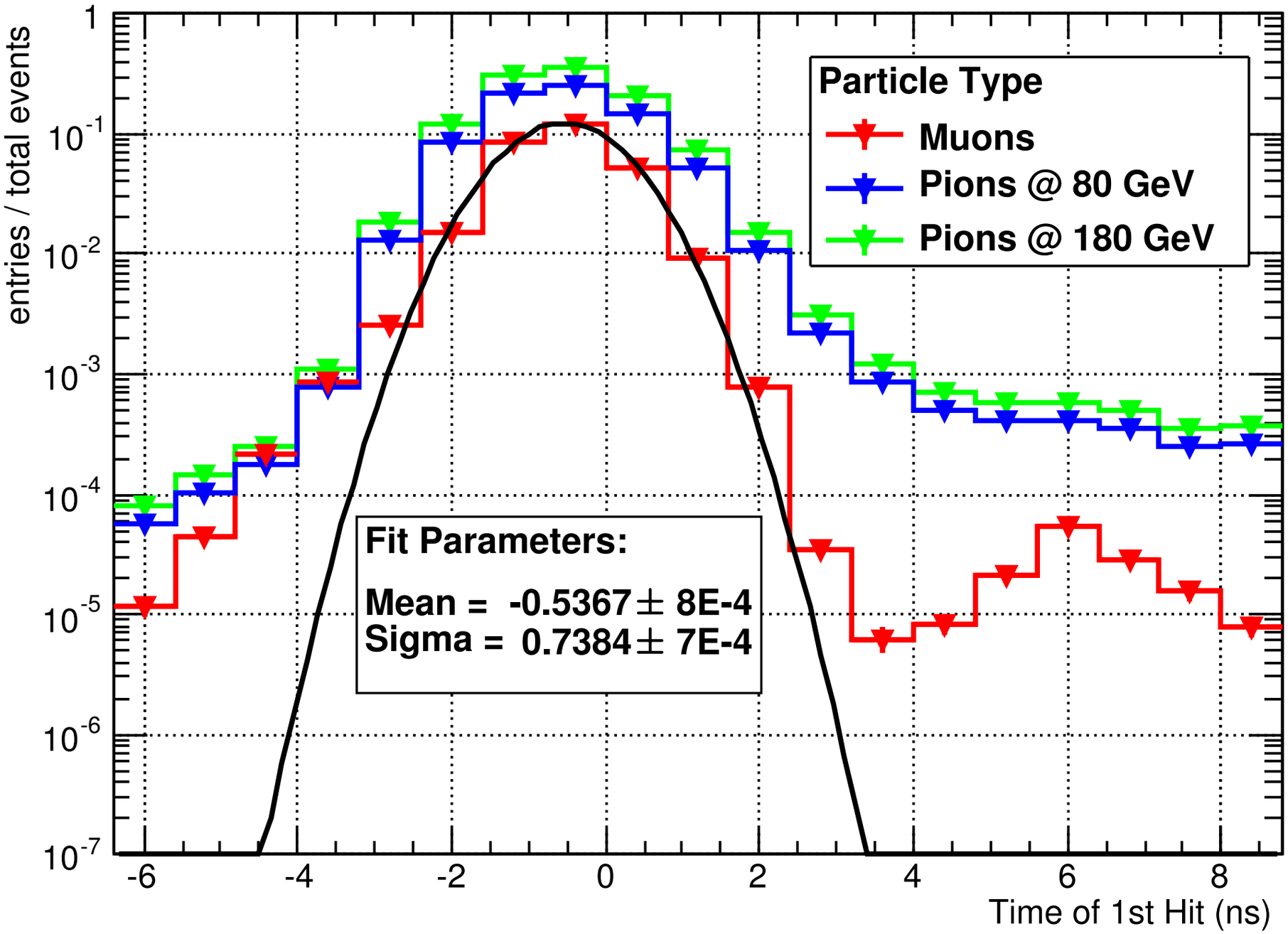


TSpectrum - peak finder



Backup:

