T3B – Towards Publication

CALICE Collaboration Meeting
Annecy

9. September 2013

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Max-Planck-Institut für Physik

Outline

Convert T3B Results into 3 Publications:

1. T3B - An Experiment to Measure the Time Structure of Hadronic Showers

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Technical, few author MPP publication - Related to CAN-033:

- T3B Detector Layout
- T3B Data Acquisition System
- Signal Reconstruction of SiPM Signals
- Calibration Routines:

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- Calibration Routines:

MIP Energy Scale	Afterpulsing Correction and Study
Timing Corrections	Digitization of Simulated Data

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Convert T3B Results into 3 Publications:

2. The Time Structure of Hadronic Showers in Highly Granular Calorimeters with Tungsten and Steel Absorbers

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Full CALICE collaboration paper - Related to CAN-038:

- T3B Setup at the SPS Test Beam with SDHCAL and W-AHCAL
- Hadronic Cascade Models and their Timing Capabilities
- T3B Standalone
  Analysis Results:

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- T3B Standalone Analysis Results:

Timing Comparison Steel vs. Tungsten	Radial Shower Timing
Data vs. MC Comparison	

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3. Longitudinally Resolved Hadronic Shower Timing in a Highly Granular Scintillator Tungsten Calorimeter

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Full CALICE collaboration paper – Mostly new Analysis Results:

- Synchronization of T3B to CALICE W-AHCAL Data
- Shower Start Identification
- T3B Sync

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- Synchronization of T3B to CALICE W-AHCAL Data
- Shower Start Identification
- T3B Sync Analysis Results:

Longitudinal Shower Timing	Total Energy Deposition Fraction vs. Time
Longitudinal Shower and Calorimeter Profile	Timing Comparison Pion vs. Proton Response

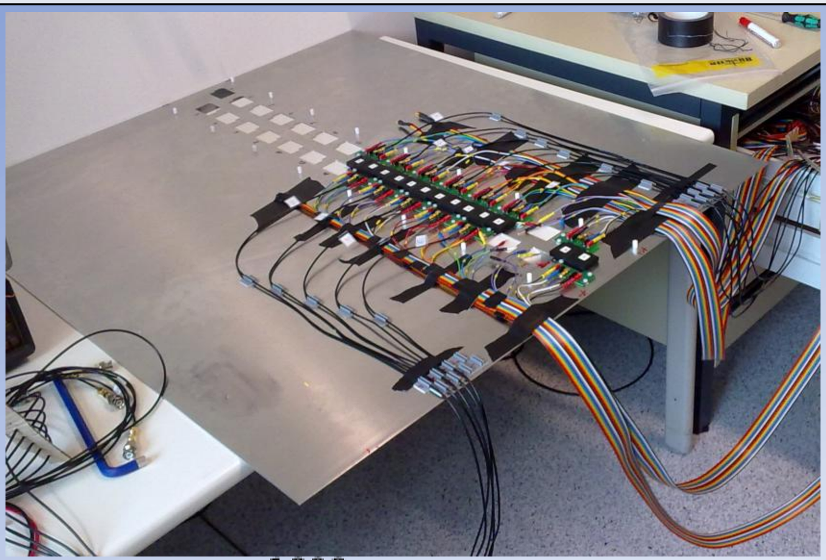
HIGHLIGHTS PAPER 1:

T3B – An Experiment to Measure the Time Structure of Hadronic Showers

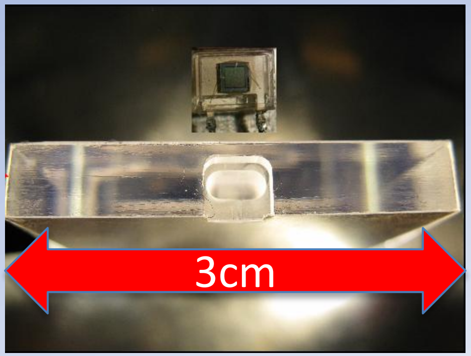
The T3B Experiment

What is T3B?

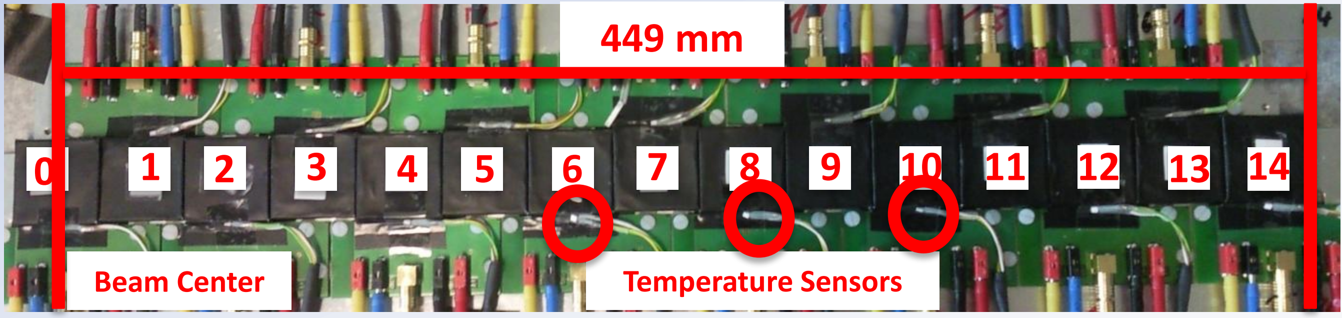
- One strip with 15 scintillator cells
- Cell dimensions: 3 x 3 x 0.5 cm^3
- Light readout by SiPMs: MPPC-50P
- Data acquisition: 4 USB oscilloscopes with 1.25 GSa/Sec at all channels



Setup optimized to measure the time development of hadronic showers



Tile geometry optimized for direct coupling

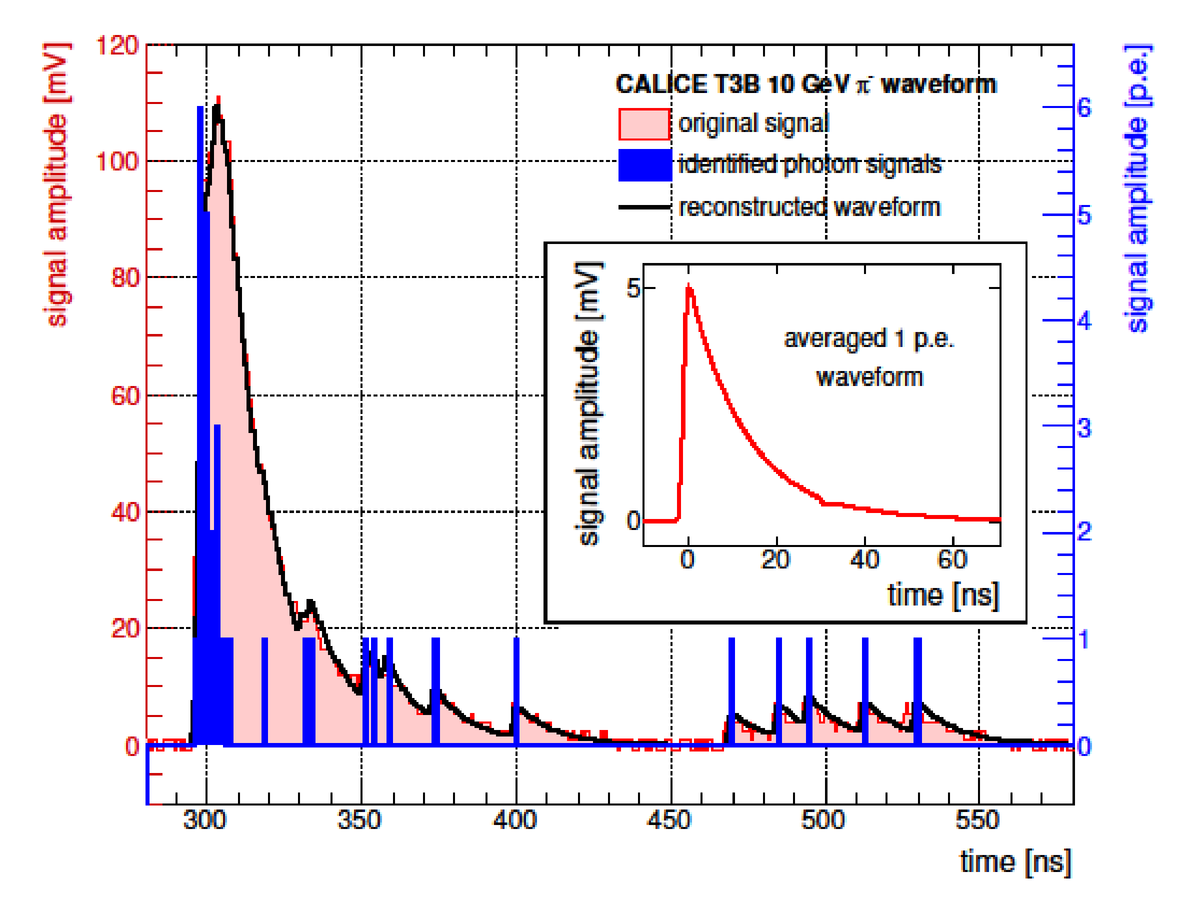


1 Temperature Sensor PT1000 for each T3B cell

Paper 1: Signal Reconstruction

Waveform Decomposition:

- Determine averaged 1 pixel response (monitored live @ test beam)
- Subtract 1 pixel waveform iteratively from local maximum of physics waveform
- Obtain the time of detection of a photon by the SiPM with subnanosec precision



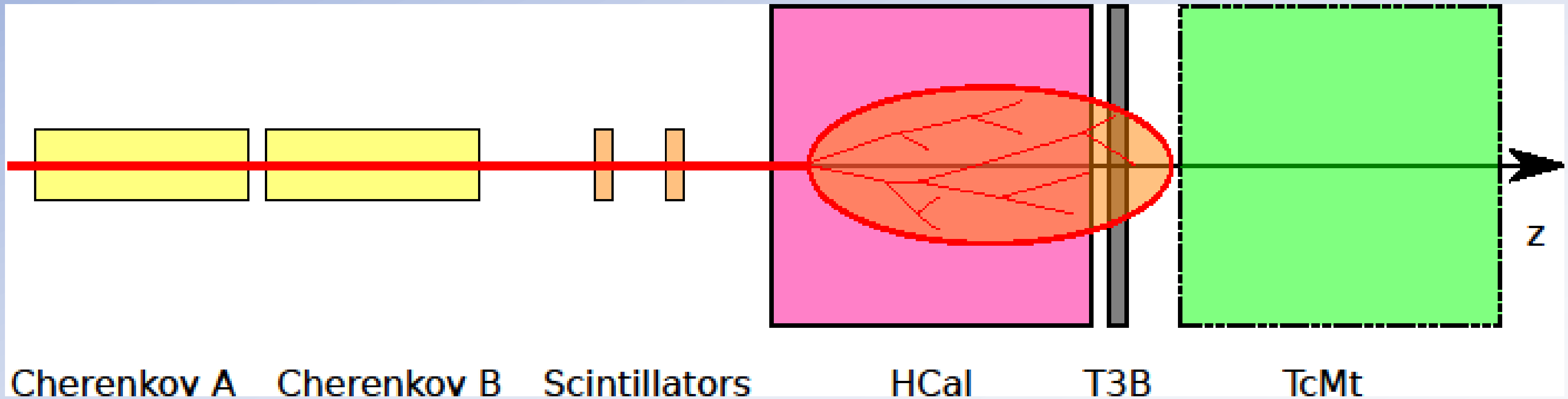
HIGHLIGHTS PAPER 2:

The Time Structure of Hadronic Showers in Highly Granular Calorimeters with Tungsten and Steel Absorbers

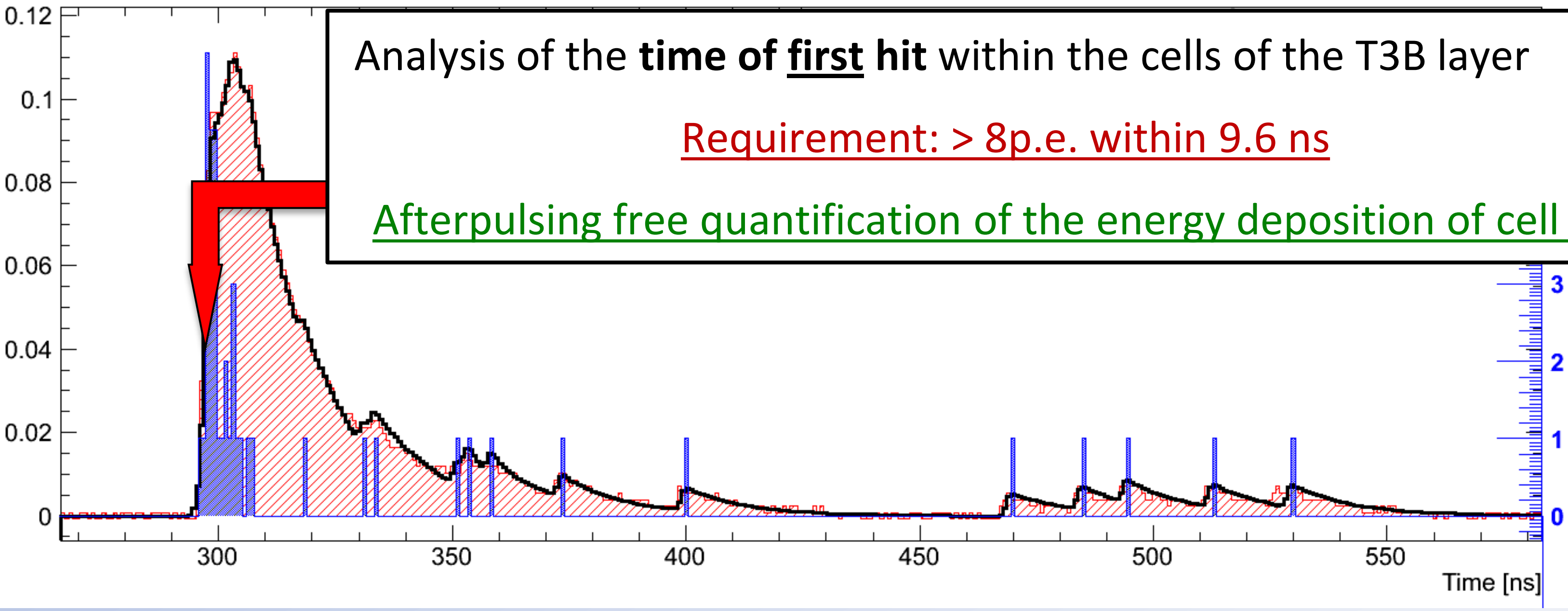
Paper 2: Test Beam Setup

Data Sets (acquired at SPS in 2011):

- 60 GeV hadrons @ Tungsten-AHCAL or Steel-SDHCAL
- 180 GeV muons for comparison
- Particle identification with information from Cerenkov counters possible
- Test beam setup also implemented into custom GEANT4 simulation
- Focus on T3B standalone analysis in Paper 2



