

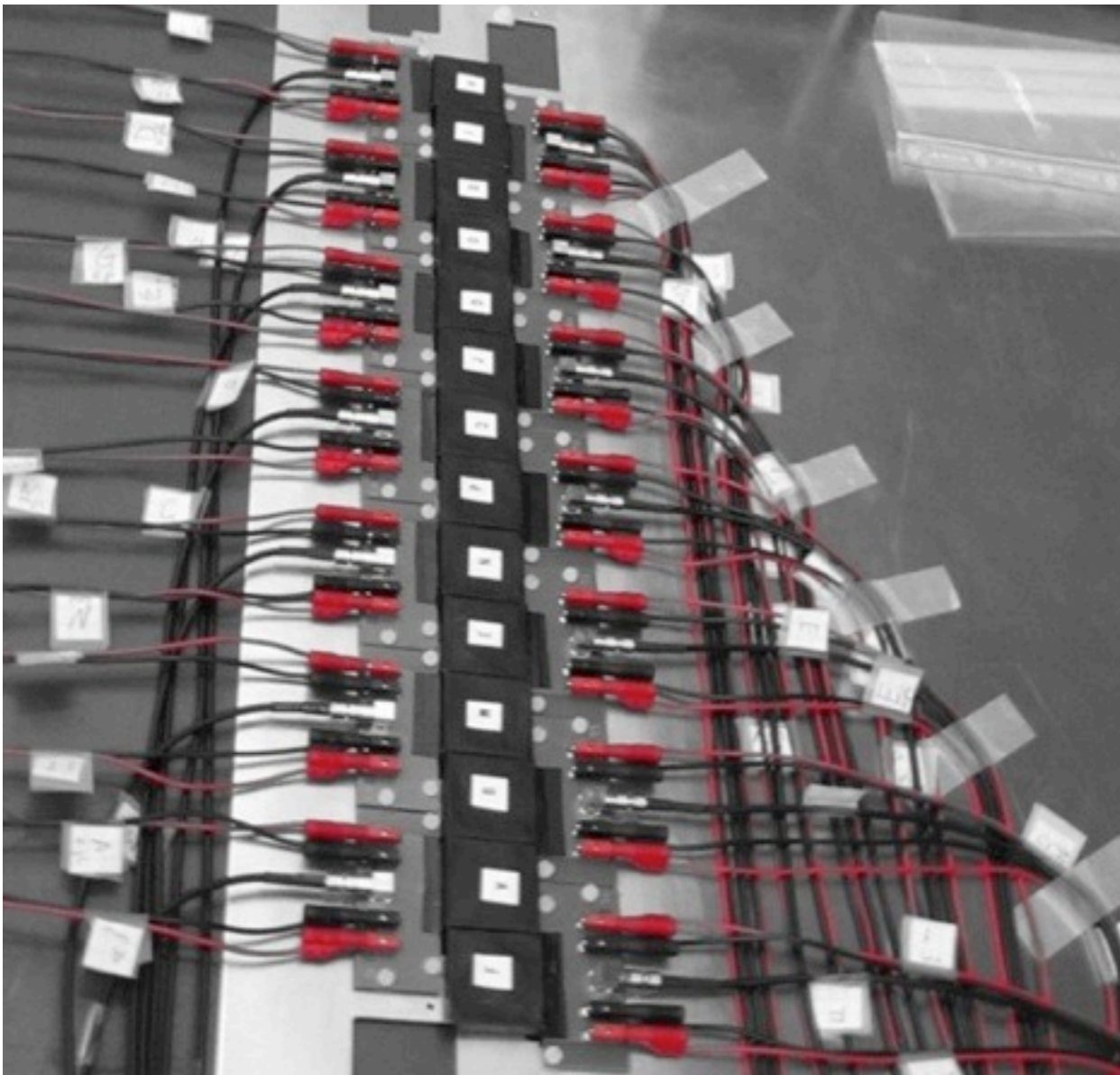


# T3B: Behind the Scenes

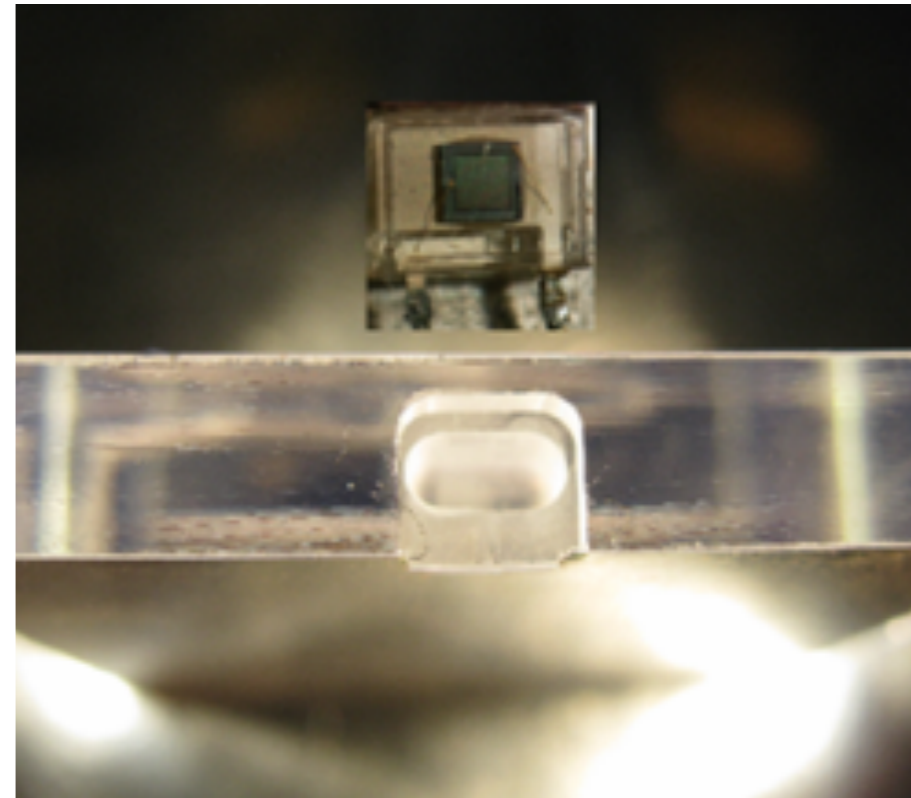
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Max-Planck-Institut für Physik  
Munich, Germany

*AHCAL Main Meeting, DESY Hamburg, December 2012*