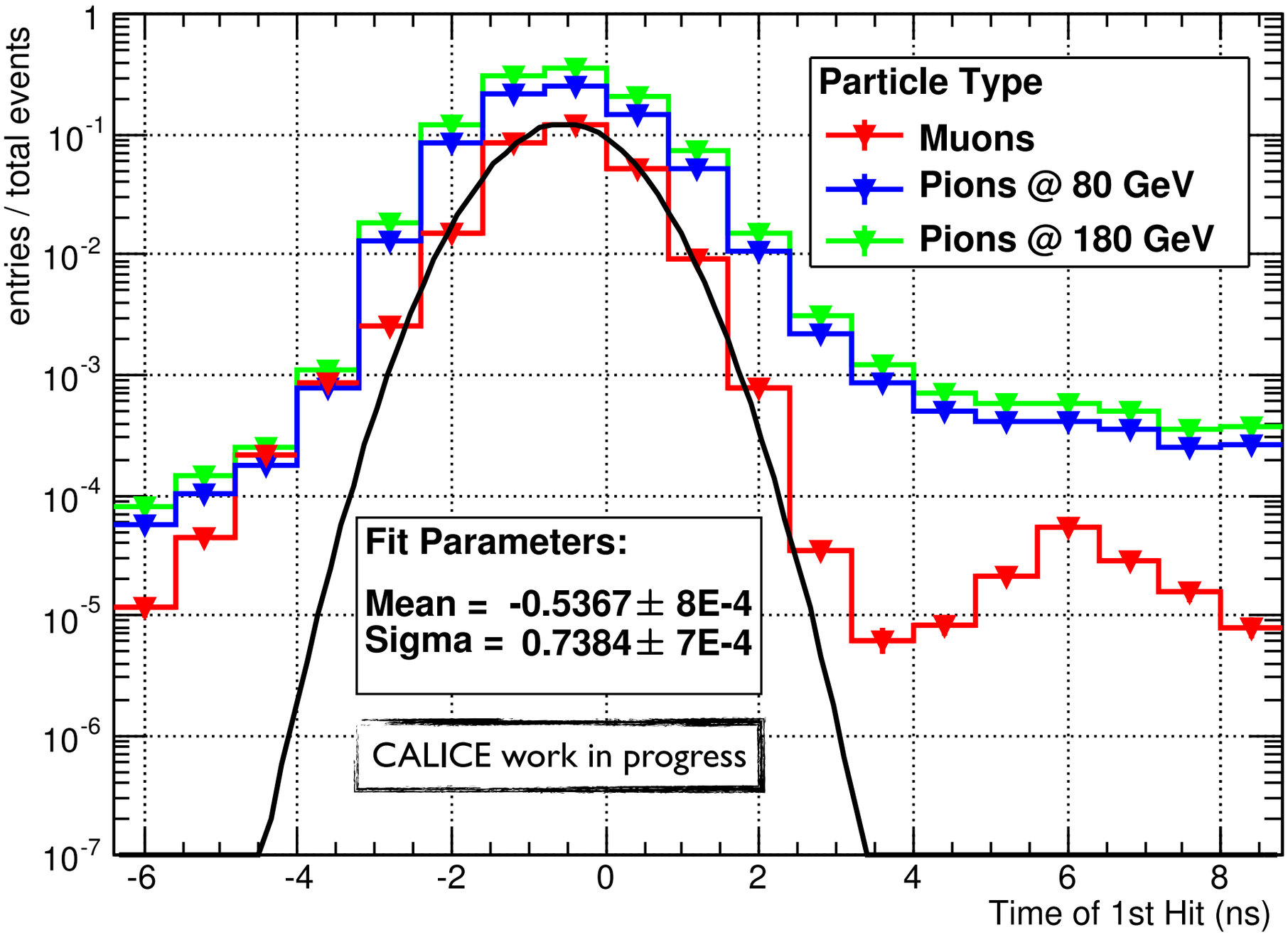
FastRPC - Time Resolution



Dominated by jitter in the triggers

Backup:

FastRPC - Time Resolution



Dominated by jitter in the triggers

Testbeam at CERN

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

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

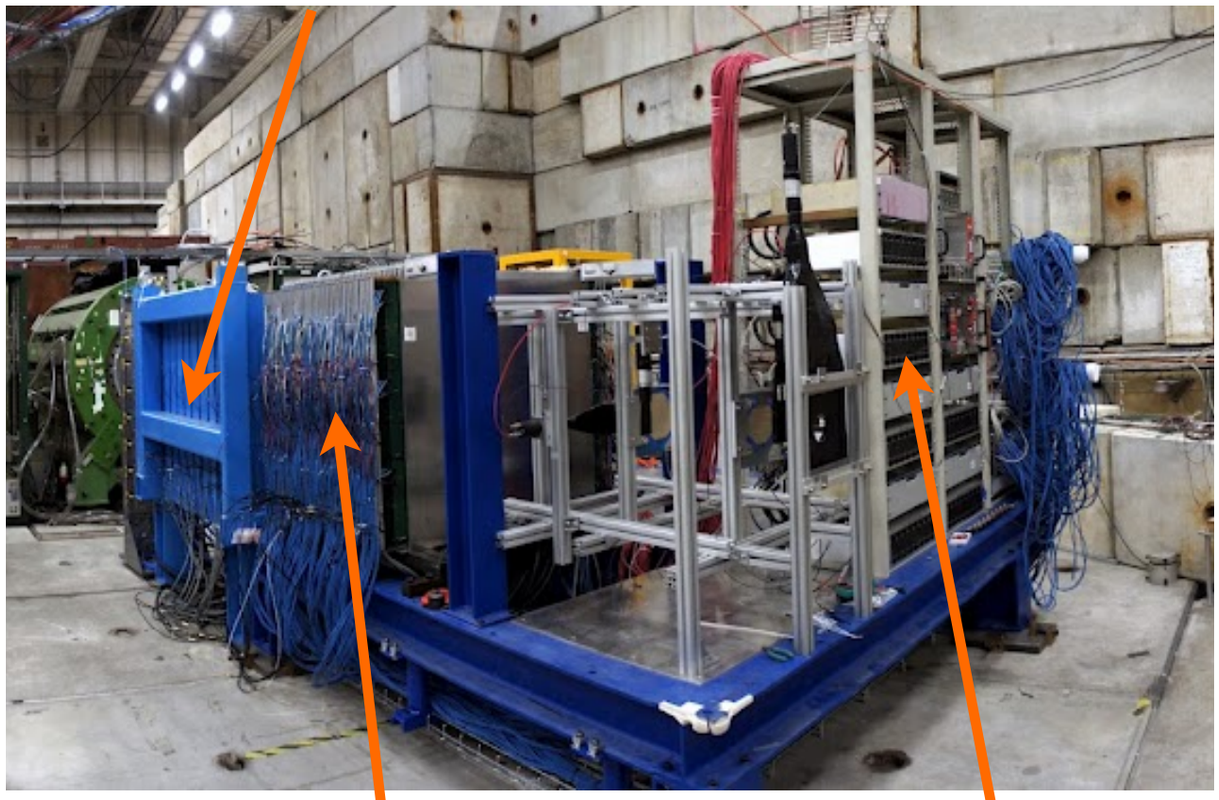
- Physics run at SPS
  hadrons & muons runs up to 180GeV