Paper 2: Time of first Hit Analysis



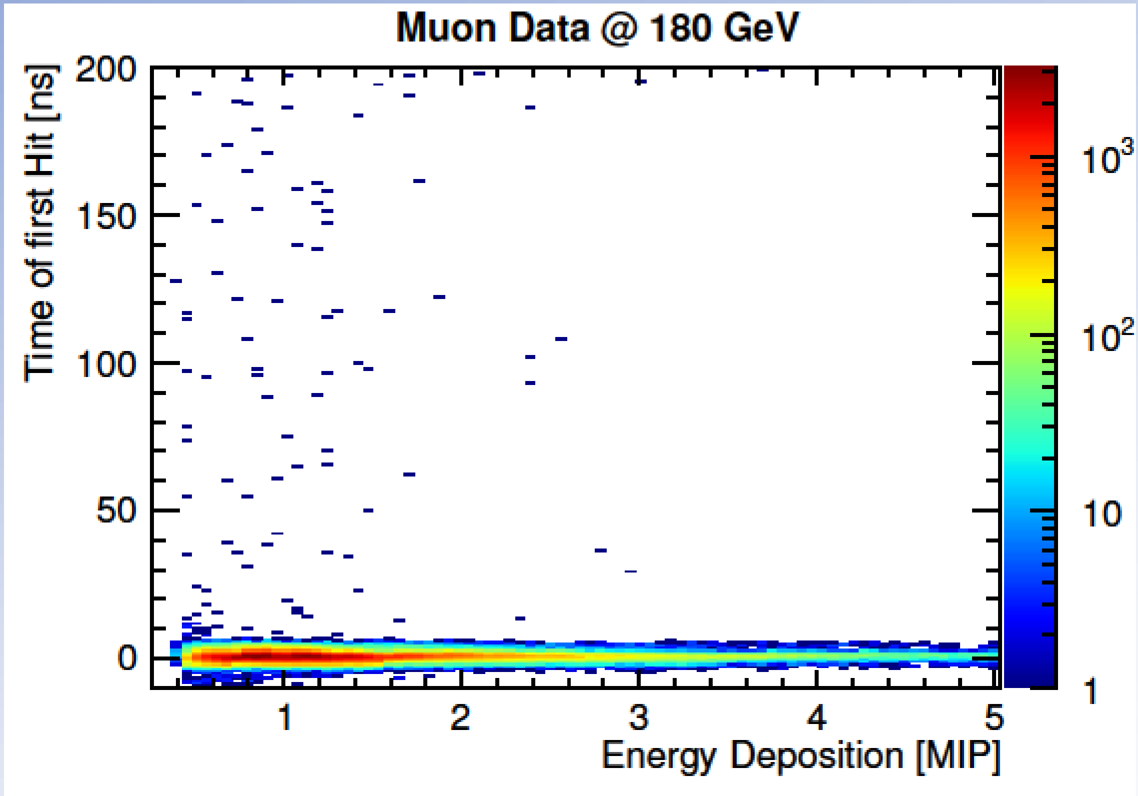
Analysis of the **time of <u>first</u> hit** within the cells of the T3B layer

Requirement: > 8p.e. within 9.6 ns

Afterpulsing free quantification of the energy deposition of cell hits

Paper 2: Time of first Hit Analysis

- 2D Histogram (one per T3B cell): E_{dep} vs TofH
  ➔ Represents the full timing information of the TofH analysis!
- Study projections of histogram for different run characteristics:
  - Steel vs W absorber
  - Mean TofH vs Radius
  - Data vs MC



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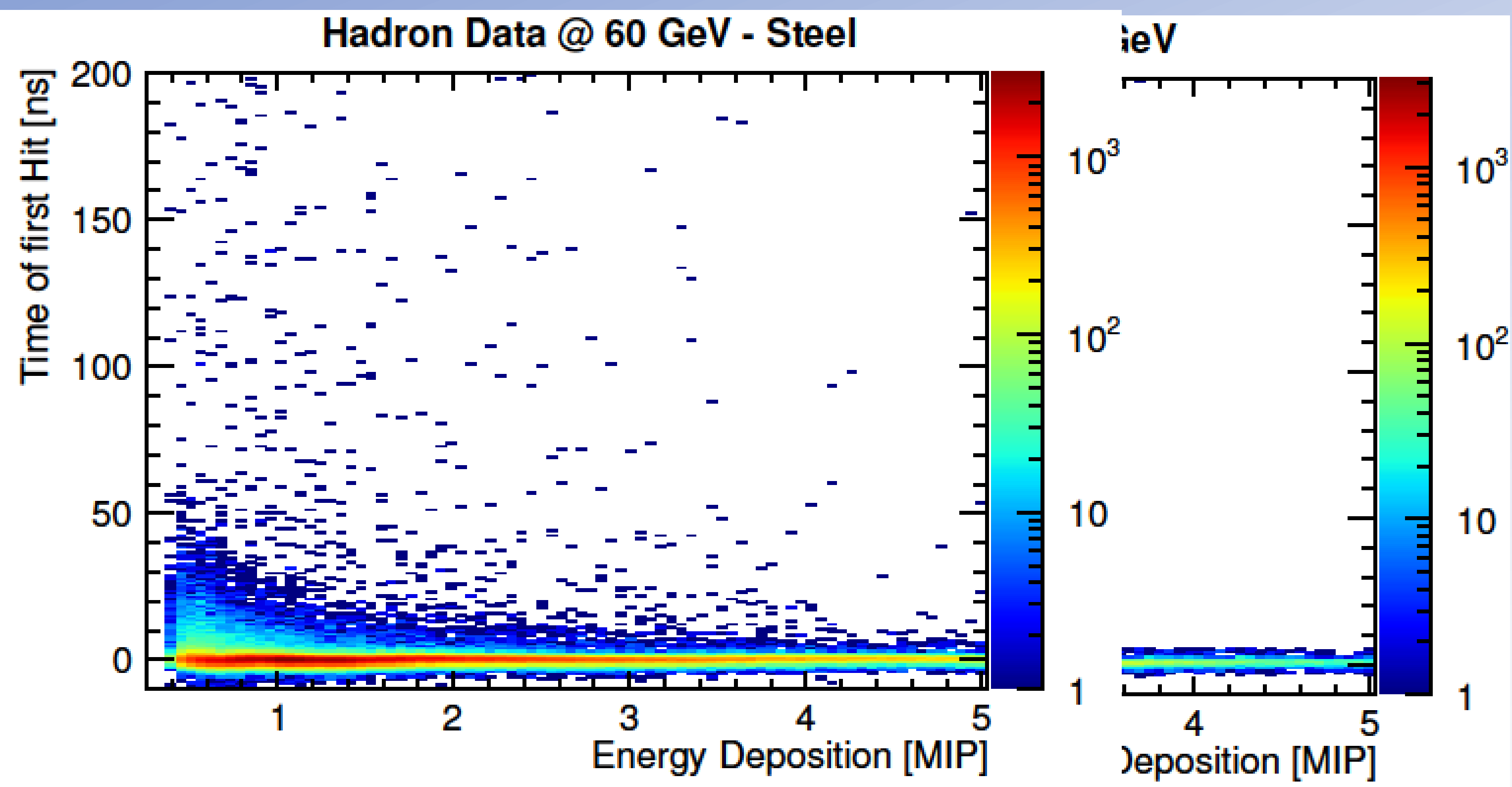

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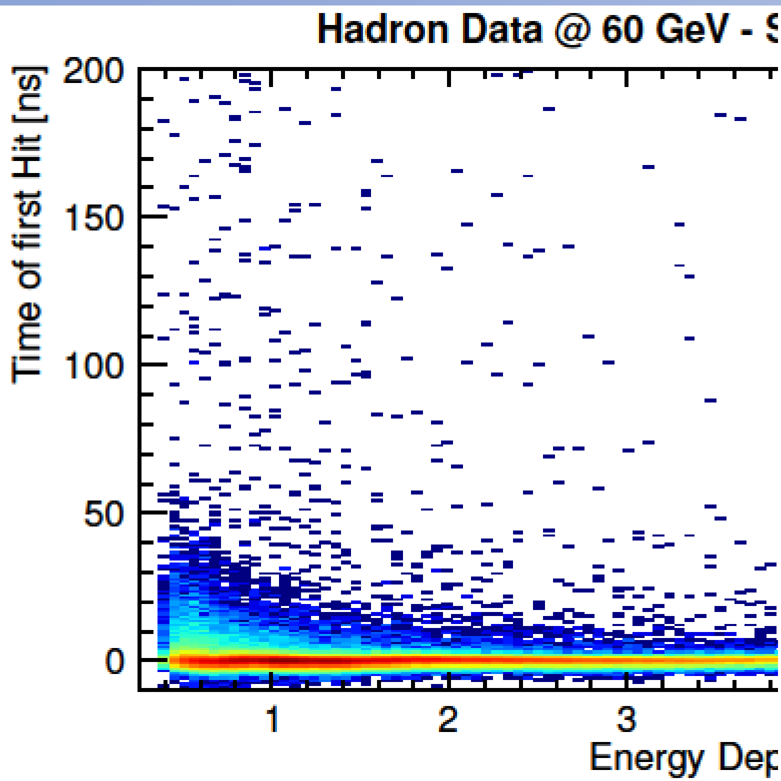
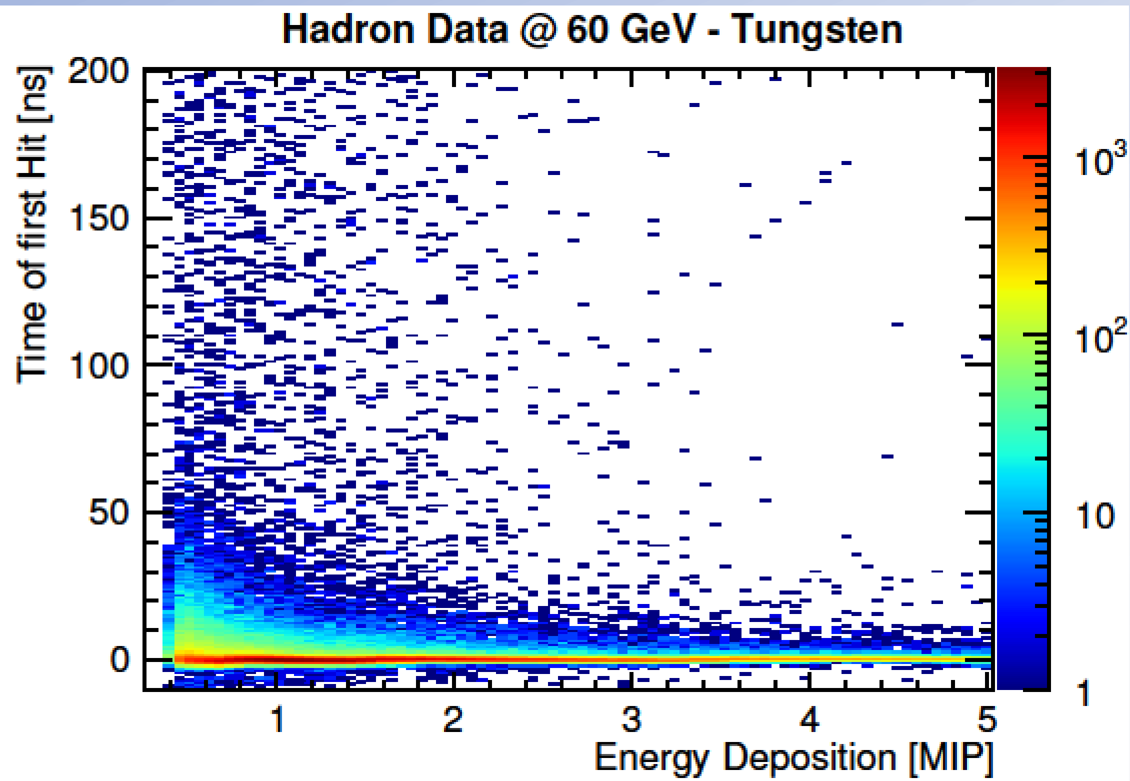
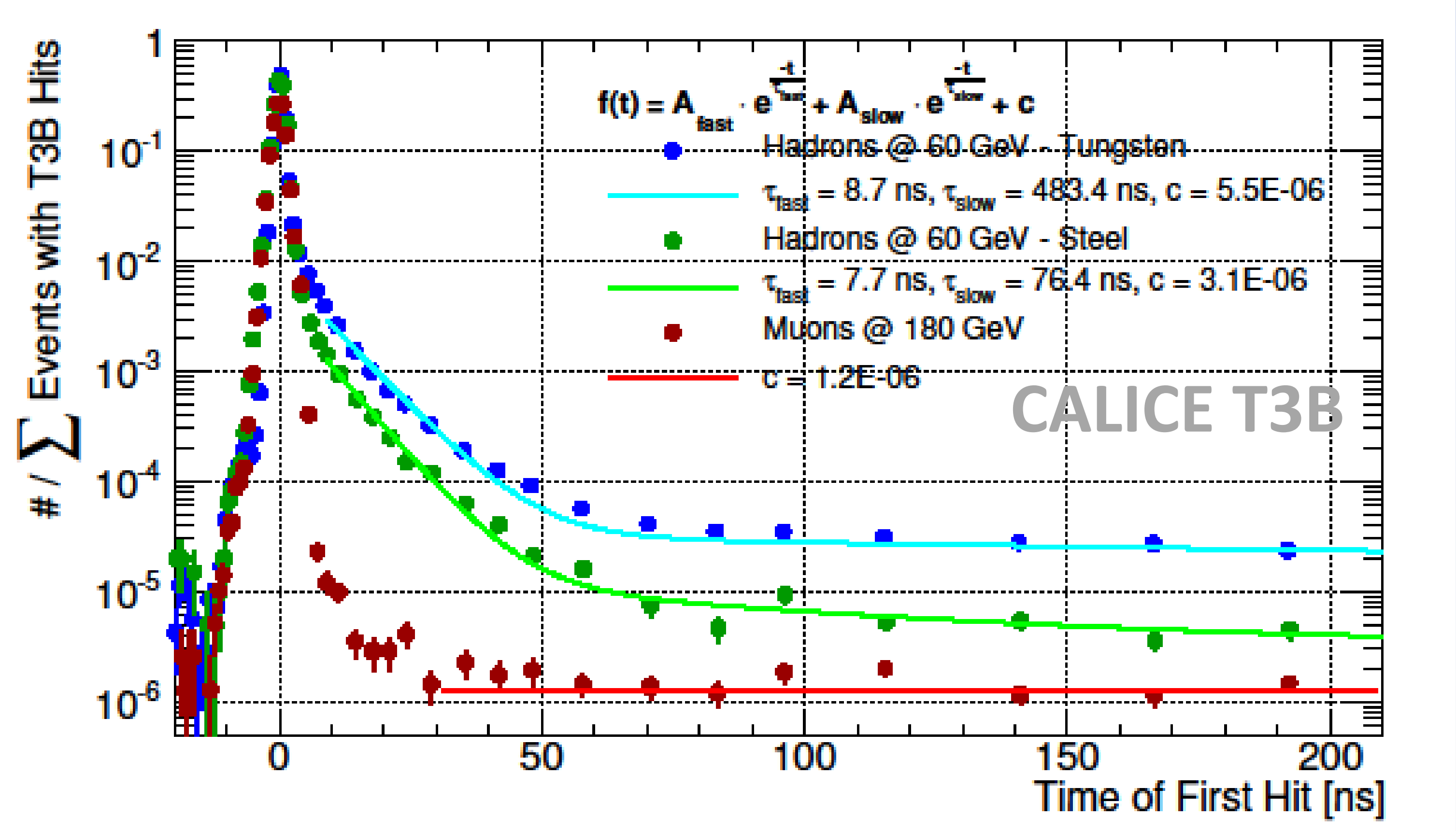




Paper 2: TofH Distribution

Muon, Steel, Tungsten Comparison - clear distinction between:

- Dominant prompt shower component
- Fast delayed shower component (cascade neutrons)
- Slow delayed shower component (evaporation neutrons)