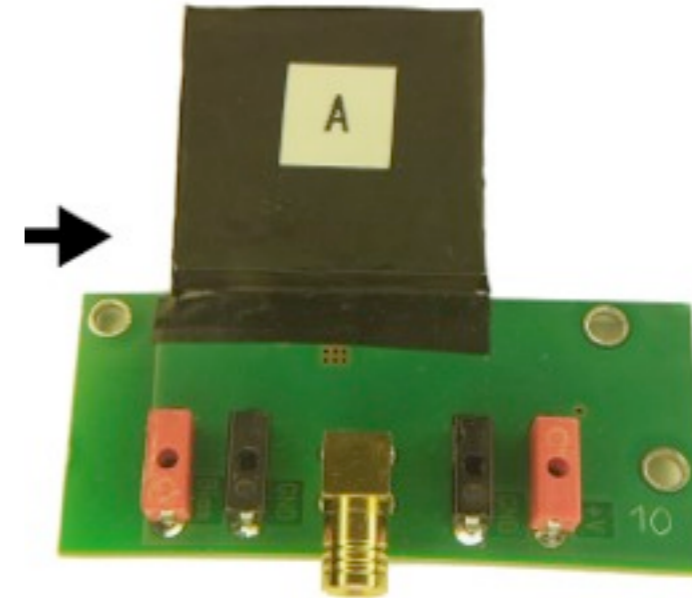


- 15 cells behind the WAHCAL / SDHCAL



- Directly coupled MPPC-50P
- Bicron BC420 scintillator (391 nm peak emission, pulse FWHM 1.3 ns, 0.5 ns rise time)
- Wrapped in 3M reflective foil