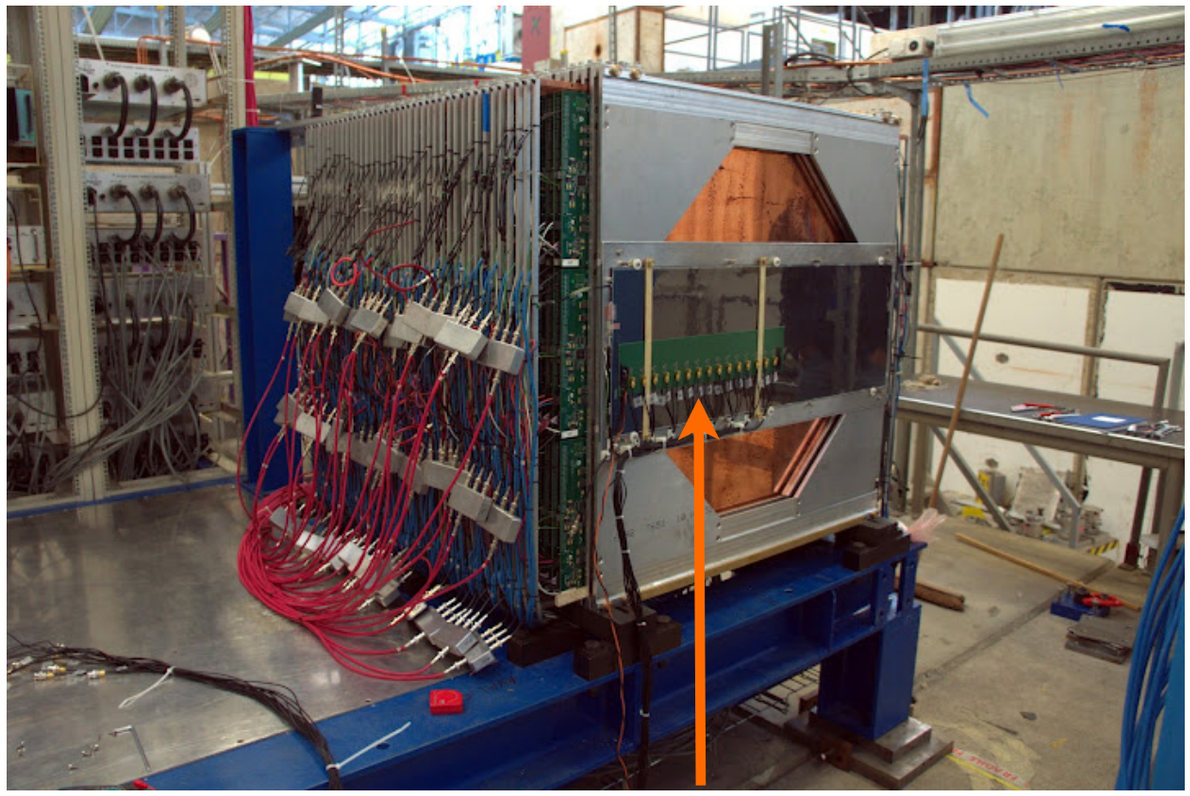
- ~3Mio muon and ~7Mio hadron triggers (luminosity limited by DHCAL trigger rate)