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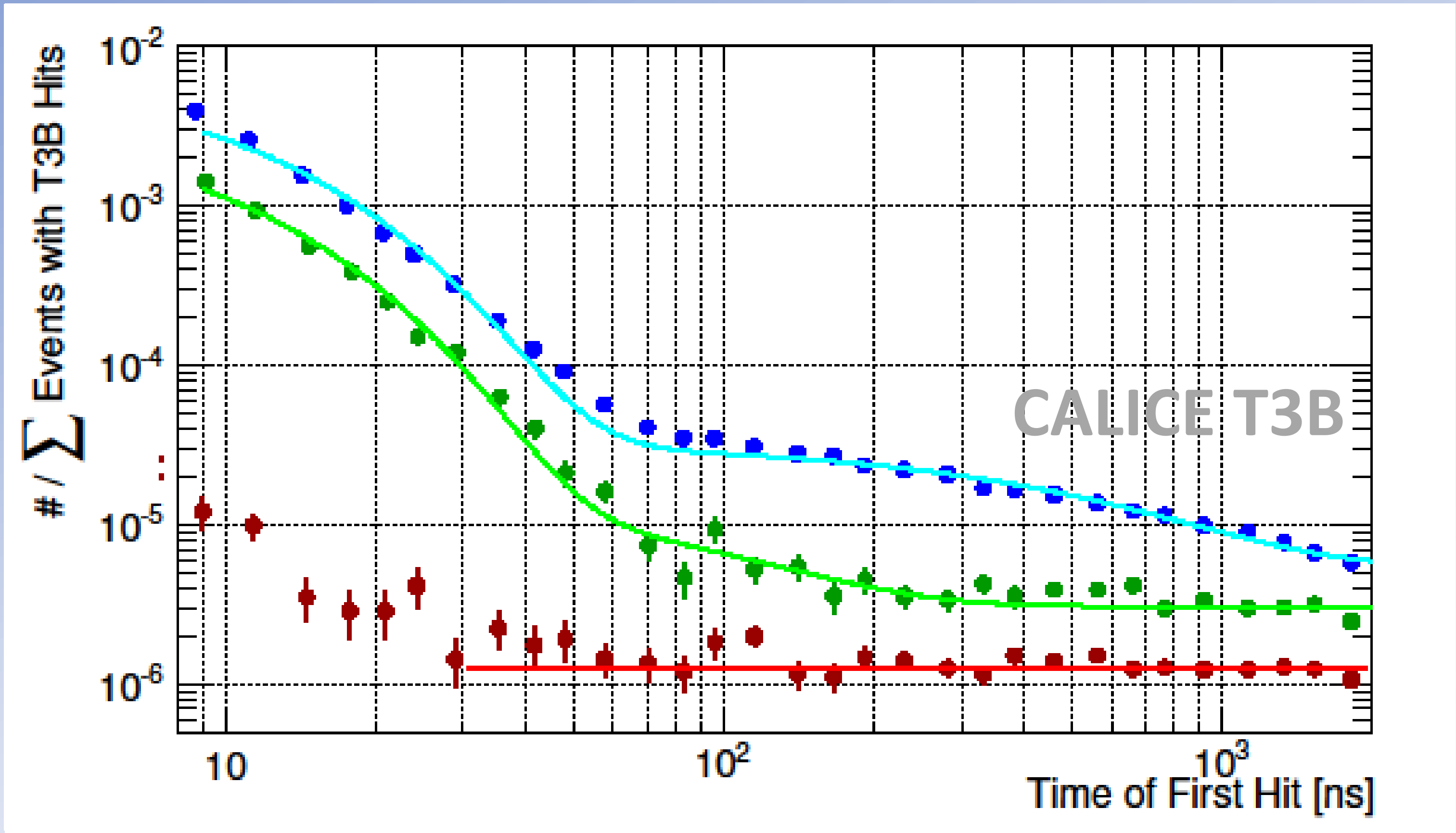
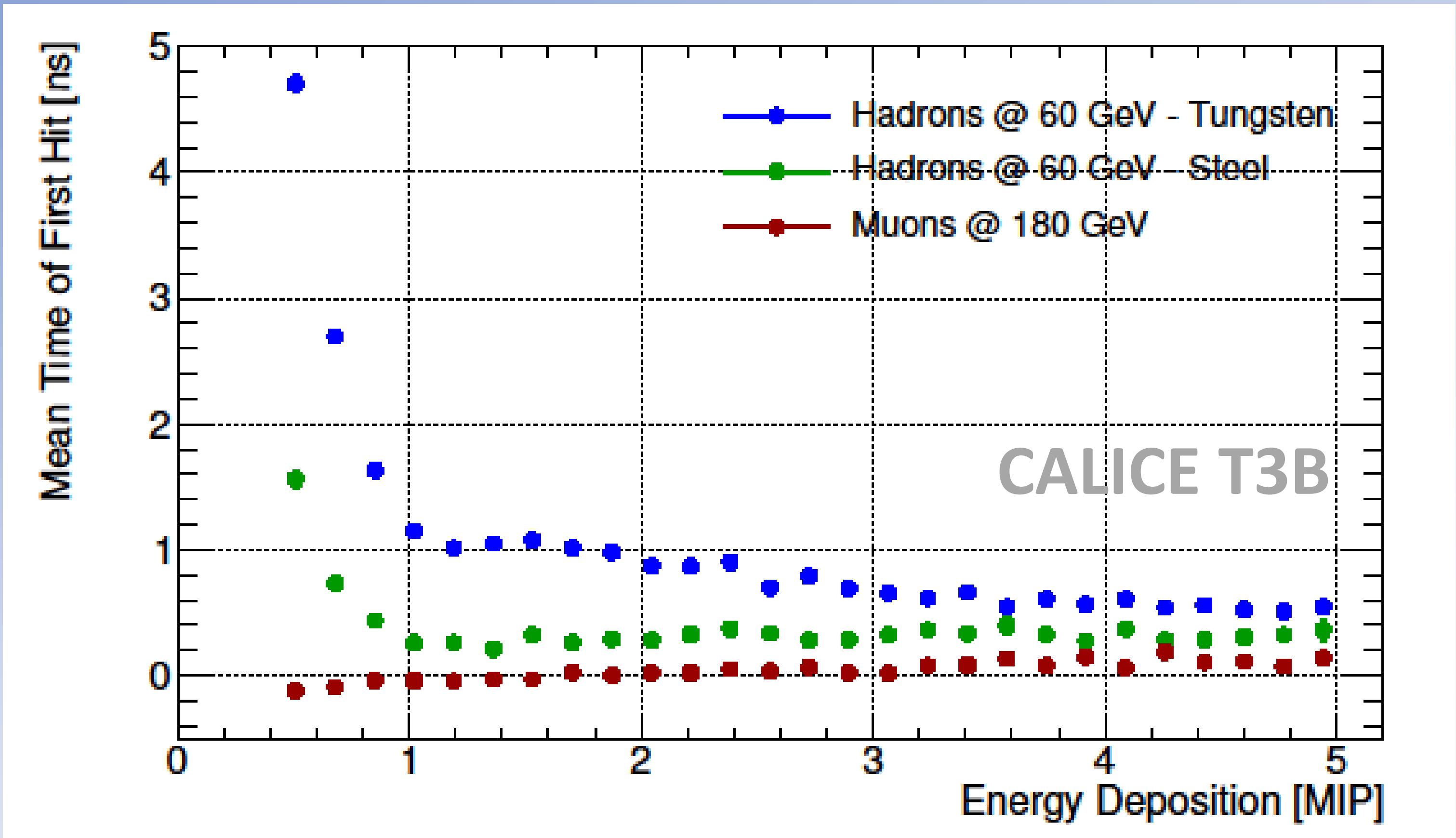


Paper 2: Mean TofH vs Edep

Mean TofH: @ -20 ns to +200 ns:

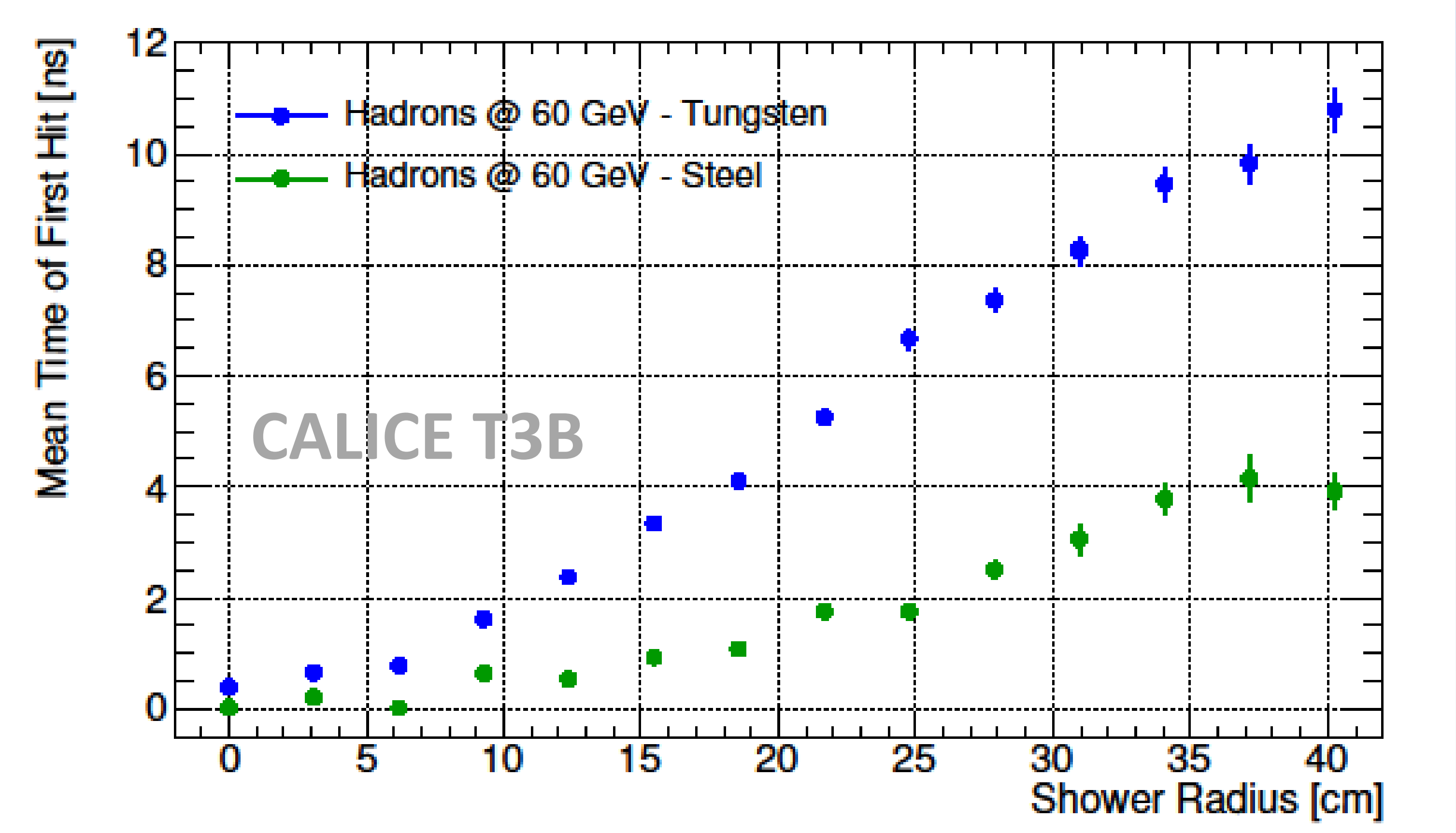
- Muons: No delayed component
- Steel: Delayed hits w/ small E_{dep}
- Tungsten: Delayed hits w/ E_{dep} up to 5 MIP



Paper 2: Mean TofH vs Radius

Mean TofH in range -20 ns to +200 ns:

- Prompt shower core (mainly π^0 decay)
  Surrounded by hadronic halo (influenced by delayed neutrons)
- Delayed components: W >> Fe

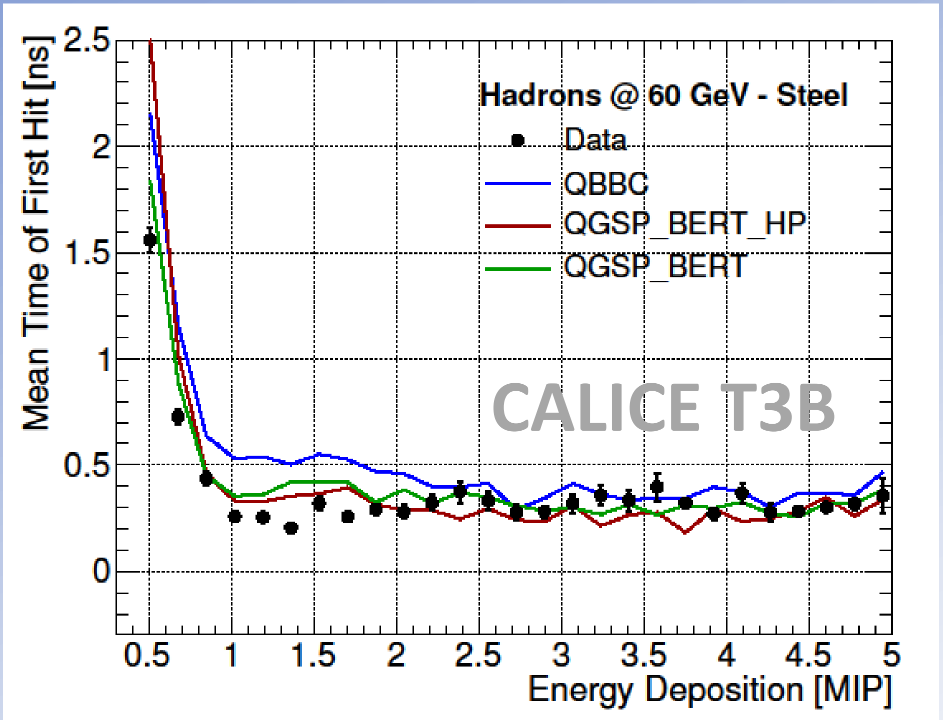


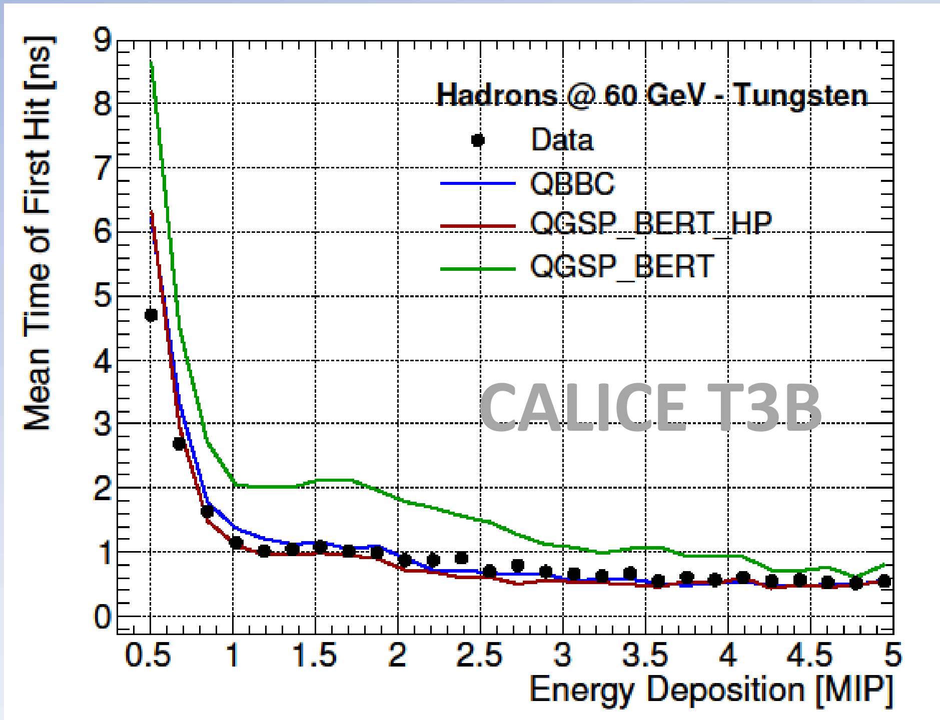
Paper 2: MC vs Data Comparison
Mean TofH vs Edep

Data	QGSP_BERT
QBBC	QGSP_BERT_HP

MC ⇔ Data: Mean TofH vs E_{dep}

- Steel: All models reproduce data well
- Tungsten: QGSP_BERT overestimates delayed shower component