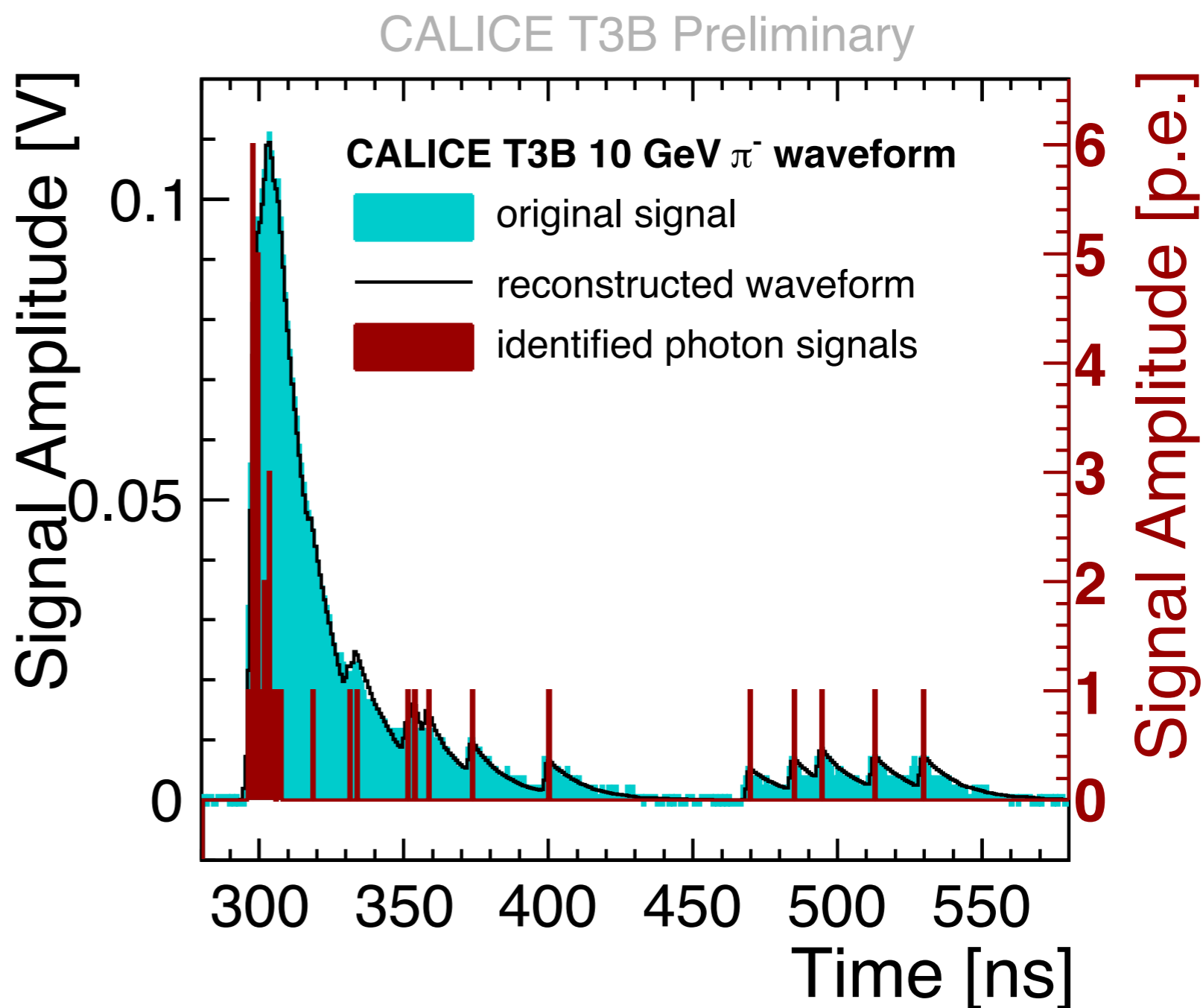
- SiPM mounted to high band-width preamplifier (x8.9 amplification)



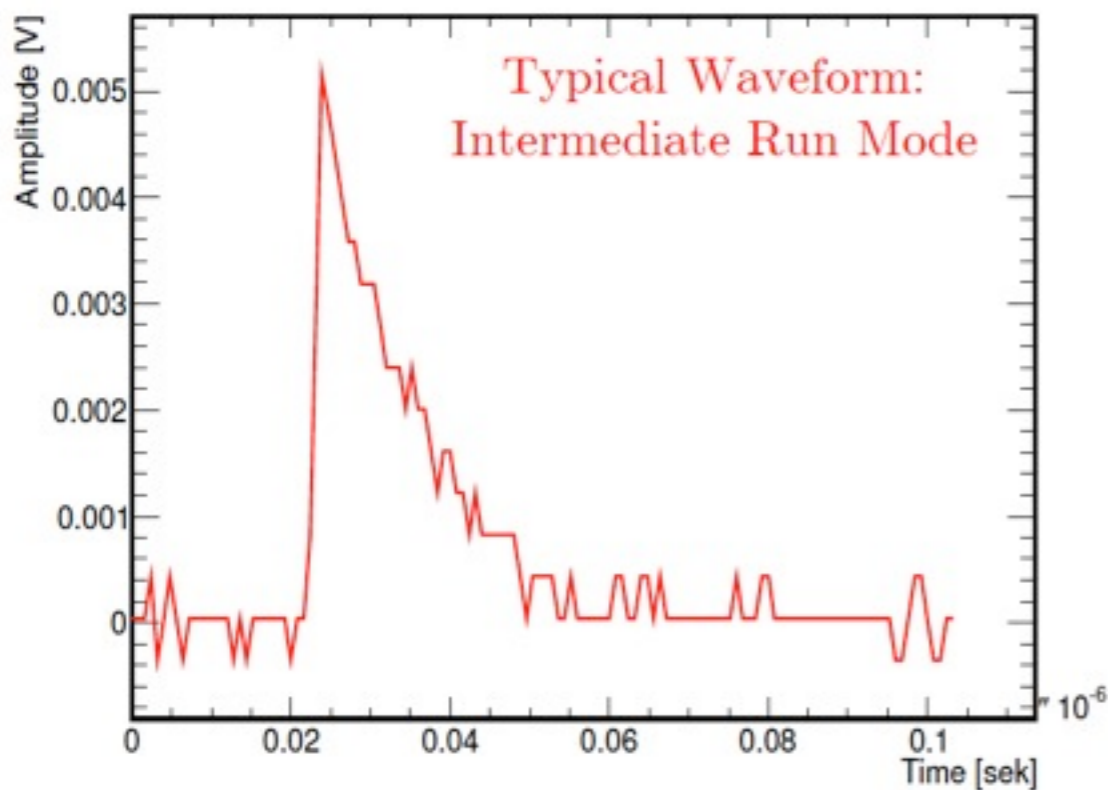
- Each channel read out with PicoScope PS6403
  - 1.25 GS/s
  - 2.4  $\mu$ s acquisition window
  - max. trigger rate > 100 kHz