The FastRPC setup:
Overview

Experimental setup in place at CERN PS facility

Tail catcher with RPC readout

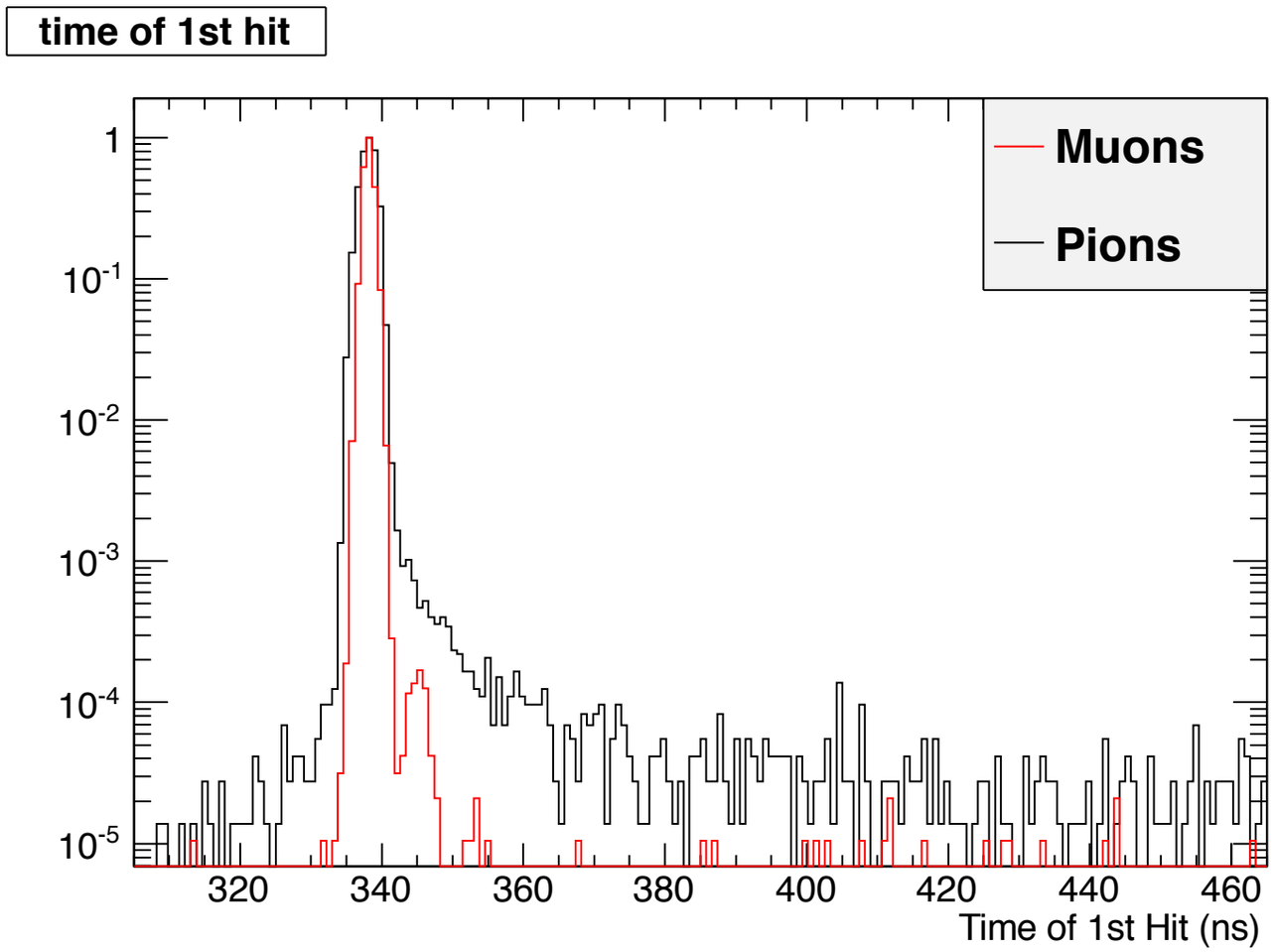




Almost 500000 channels in total:
a record for a calorimeter system!

Backup:

Data Analysis - ToFH - Radial

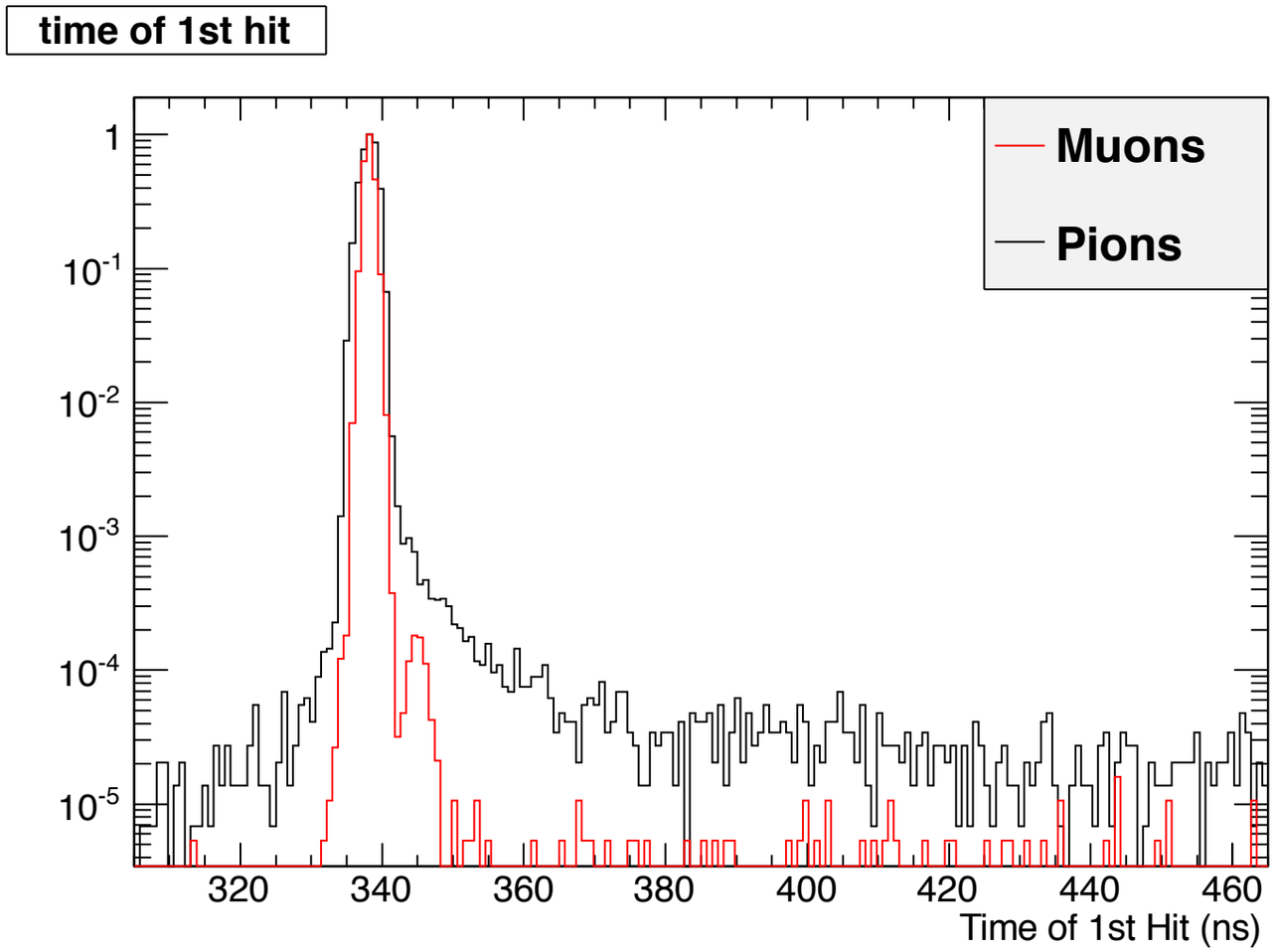


Center of the shower: Dominated by instantaneous contribution from relativistic particles, including muons and punch-through pions

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

Backup:

Data Analysis - ToFH - Radial

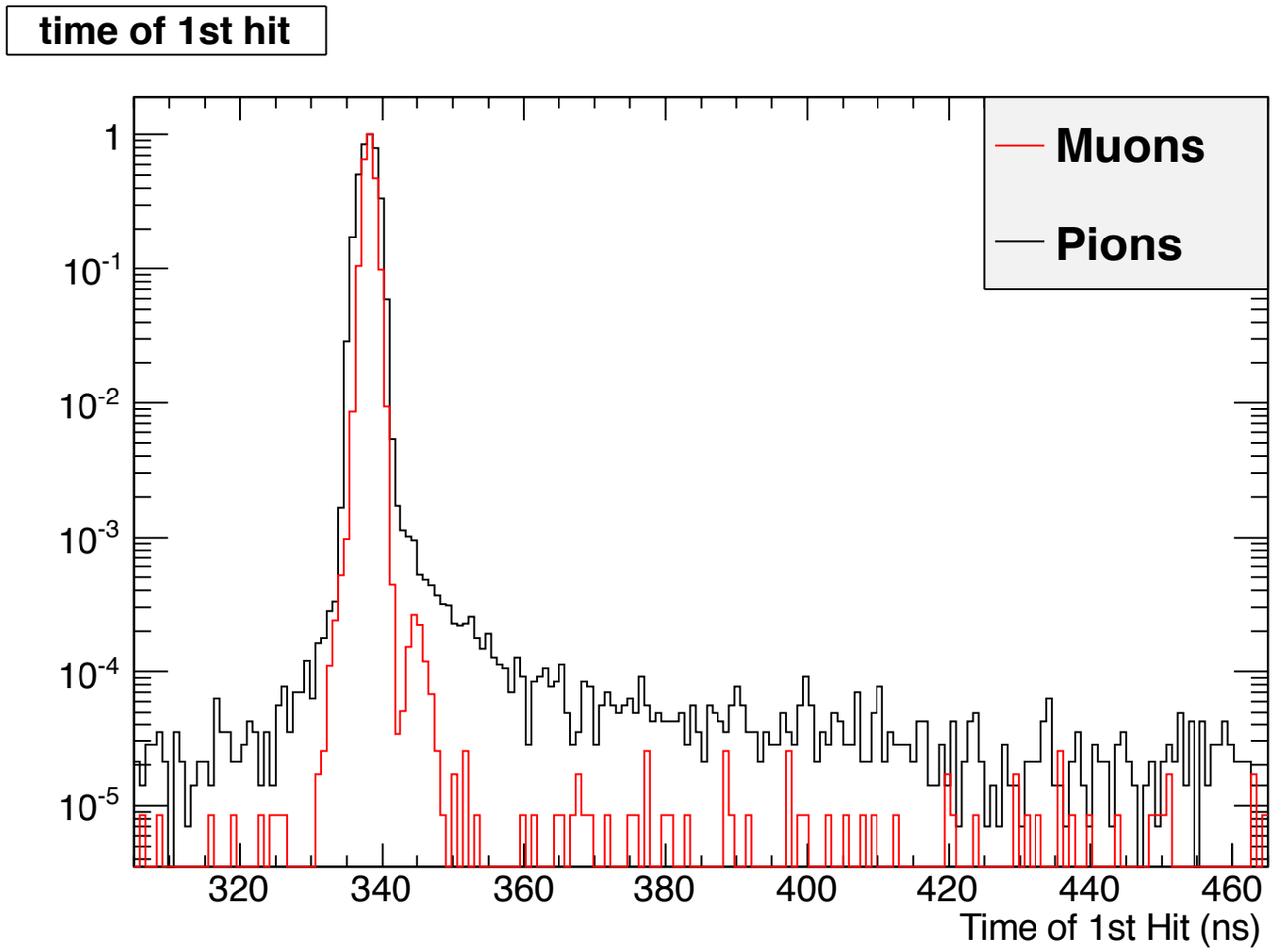


3cm from center:
still lot dominated by
instantaneous components

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

Backup:

Data Analysis - ToFH - Radial

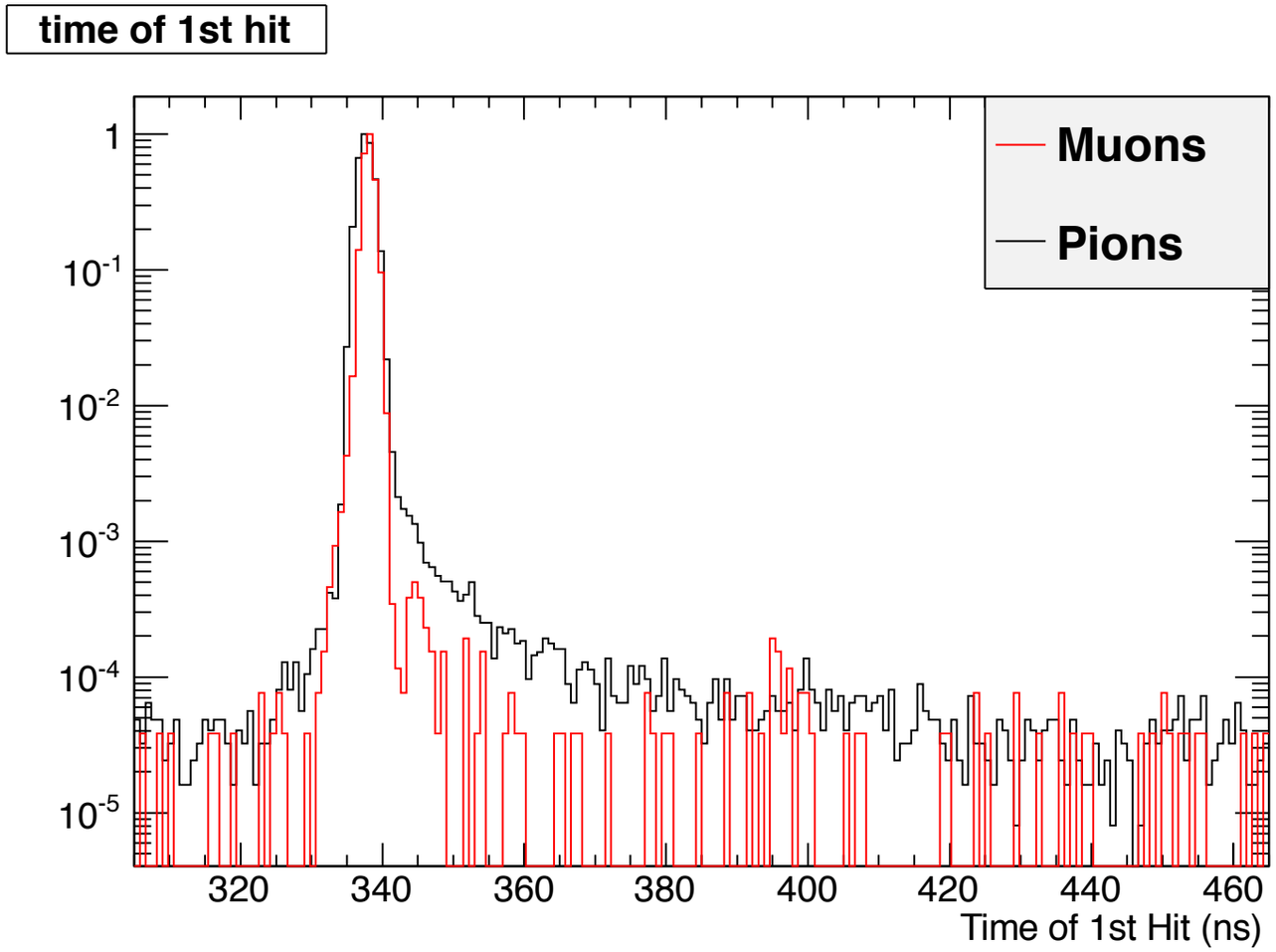


6cm from center

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

Backup:

Data Analysis - ToFH - Radial

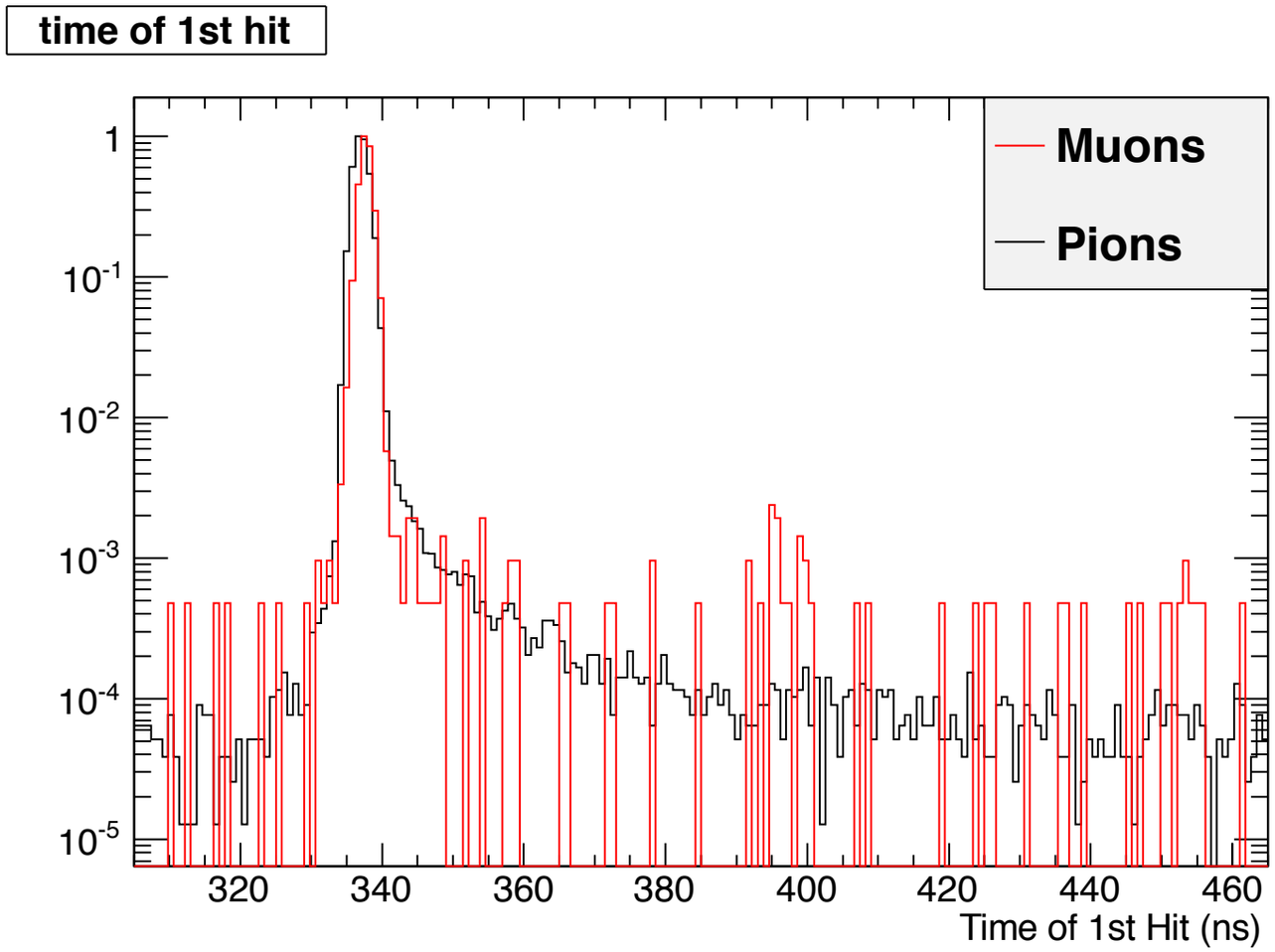


9cm from center

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

Backup:

Data Analysis - ToFH - Radial

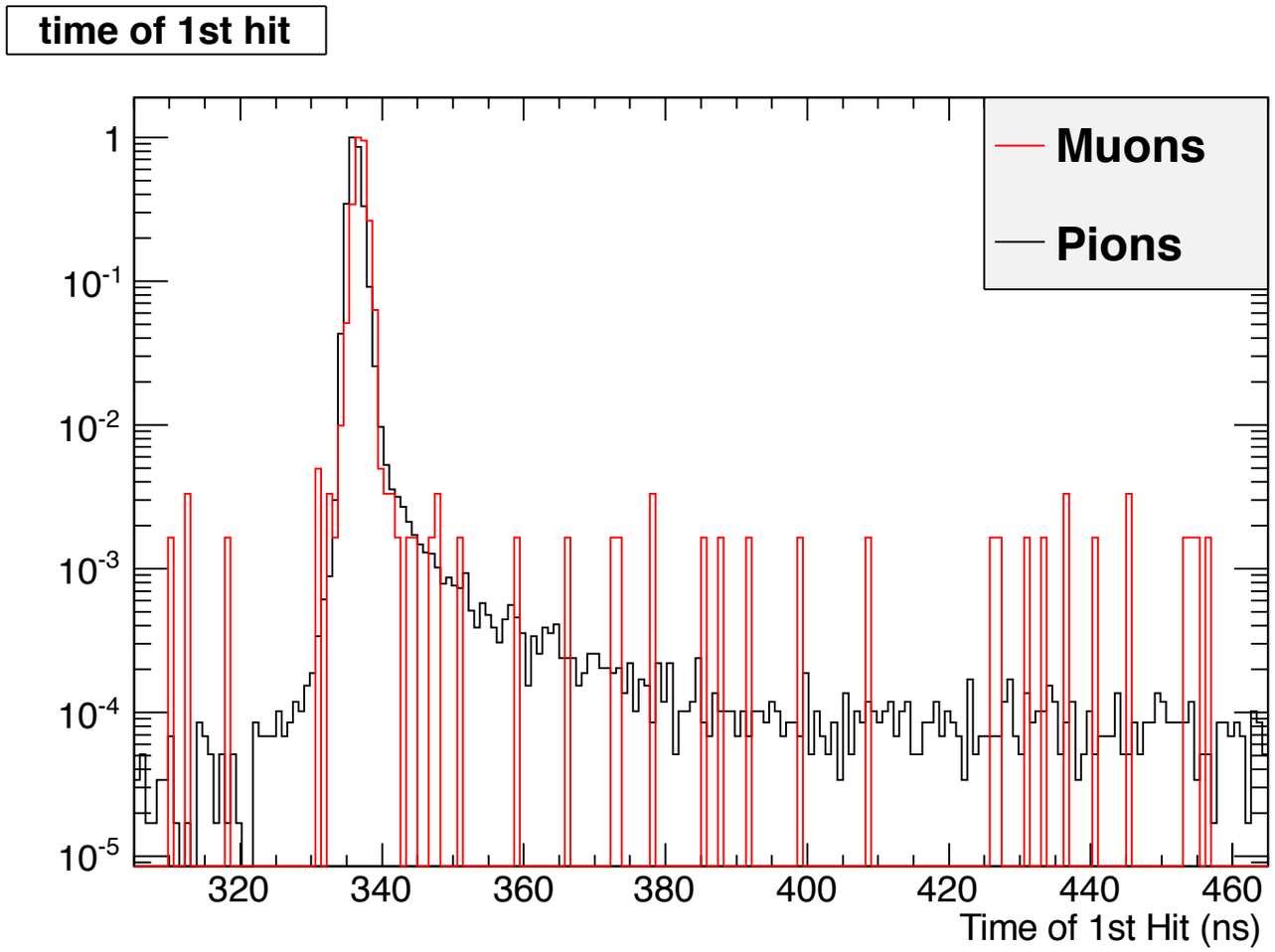


12cm from center

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

Backup:

Data Analysis - ToFH - Radial

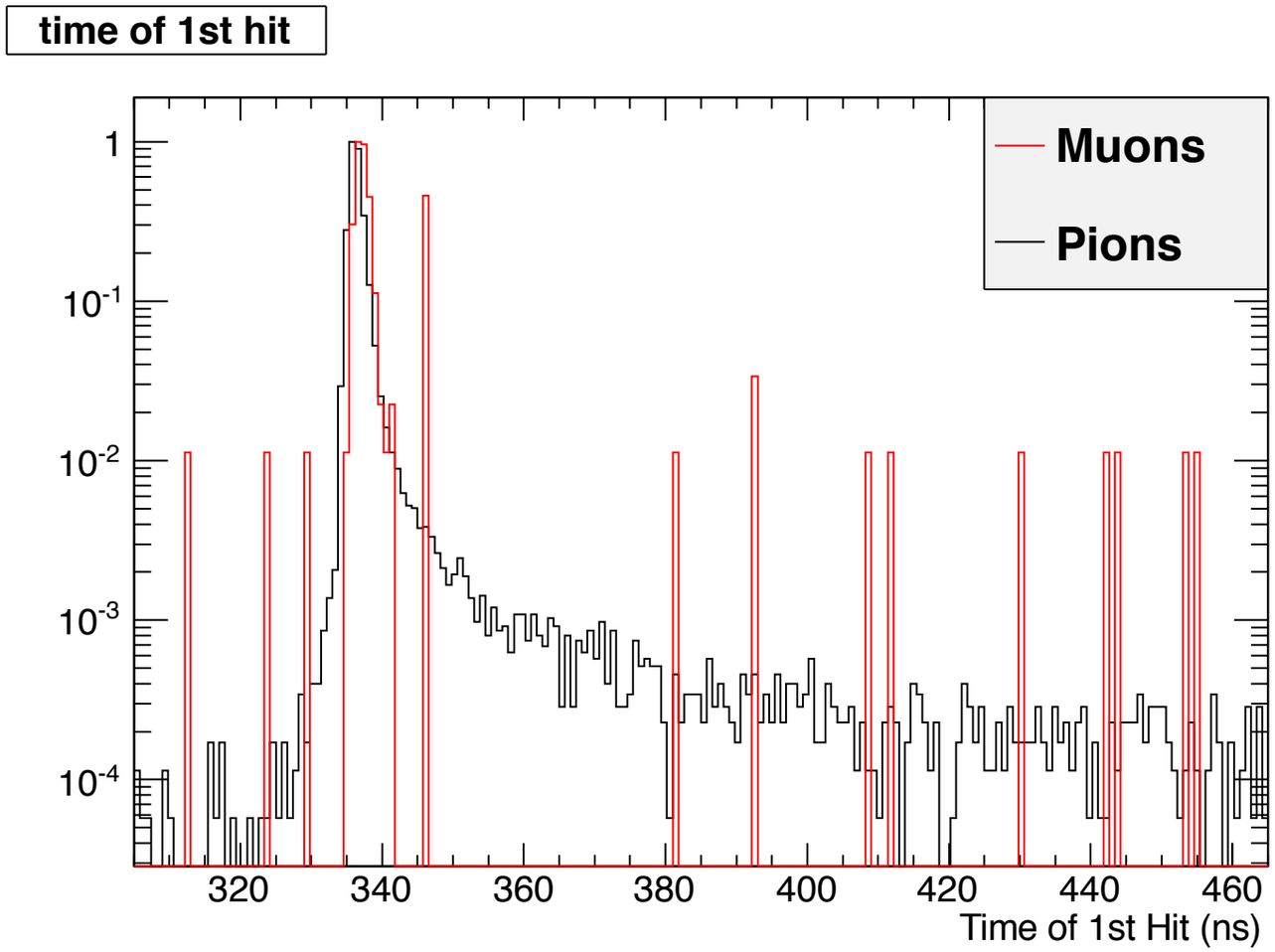


15cm from center

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

Backup:

Data Analysis - ToFH - Radial

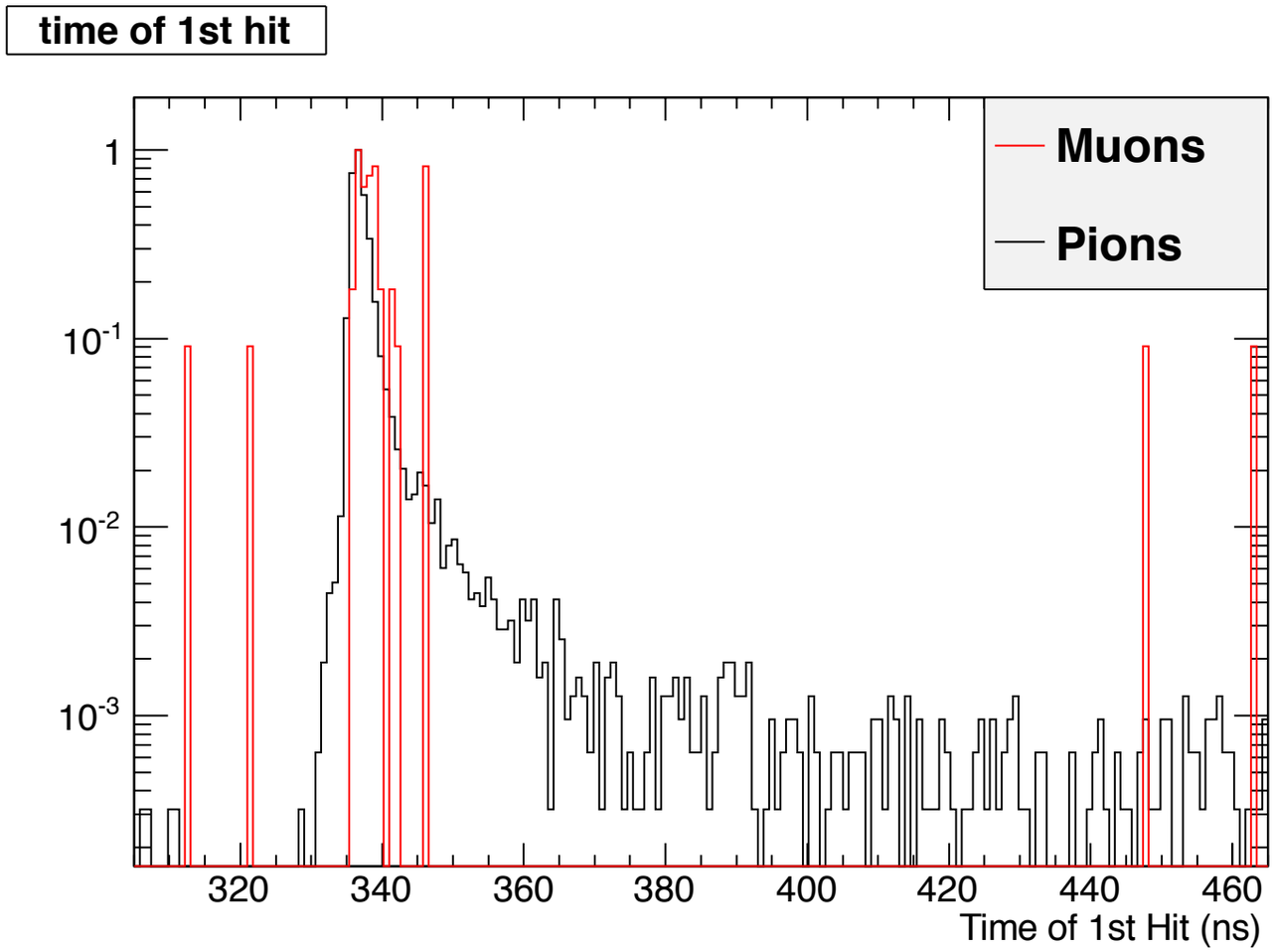


21cm from center

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

Backup:

Data Analysis - ToFH - Radial



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