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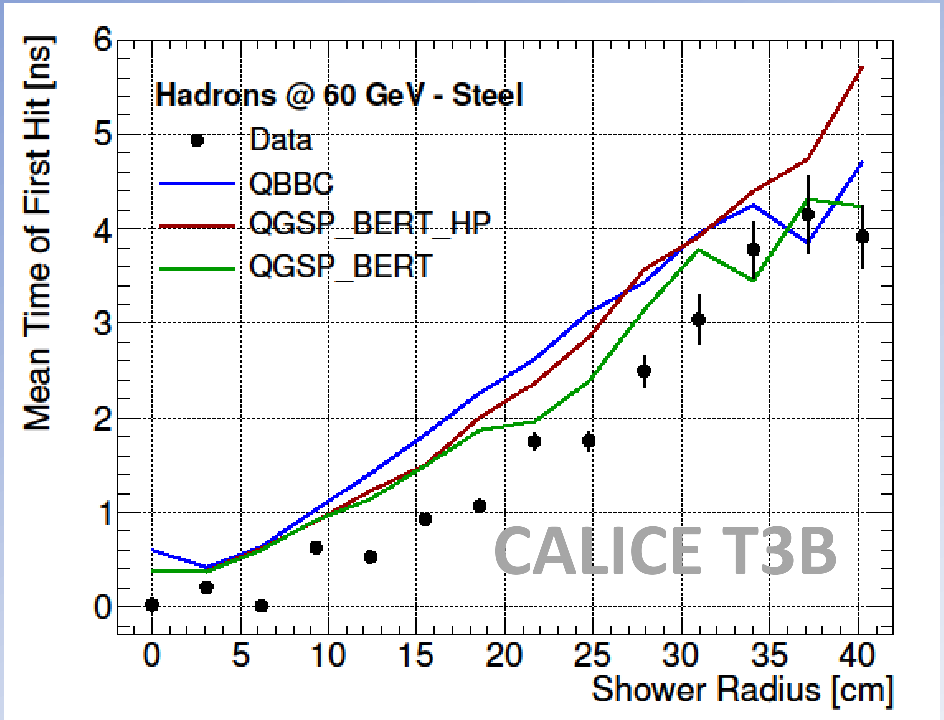
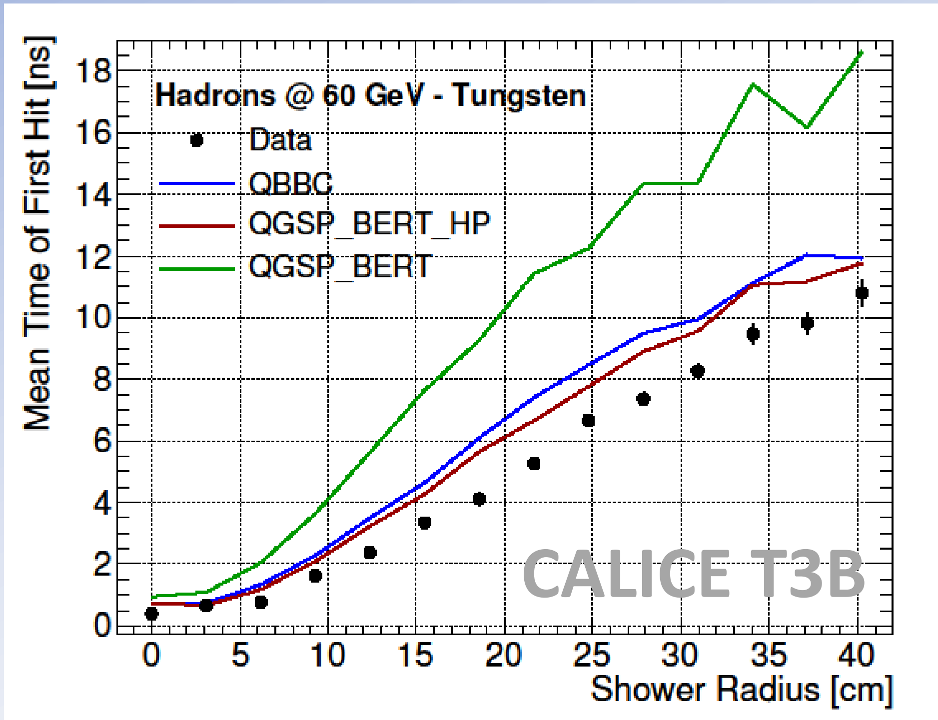




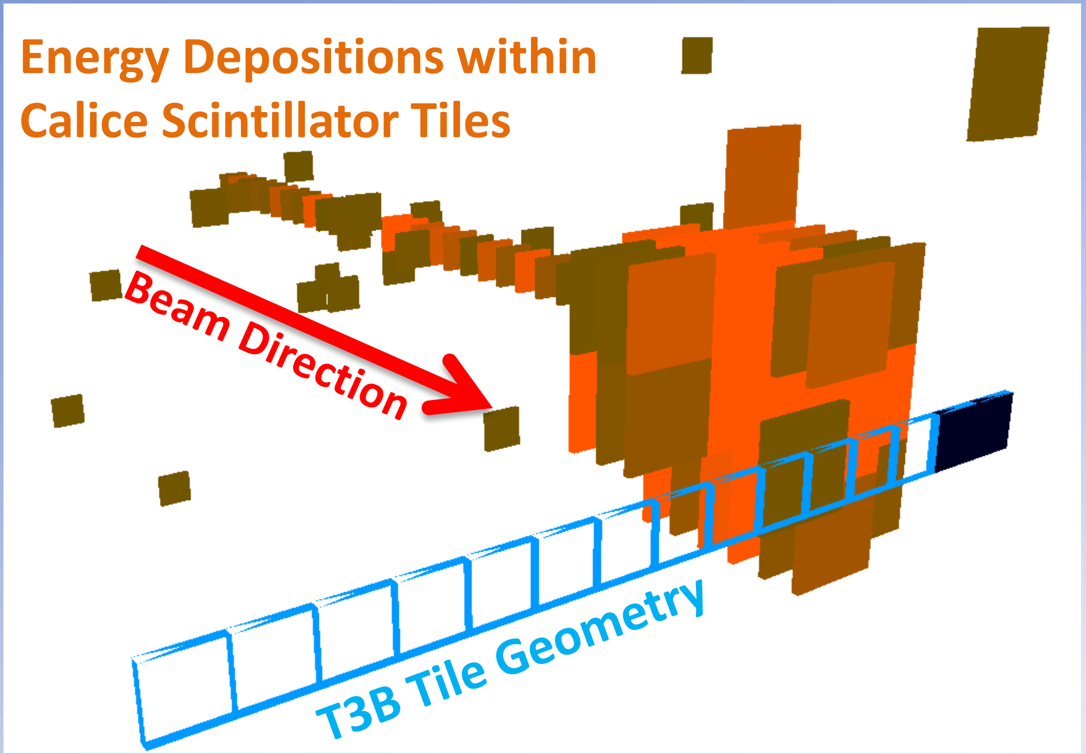
HIGHLIGHTS PAPER 3:

Longitudinally Resolved Hadronic Shower Timing in a

Highly Granular Scintillator Tungsten Calorimeter

Reminder:
Synchronisation W-AHCal to T3B

T3B and the CALICE W-AHCal use the same trigger signal
→ Data can be synchronized offline



Eventdisplay:
Hadron Data @ 60GeV (Tungsten)

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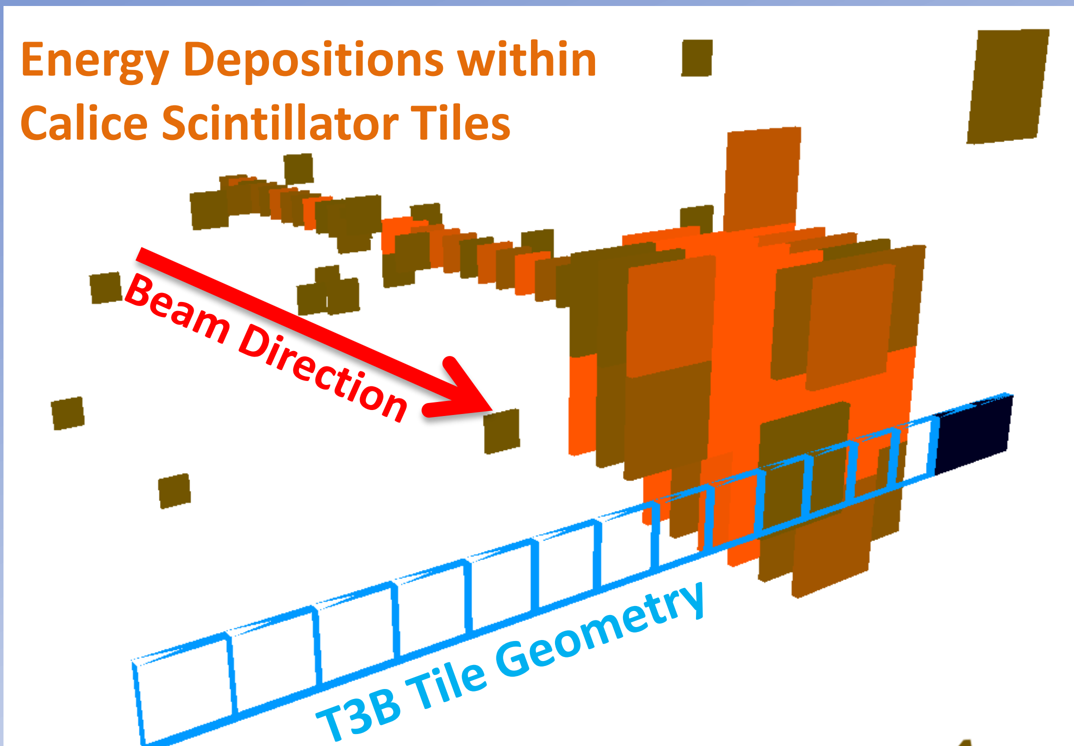

First hadronic interaction
- Happens in a certain depth
- Can be identified in CALICE W-AHCal with Marina PTF

→ Ordering of T3B Hits relative to the shower start
→ Recovery of longitudinal dimension

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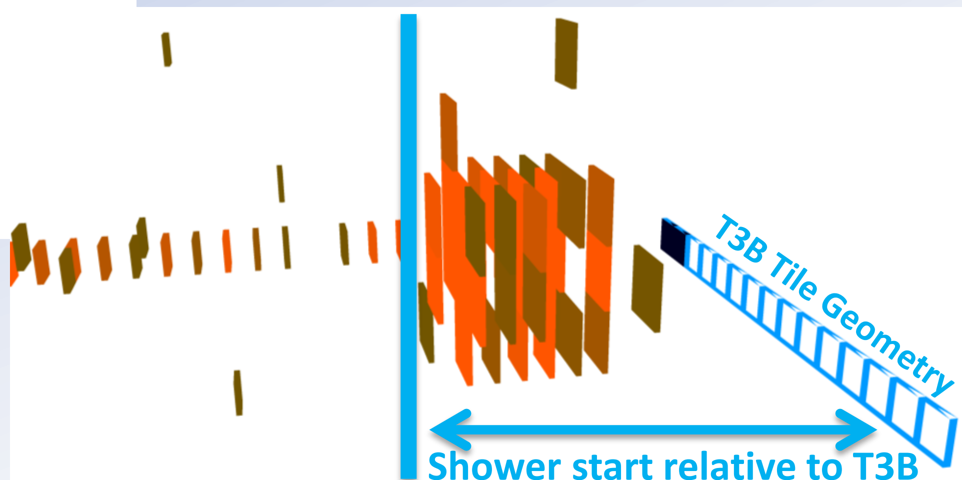
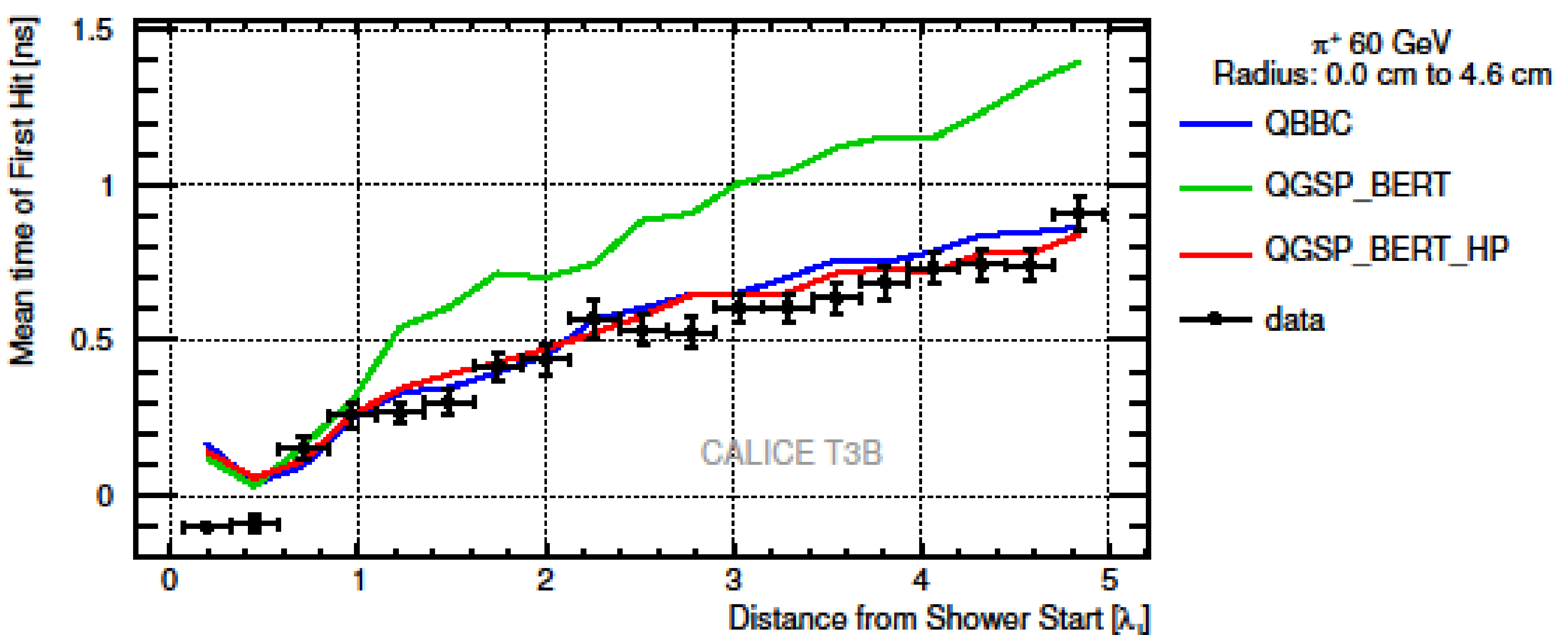


Paper 3: Mean TofH vs Distance from Shower Start

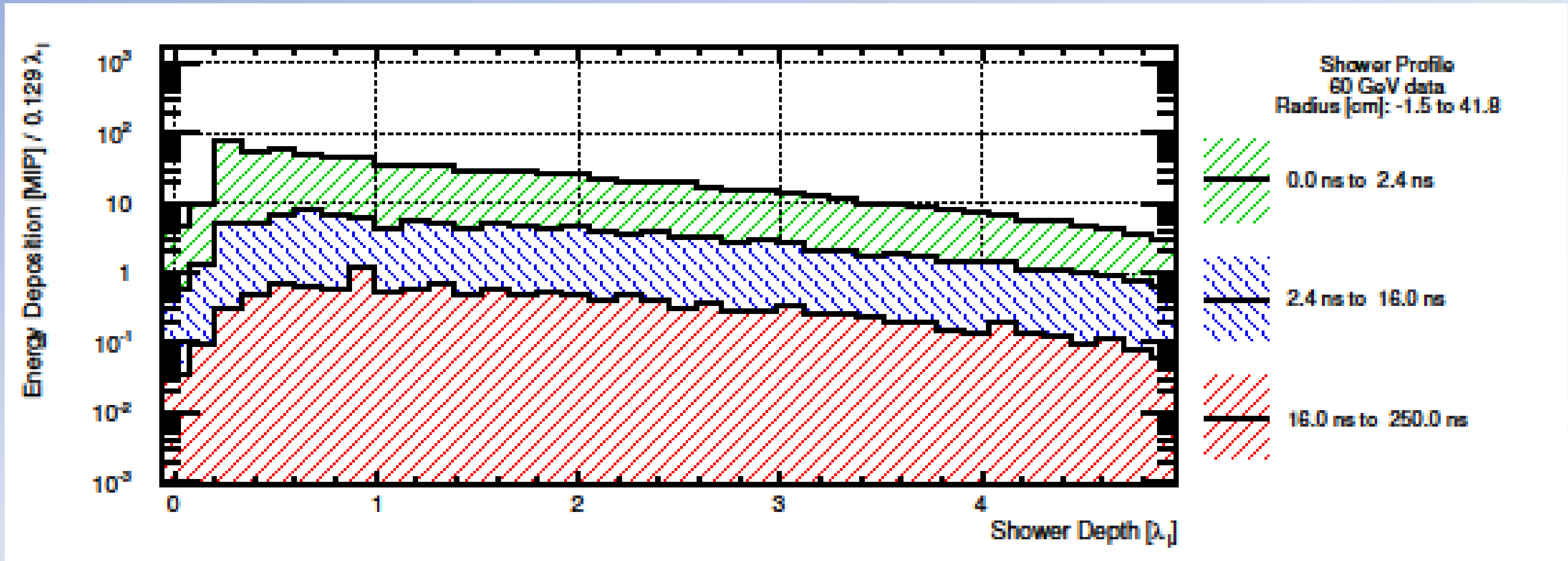
Data ⇔ MC Comparison:

- Longitudinal: ≈1 ns over 5 λ_I
  (Radius 0 to 4.6 cm, innermost two T3B Tiles)
- QGSP_BERT overestimates longitudinal delay



Paper 3: Time Resolved Shower Profile

- Shower Profile
  - Purely from Shower Start & Energy Deposition @ T3B
- Time Ranges:
  - Prompt: 0 - 2.4 ns
  - Intermediate: - 16 ns
  - Late: - 250 ns