# Data Reconstruction

- Full waveform recorded for each channel
- Individual photon arrival times (and total amplitude) determined by iteratively subtracting 1 p.e. signals

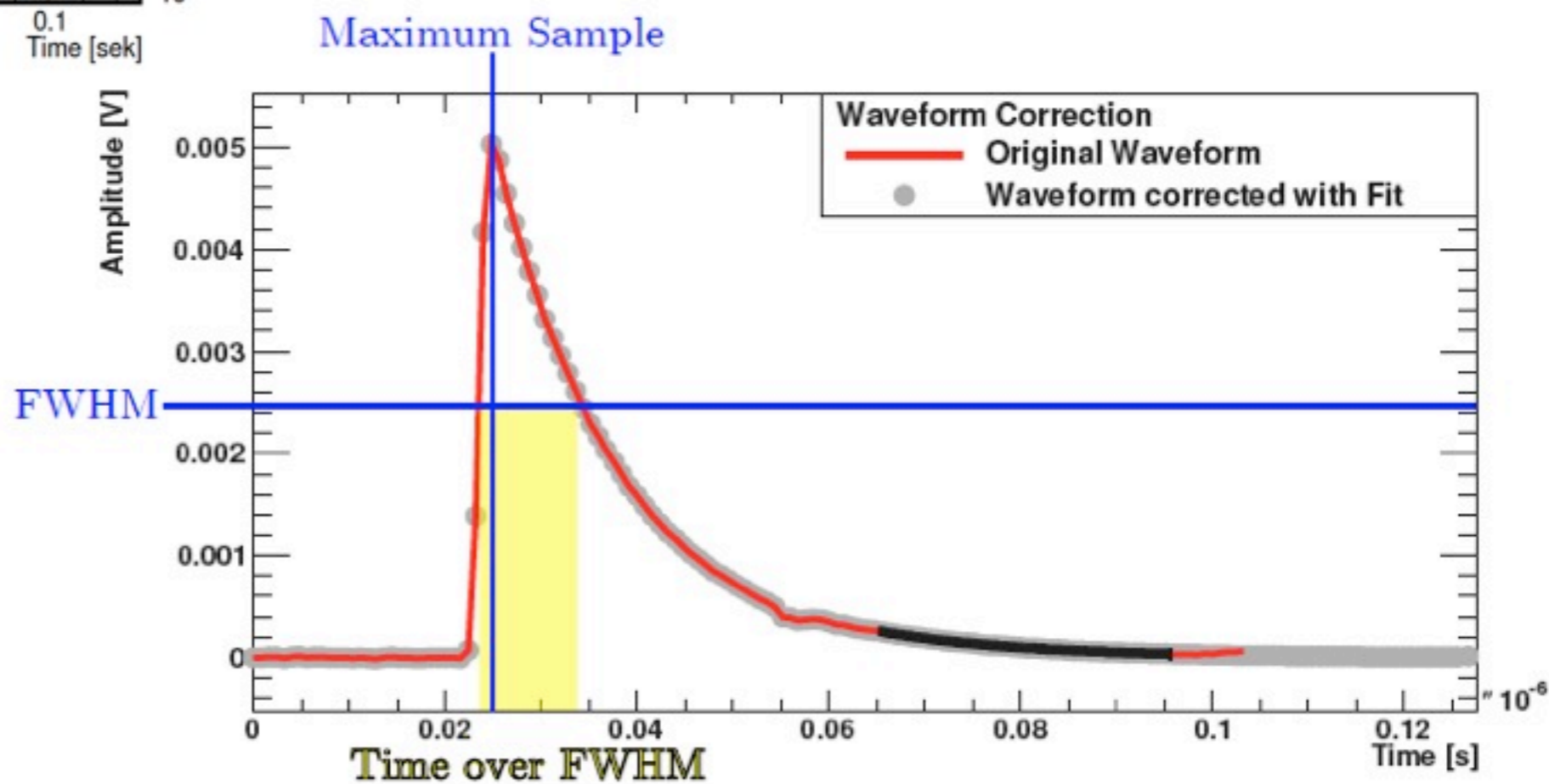


# Calibration - Average 1 p.e. signal



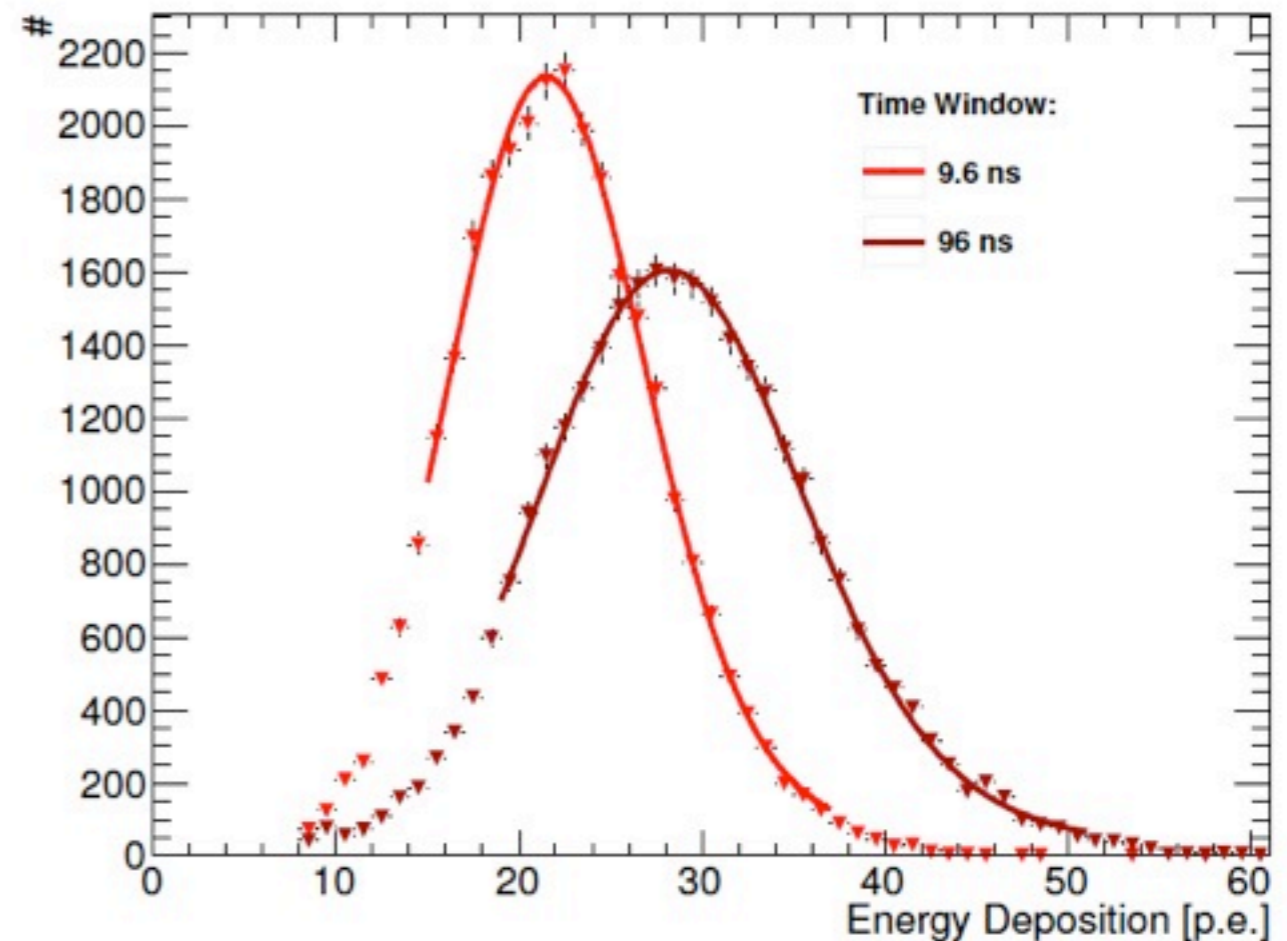
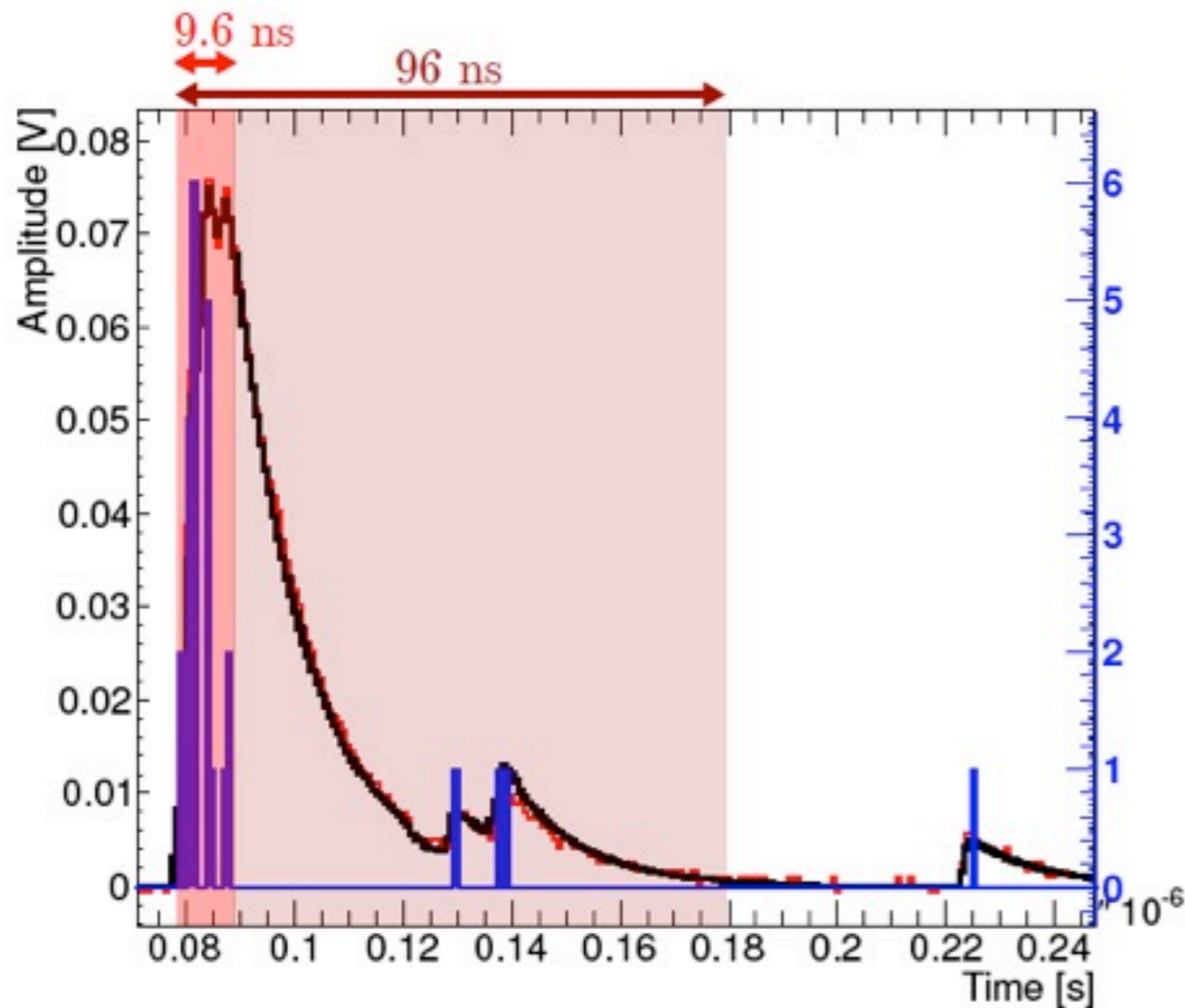
- Dark noise recorded between spills
- Every few minutes a reference 1 p.e. signal for each channel is built from data
- ▶ Automatic gain correction!