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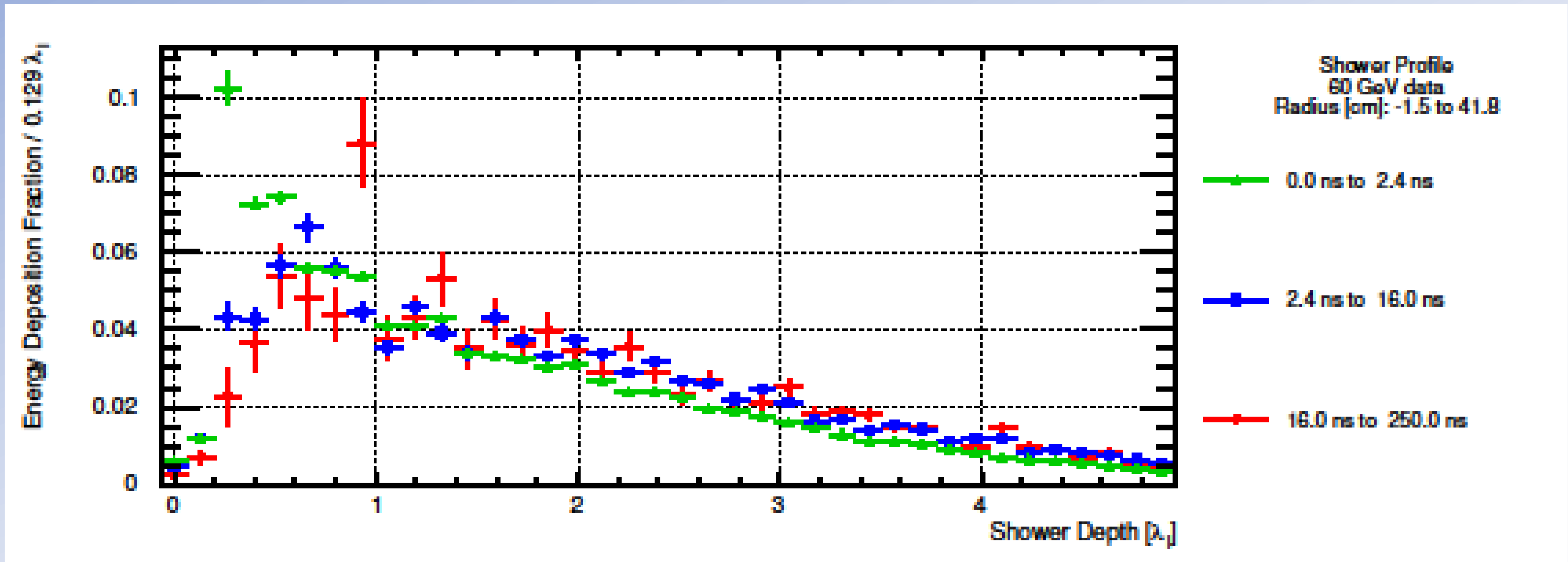

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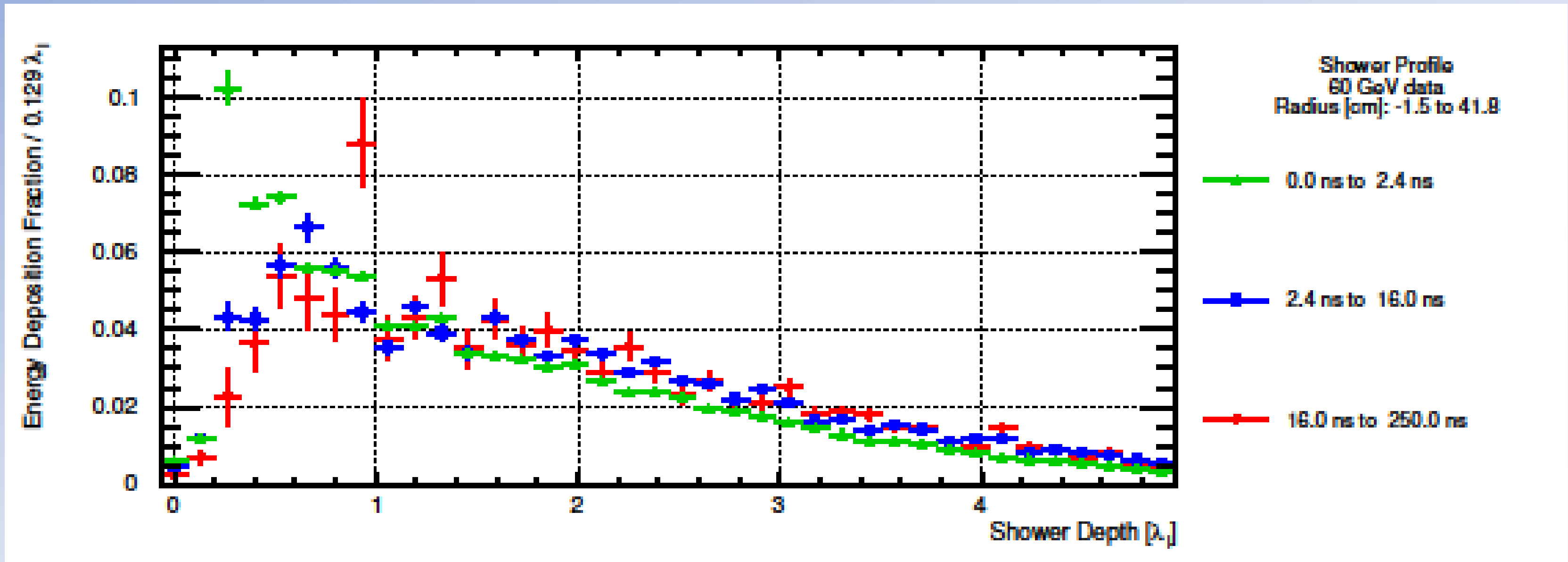

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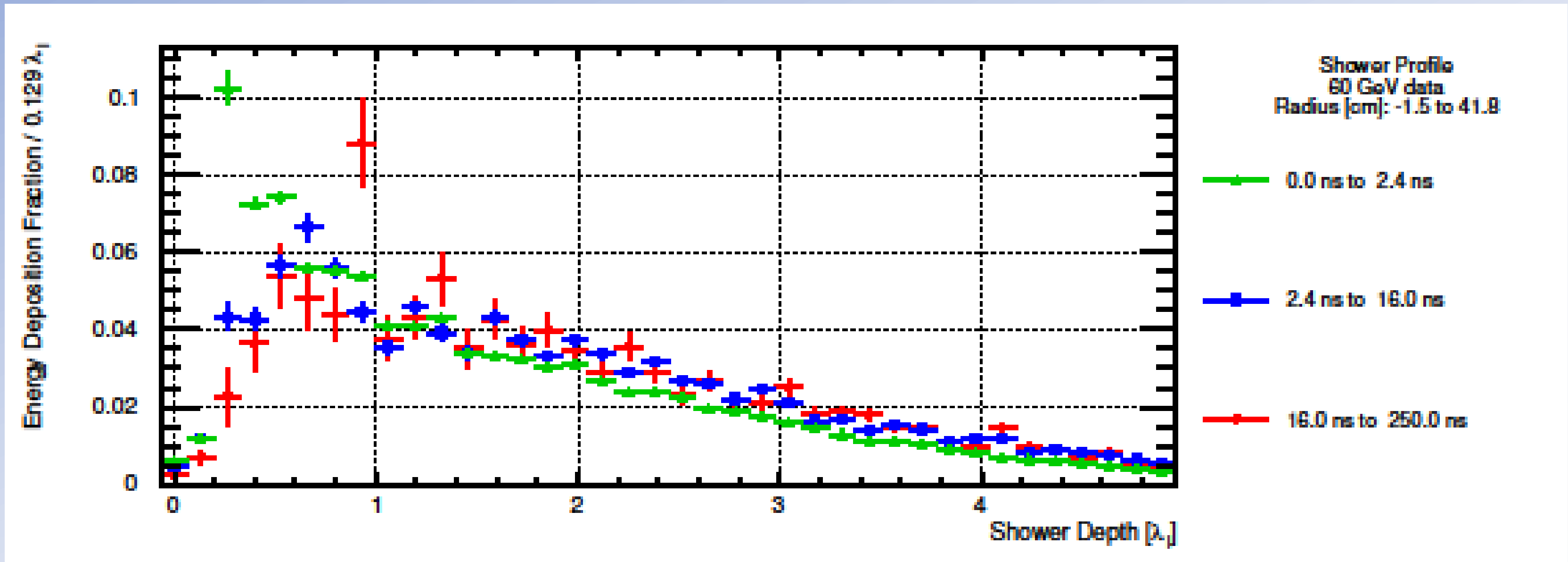
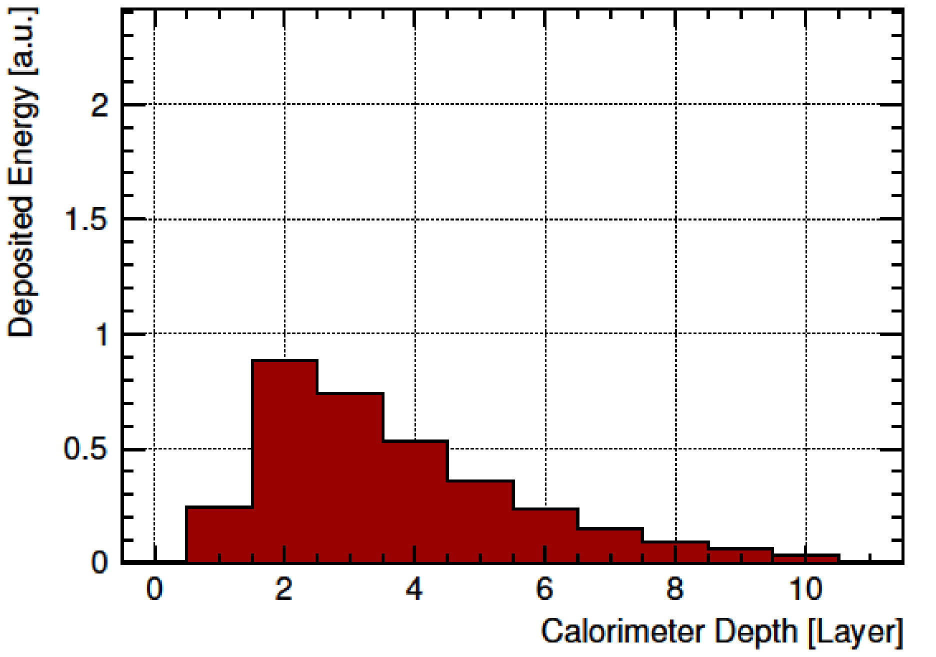
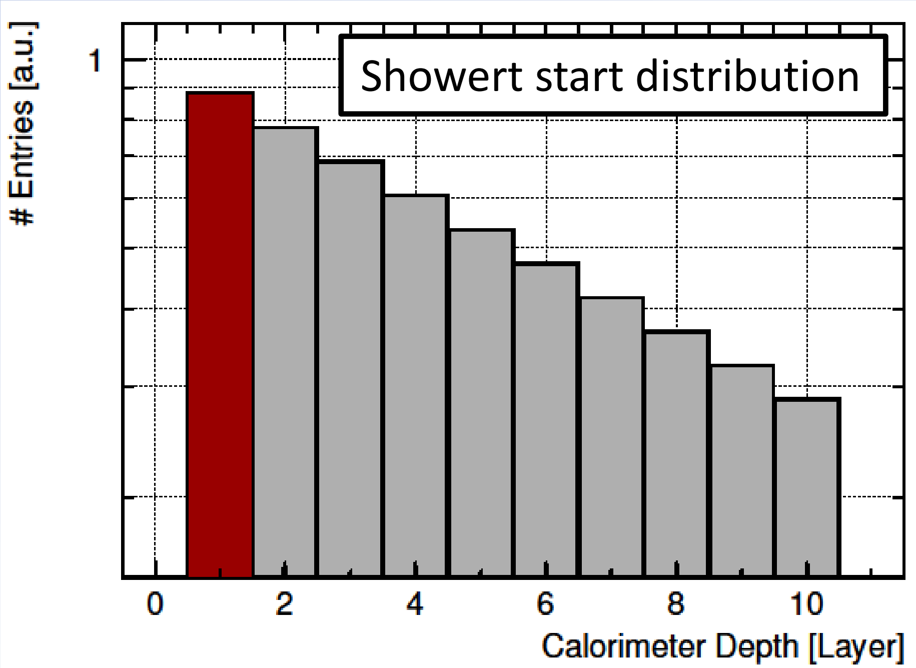
  (Intermediate and Late →) Peak Further in Calorimeter



Paper 3: Reconstruct Calorimeter Profile



- Weight longitudinal shower profile by # shower starts in layer 1



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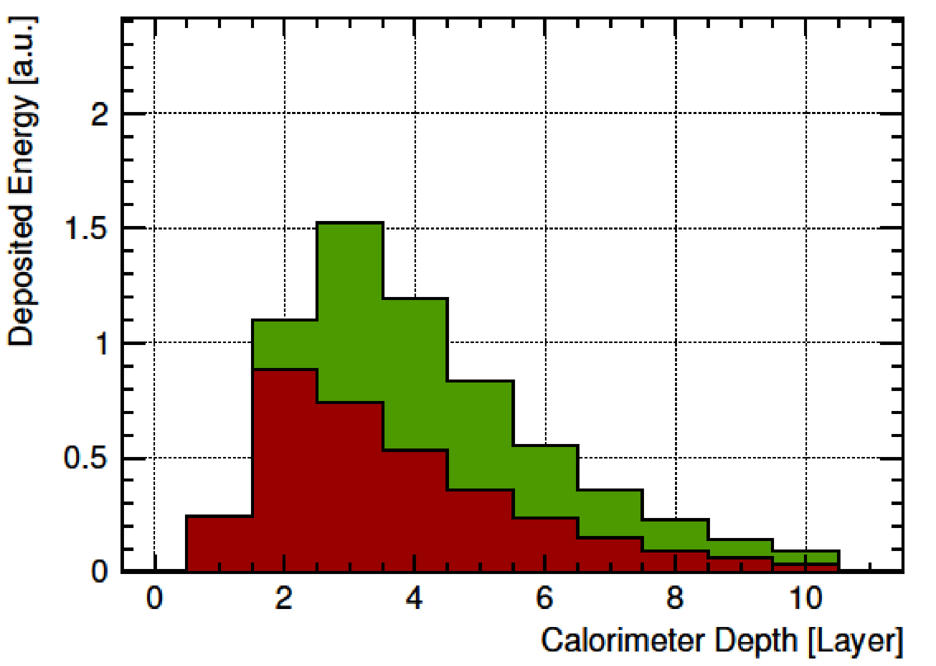
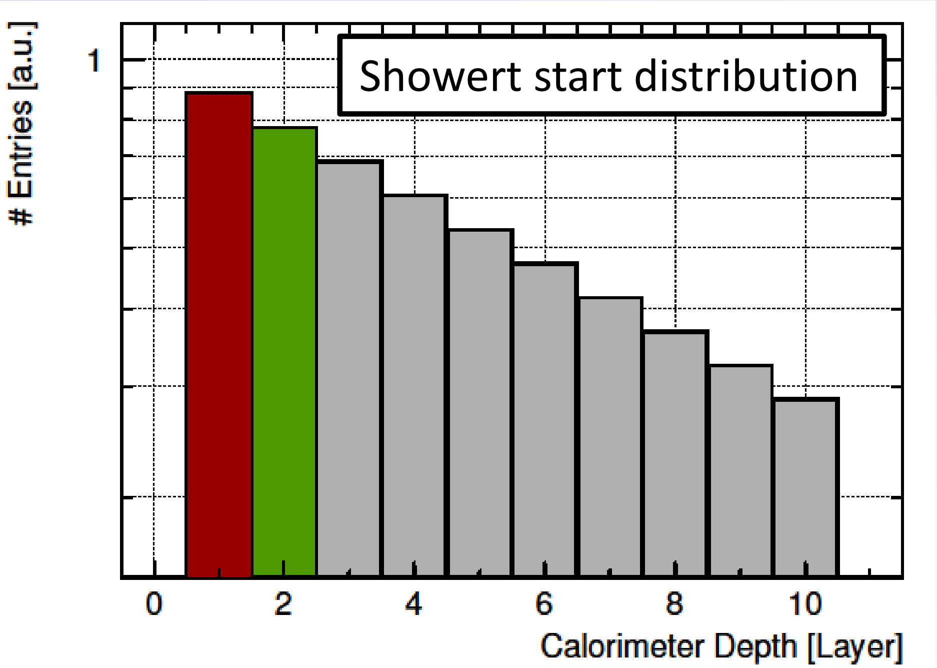