- Reference waveform determined by fit, including smooth extrapolation to avoid artifacts from end of acquisition window



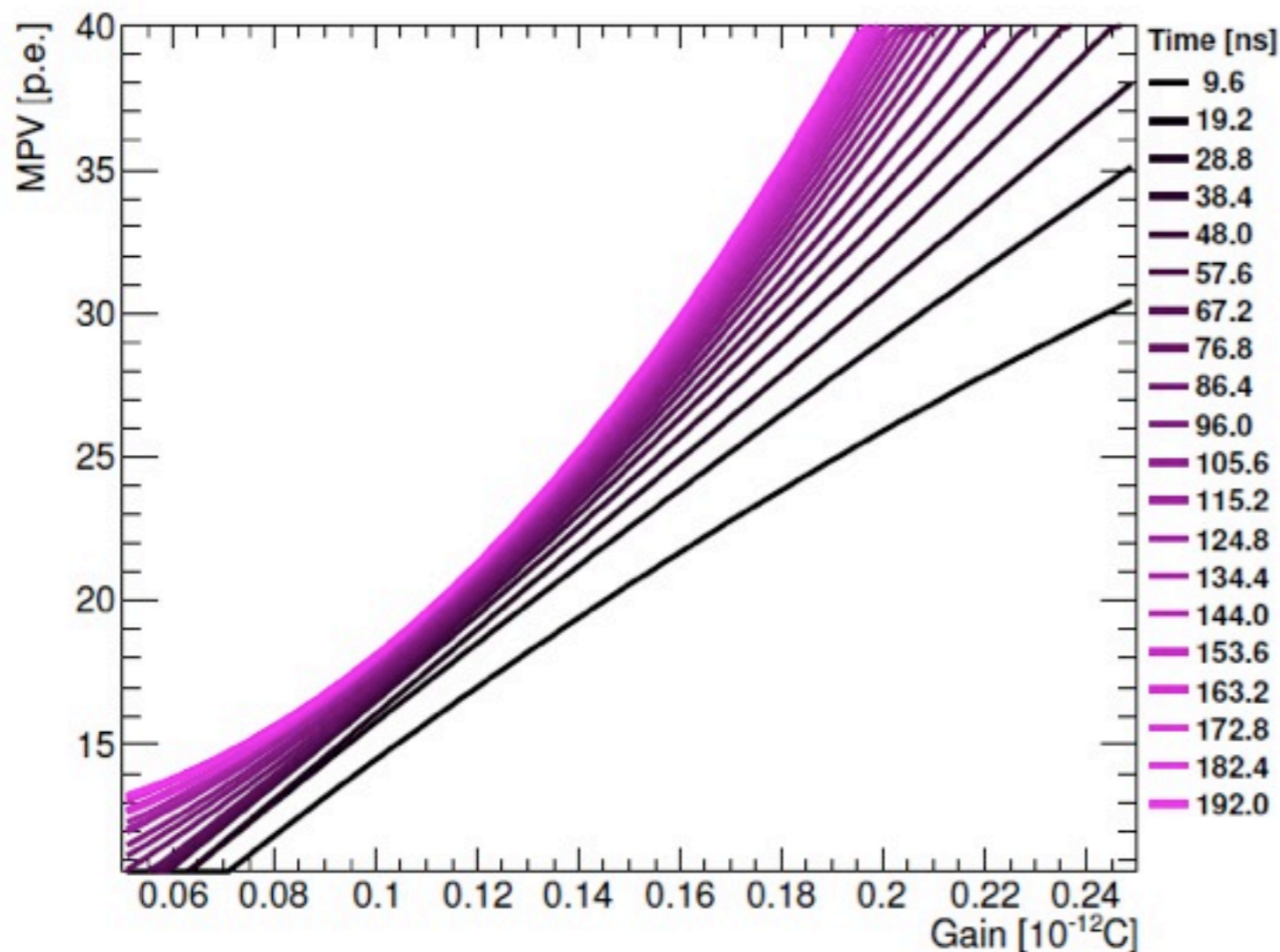
# Calibration - Energy

- Calibration of the time energy scale in the lab with a  $^{90}\text{Sr}$  source
  - Additional correction factor to MIP scale: 0.82 (deposited 805 keV for MIPs compared to  $\sim 1$  MeV for  $^{90}\text{Sr}$  electrons)



- MIP amplitude in p.e. depends strongly on integration time: Afterpulses of the photon sensor!

- Temperature matters: Direct effect on the gain (since we keep the operating voltage constant)
- But beware: Afterpulses also change with temperature and voltage!
- ▶ **Temperature correction is integration-time dependent!**



For short integration times  
( $<$  recovery time of MPPC micro-cells):  
Linear dependence of MIP on gain

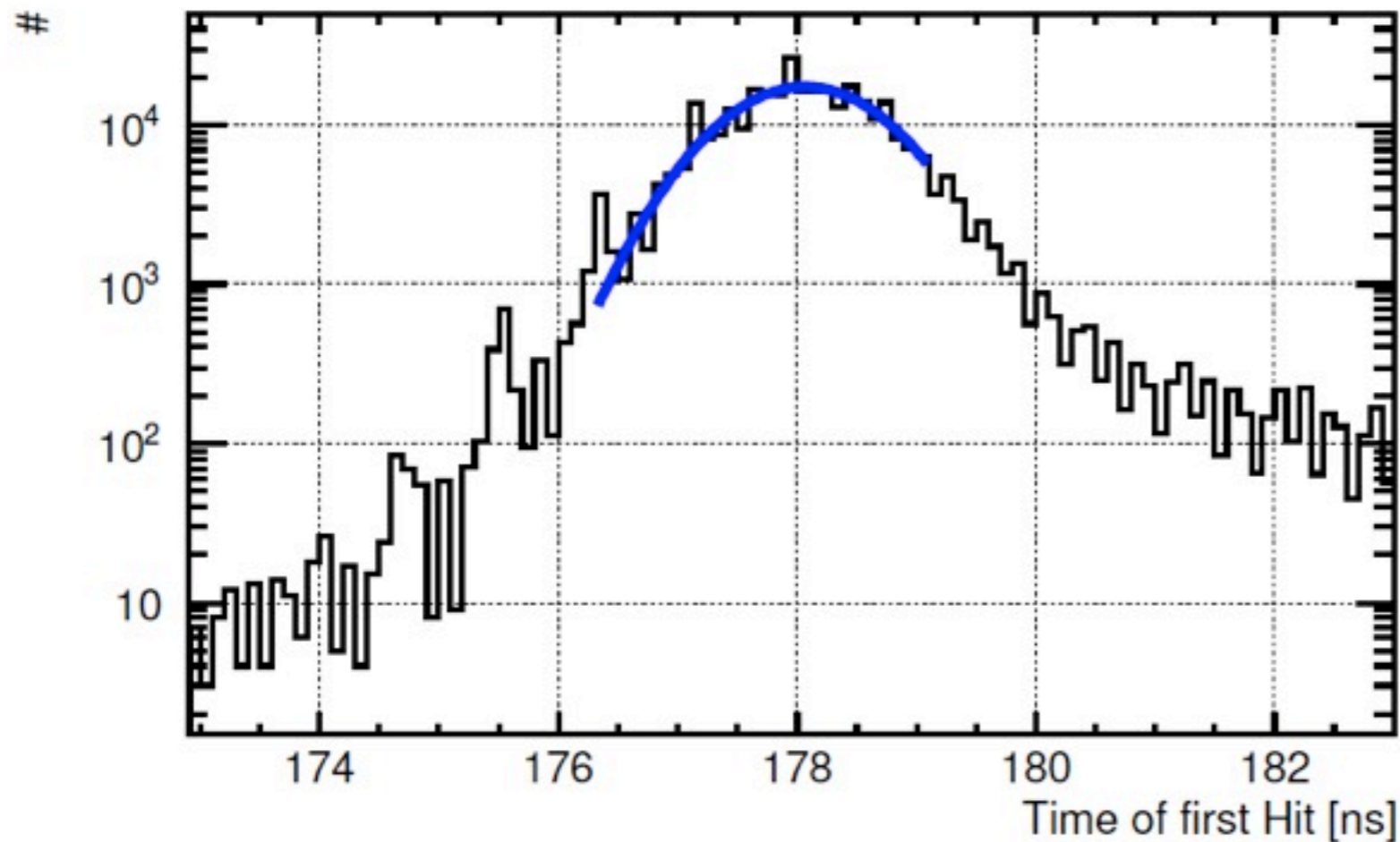
For long integration times  
( $>>$  recovery time of MPPC micro-cells):  
Quadratic dependence of MIP on gain