- Weight longitudinal shower profile by # shower starts in layer 1

- Stack weighted profile of layer 2, 3, 4 ... on top



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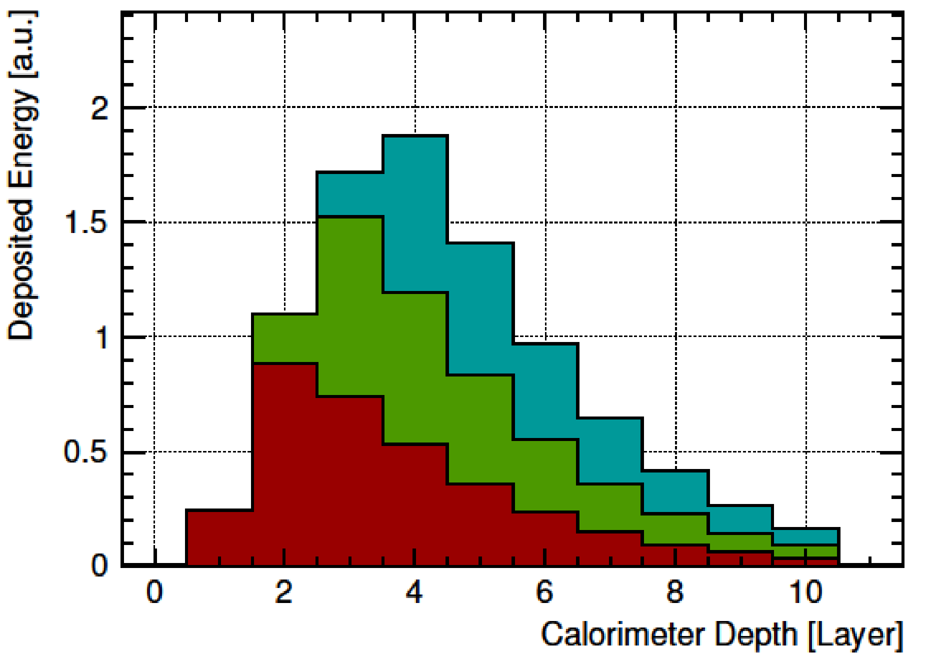

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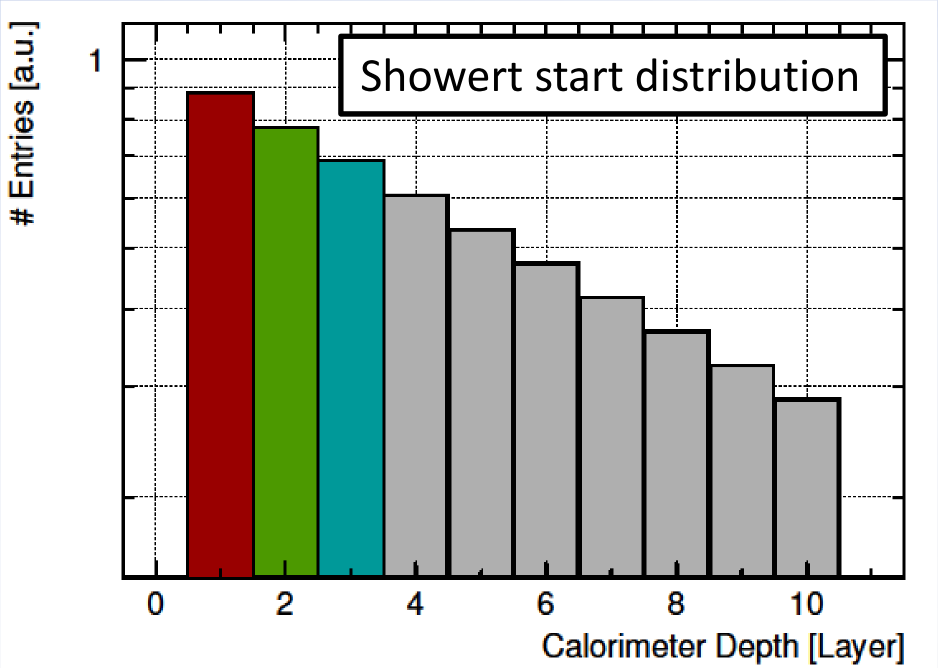

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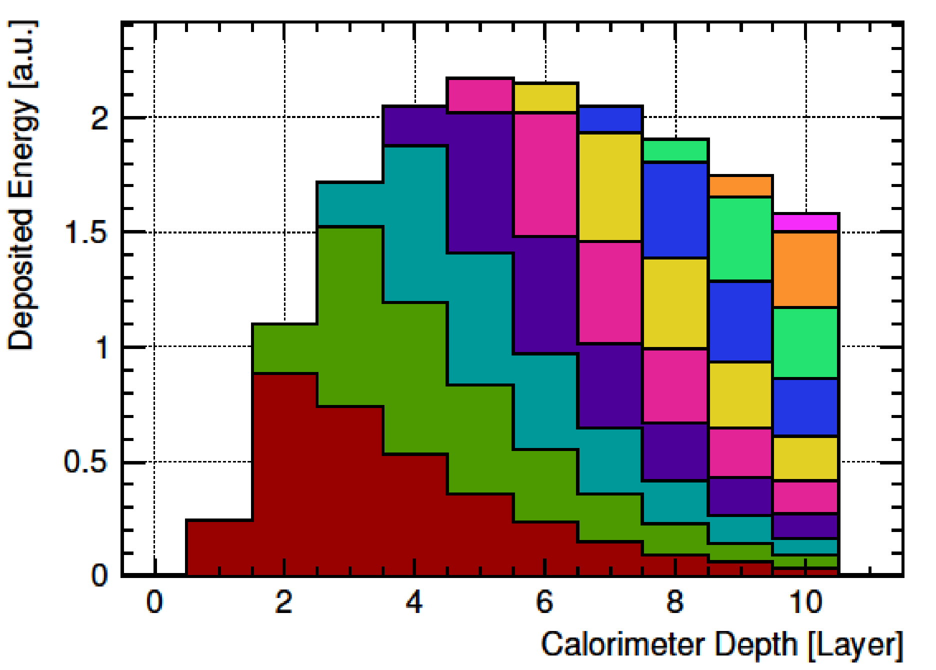

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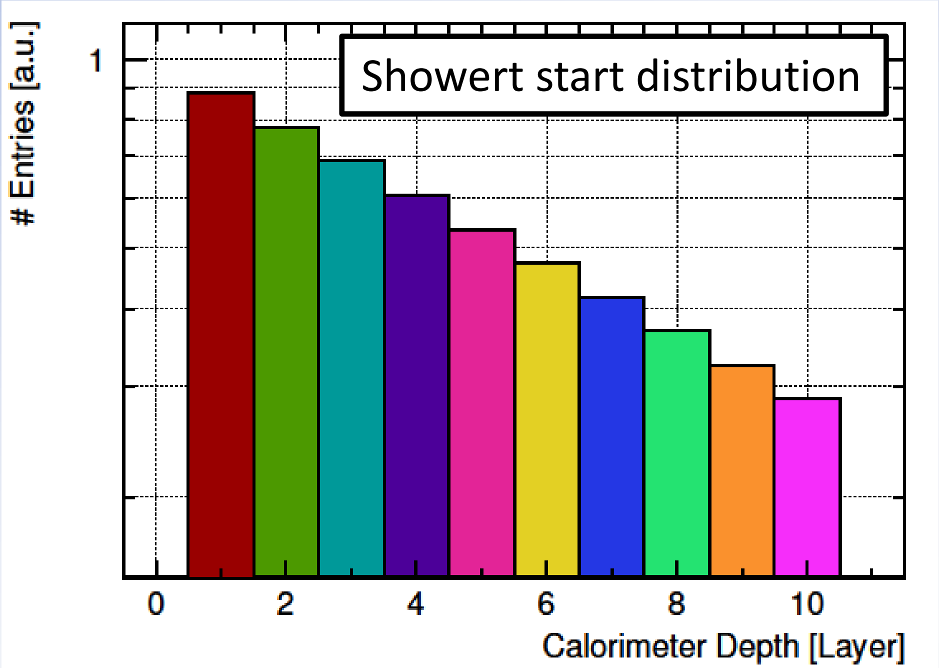


- Stack weighted profile of layer 2, 3, 4 ... on top

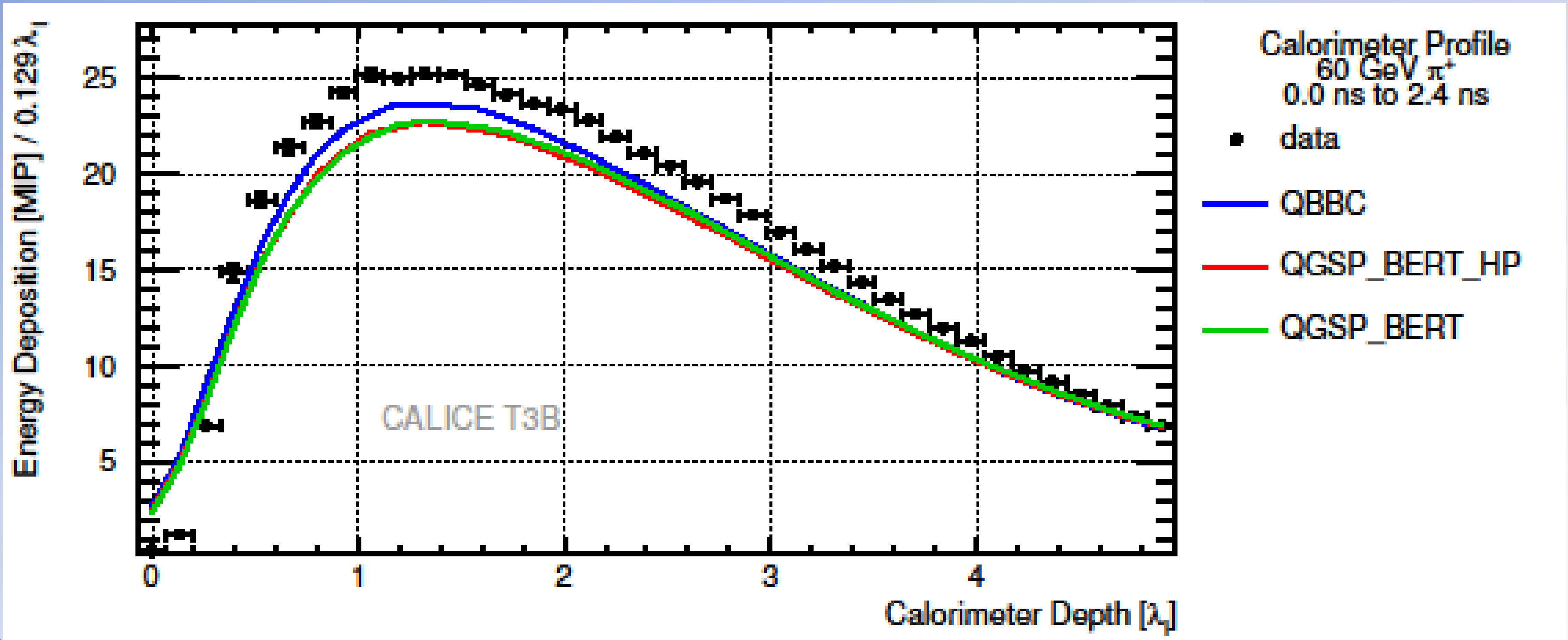
- Obtain calorimeter profile
  → can be investigated in time resolved manner

Paper 3: Time Resolved Calorimeter Profile

Calorimeter profile in 3 time ranges:

- Prompt: 0 to 2.4 ns
- Intermediate: 2.4 to 16 ns
- Late: 16 to 250 ns

→ **Good MC performance in prompt range, high discrep. in late range**



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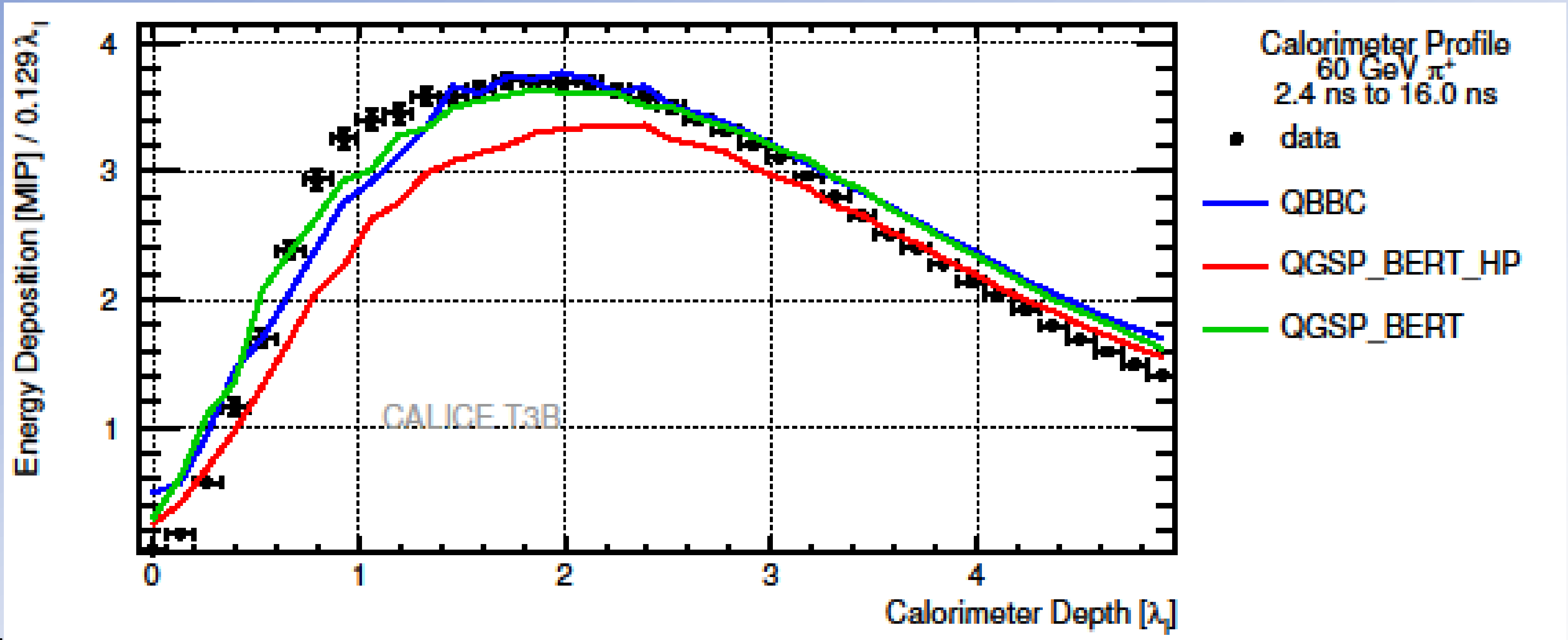

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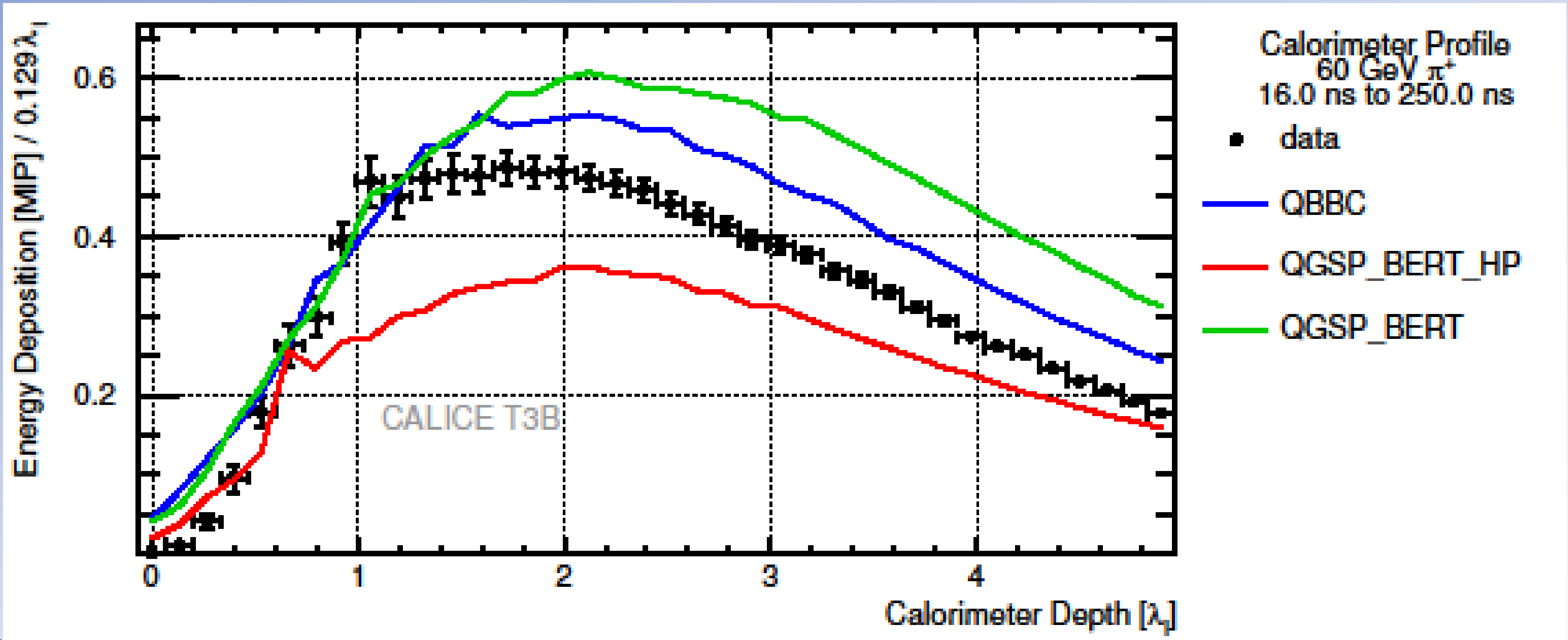
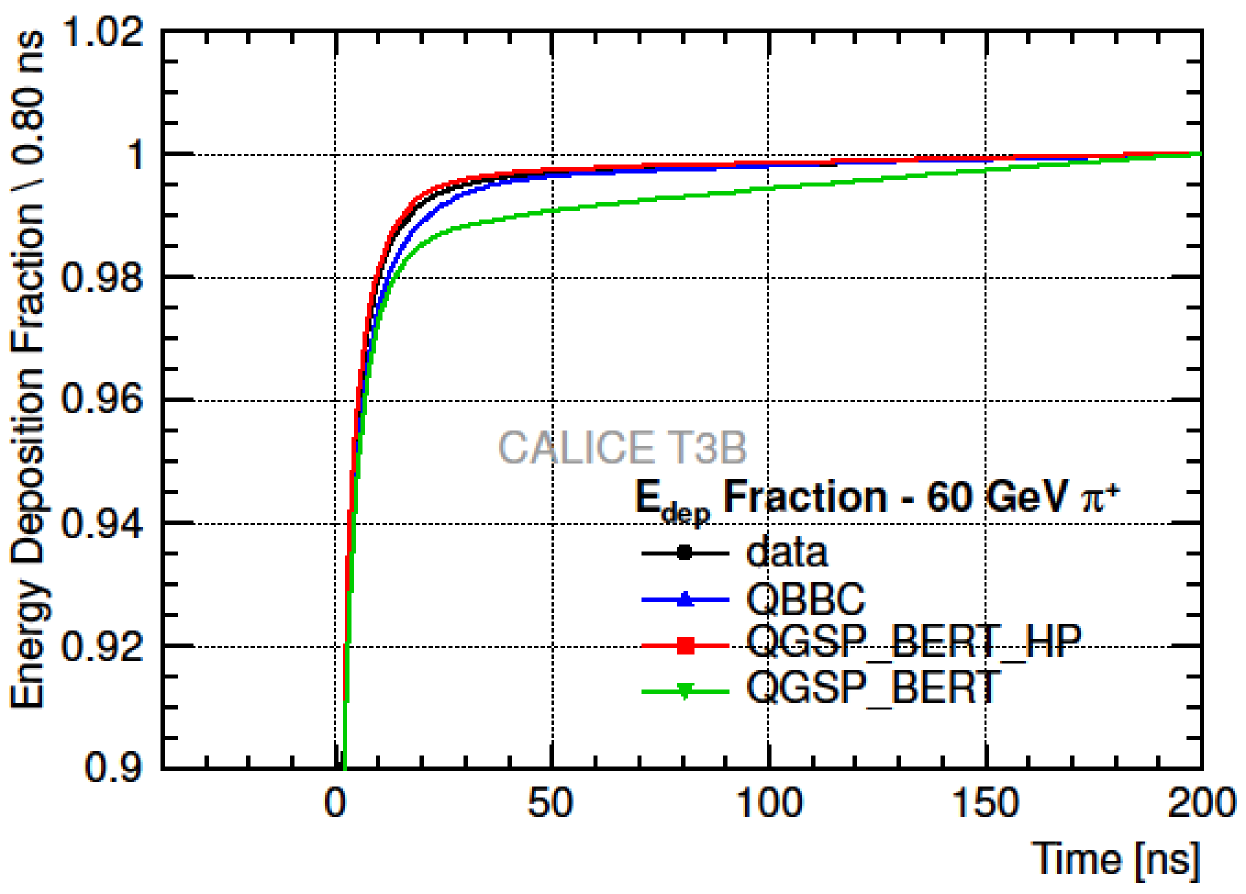


Paper 3: Fraction of Total Shower Energy vs. Time

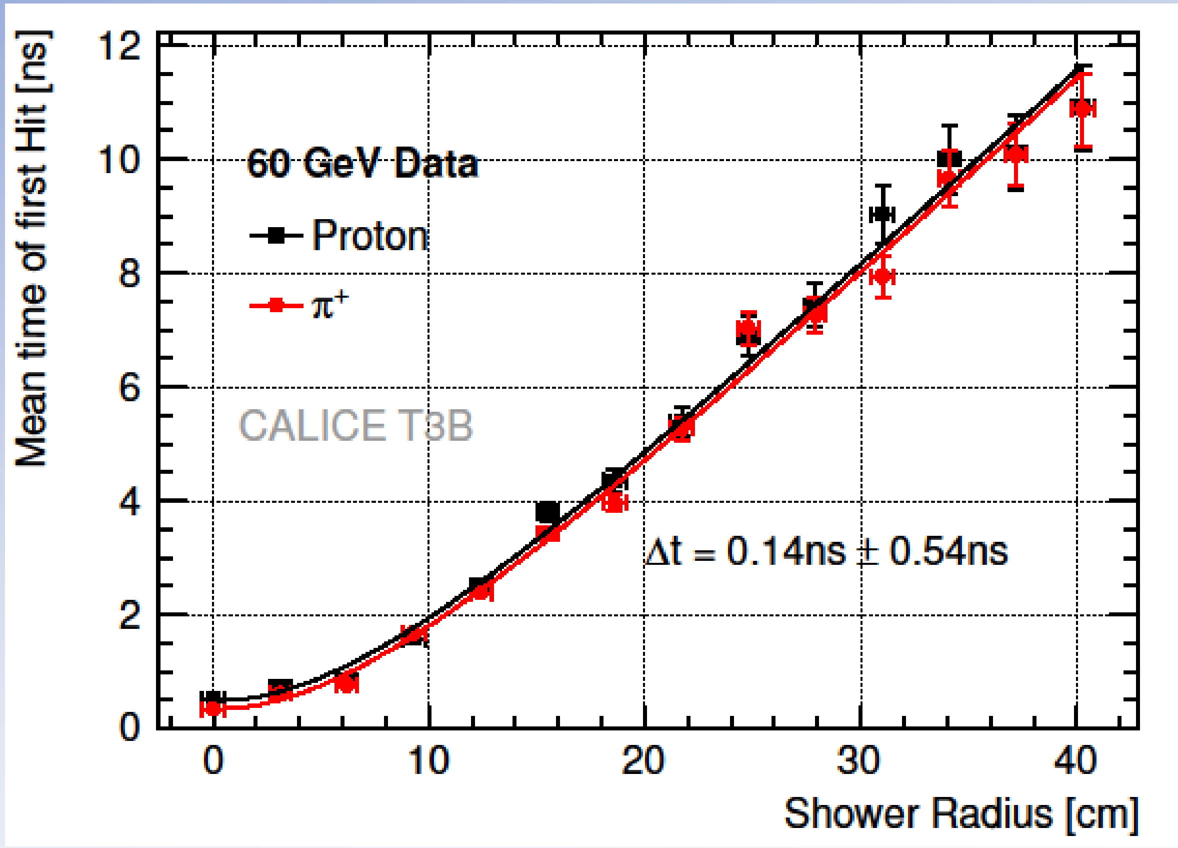
E_{dep} Fraction
- 100% := 200 ns
- > 97% of E_{dep} within 10 ns !
- QGSP_BERT overestimates delayed E_{dep}



Paper 3: Pion / Proton Difference

- Cherenkov Information → Proton vs Pion
- Mean TofH vs Shower Radius
  - Simultaneous Fit of Proton/Pion
  - Only Parameter d individual to Proton/Pion (a,b,c shared)
- No sign. Difference!

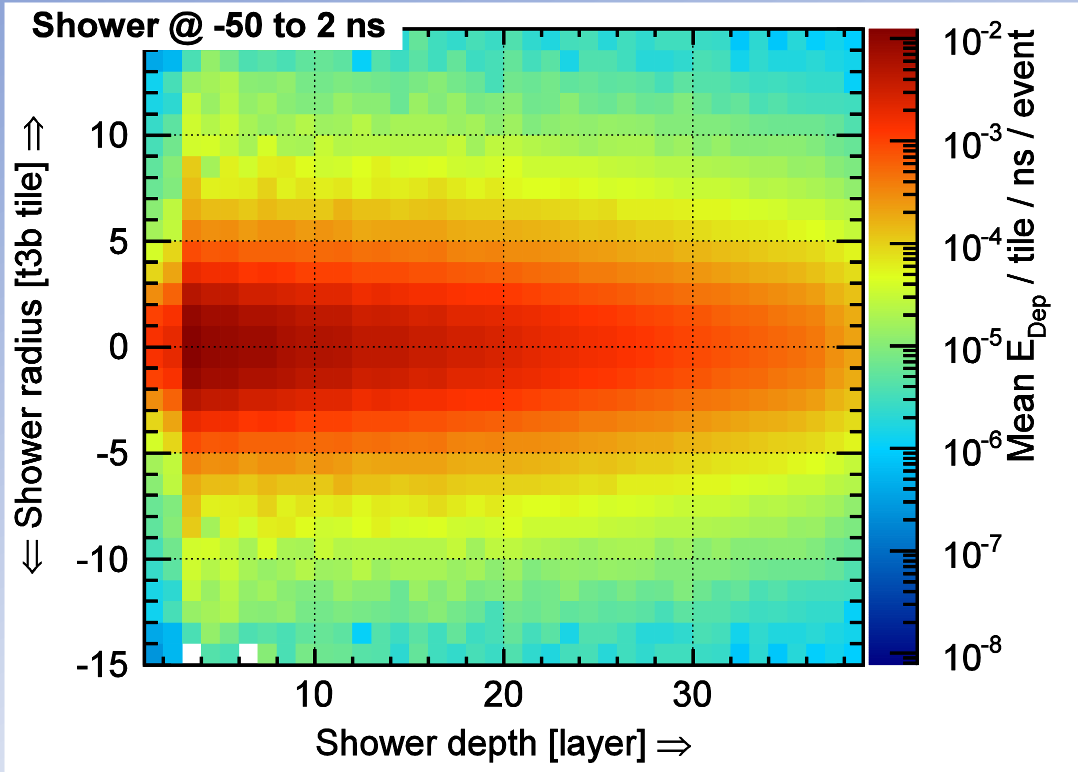
$$f(x) = \exp(ax + b) + cx + d_{p/\pi}$$



Time Resolved Hadronic Shower

Not in paper:
Mean Time Evolution of Hadronic Showers

- Large instantaneous energy deposition
  - Quickly fades away
- Afterglow up to 250ns



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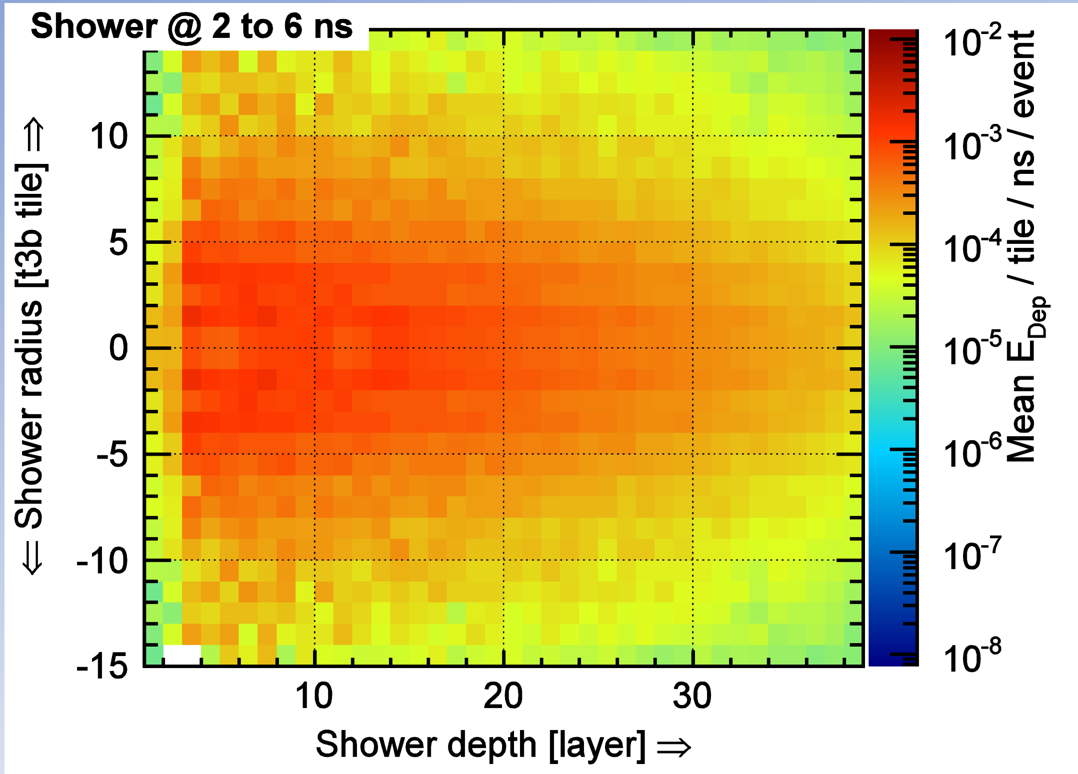

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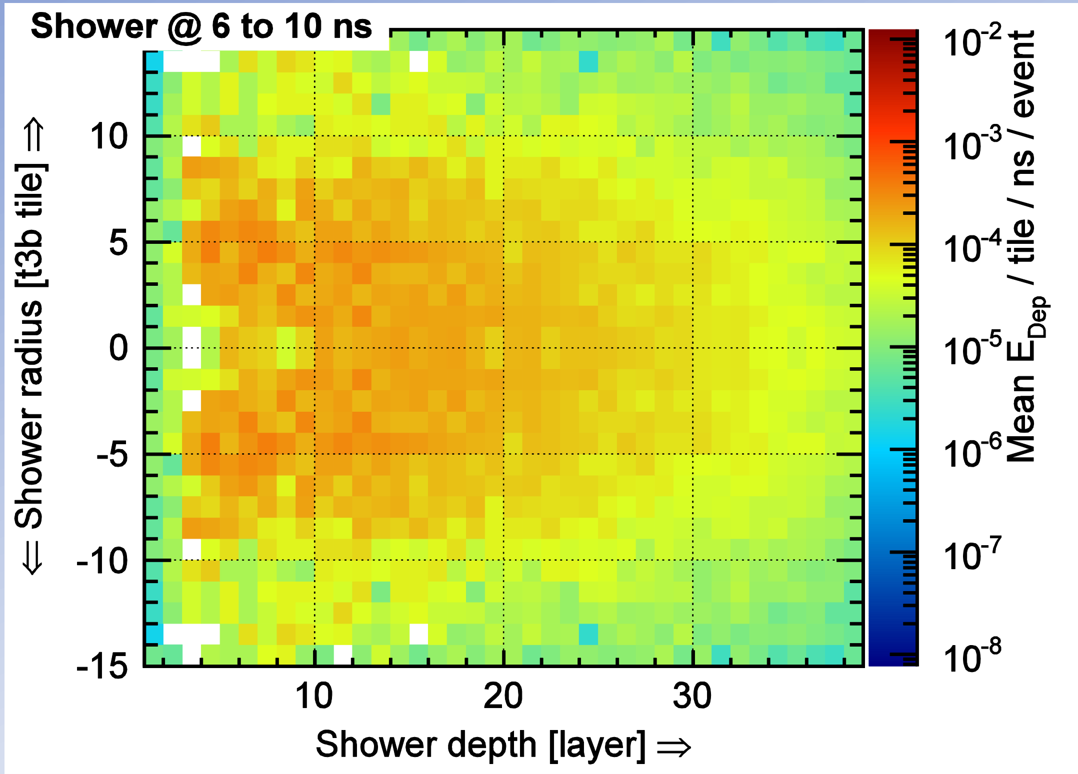

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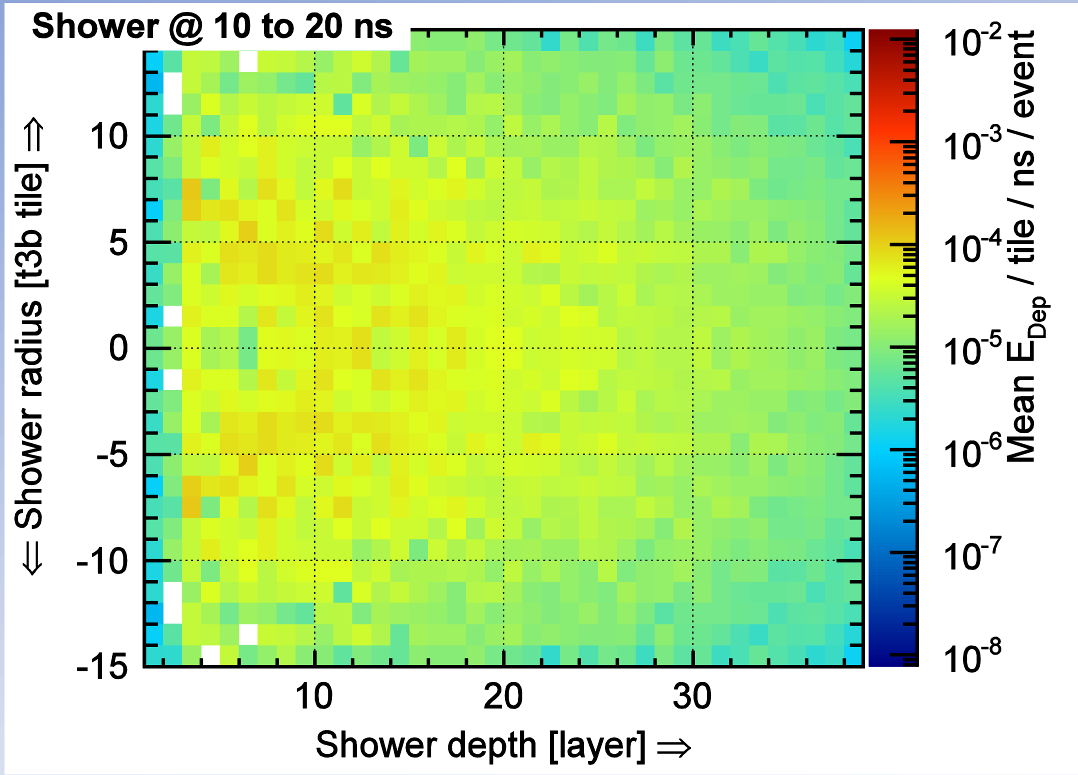

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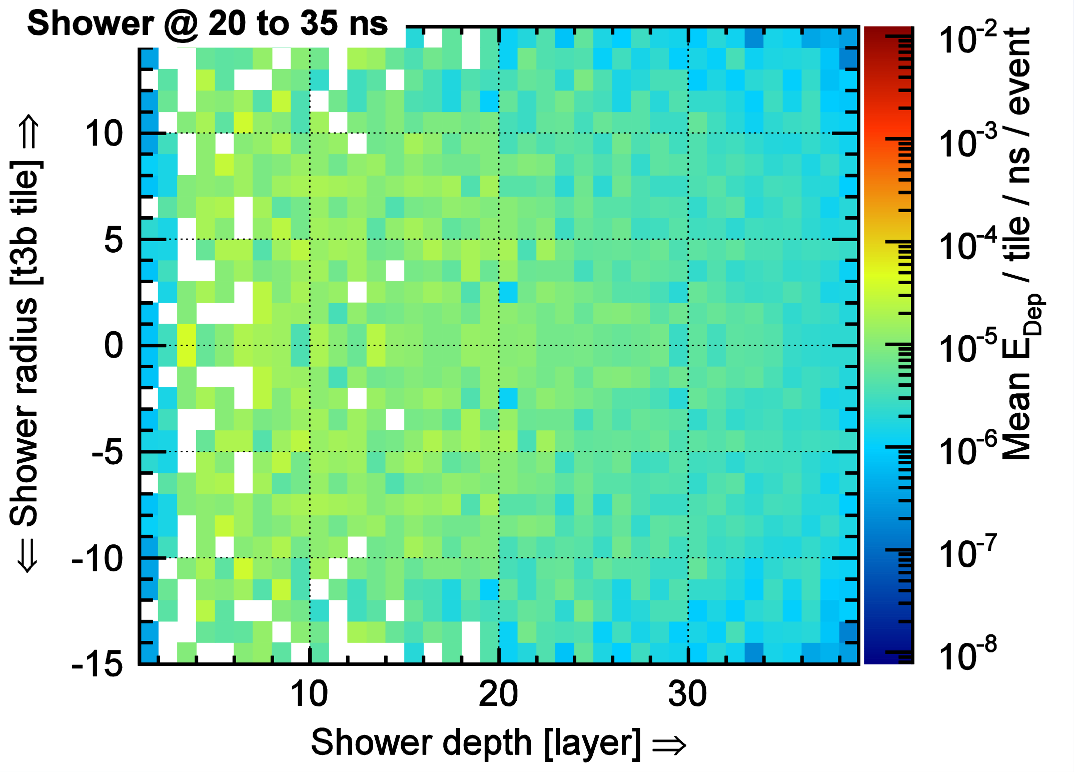

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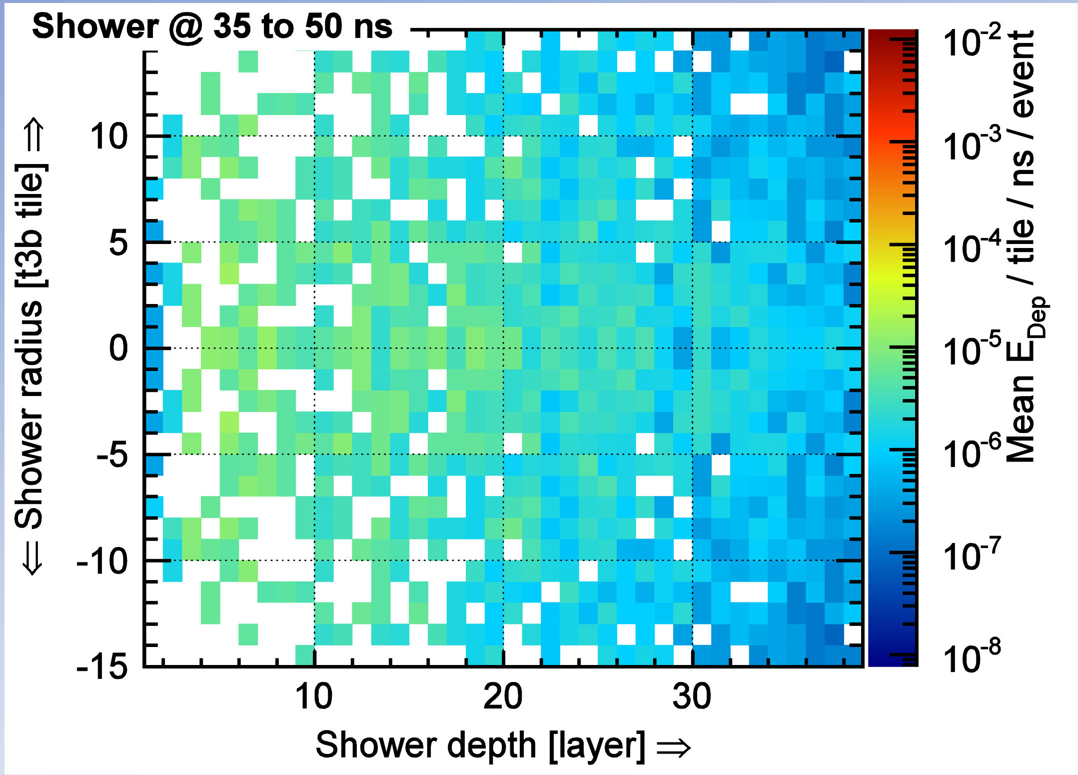

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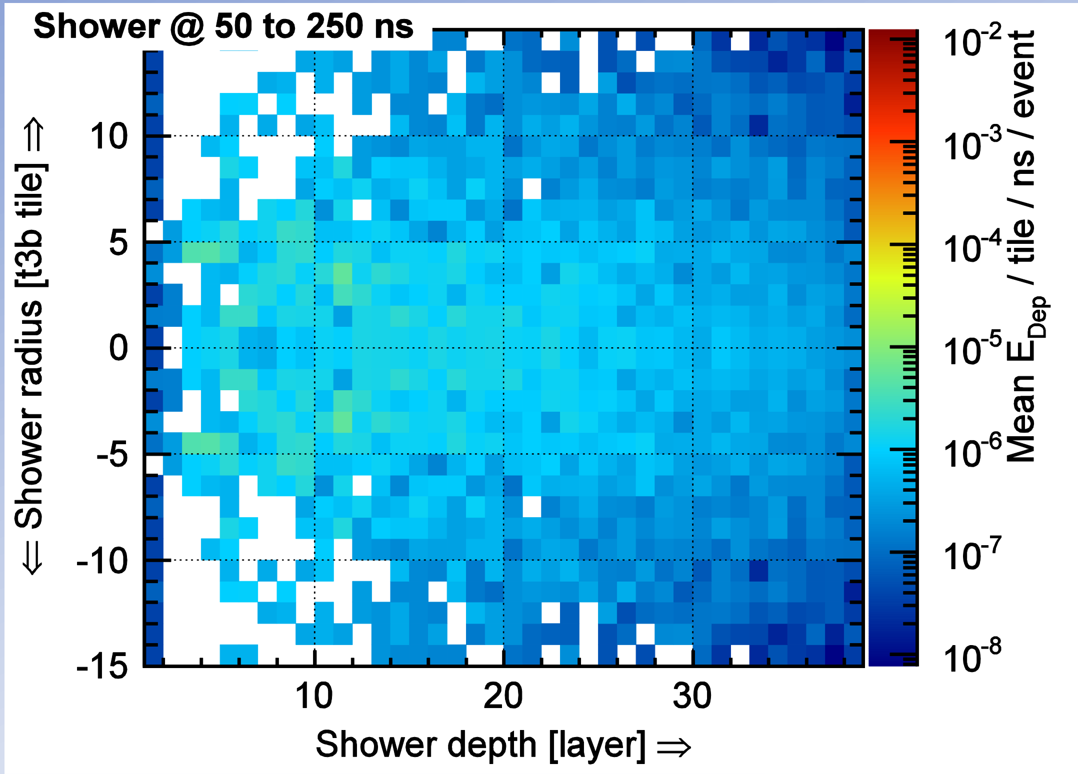
  - Quickly fades away
- Afterglow up to 250ns



CONCLUSIONS

Conclusion

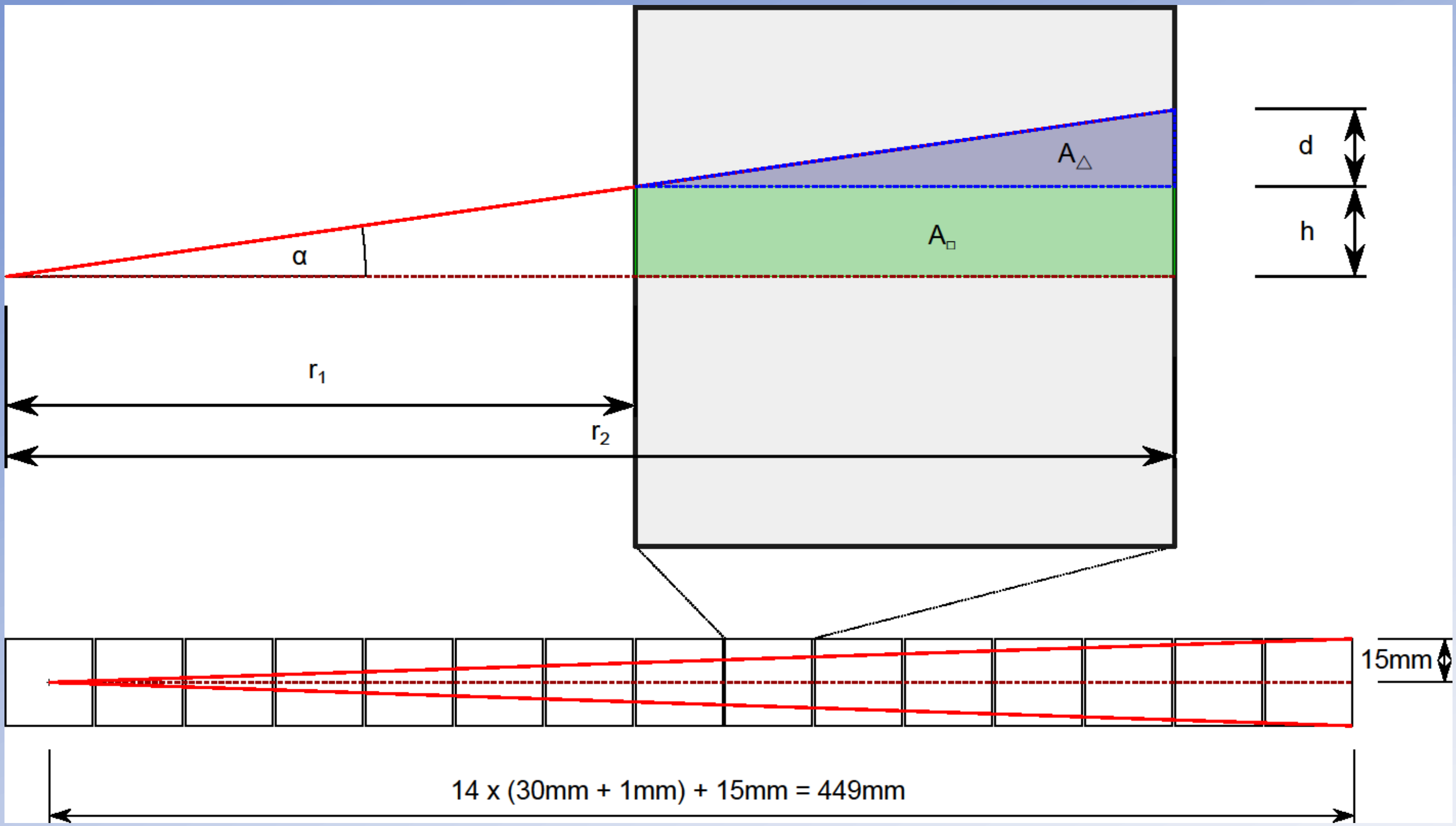
- Measurement of time evolution of hadronic showers possible!
  - Most in CAN-033 & CAN-038
  - New: Synchronization with W-AHCal
    - Pion ⇔ Proton
    - Longitudinal Mean Time of First Hit
    - Timed Shower/Calorimeter Profiles
    - Energy Deposition Fraction
- Validation of Geant4 physics lists:
  - QBBC & QGSP_BERT_HP reproduce data
  - QGSP_BERT overestimates late components

Outlook

- 3 Publications:
  1. T3B Technical & Calibration Paper
     - Small paper, few authors, almost ready for submission
  2. Analysis: Fe ⇔ W Absorber Comparison
     - Draft almost ready for CALICE Editorial Board
  3. Analysis: W Absorber with long. Information
     - Draft exists, will be given to Editorial Board after #2
- Note:
  – Lars & Chris finished their Phd in June 2013
  ➢ Will leave soon (Okt/Nov)
- Thanks for all the support!

BACKUP

Geometric Weighting



tile	1	2	3	4	5	6	7	8
weight	0,786	6,5	13	19,5	26	32,5	39	45,5
tile	9	10	11	12	13	14	15	
weight	52	58,5	65	71,4	77,9	84,4	90,9	

Energy Deposition Fraction: TofH vs Raw Geant4