- T3B is not capable of measuring absolute time: No careful study of signal running times from trigger system to T3B
  - Triggers taken from CALICE DAQ backplane with WAHCAL, directly from scintillator coincidence with SDHCAL
- But: Took great care that all oscilloscopes trigger at the same time: uniform cable lengths to Picoscope external trigger, uniform cable lengths for T3B tiles (on the 1 - 2 cm (50 - 100 ps) level)
- ▶ To measure time relative to primary particle impact, a measurement of the latency of the whole system is required
  - ▶ Since channel-to-channel timing is fixed, this can be done with a single cell



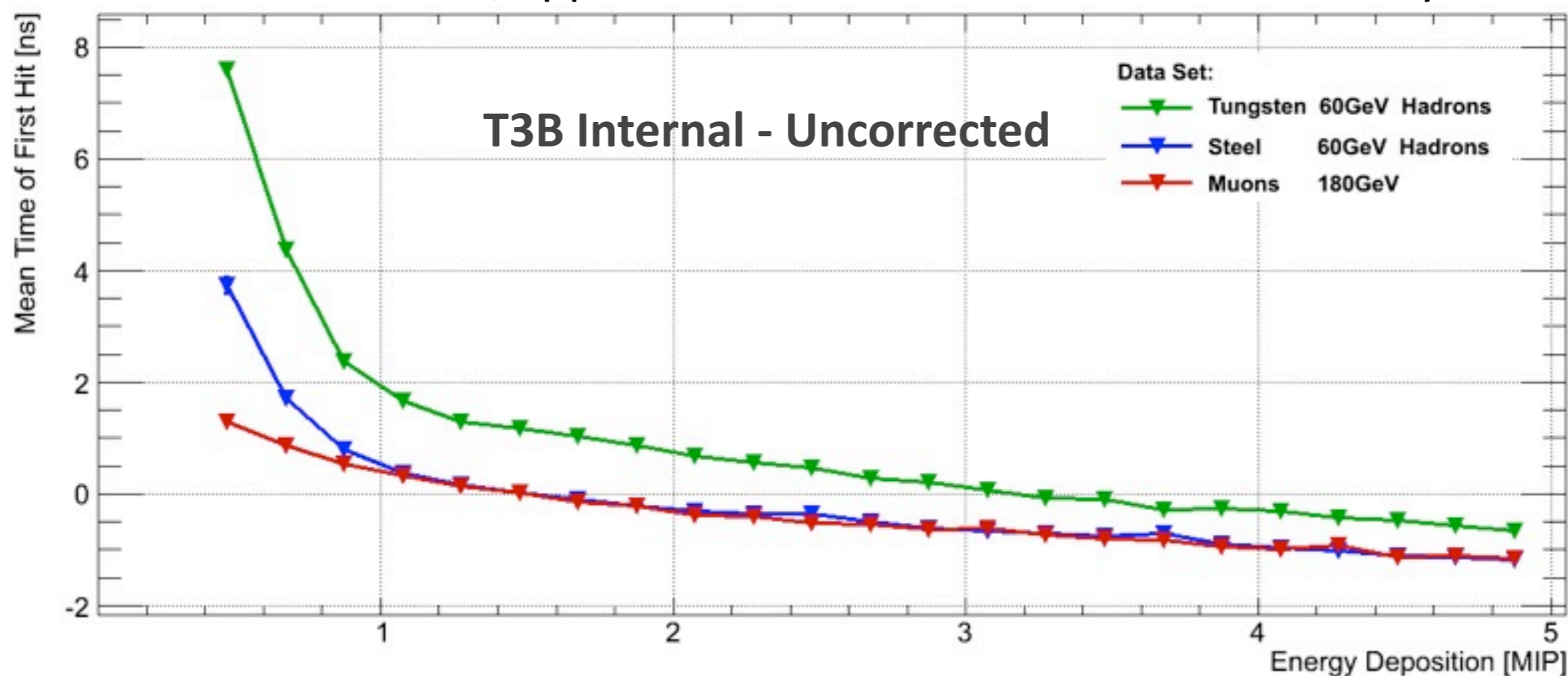




- Fix the global timing: Penetrating particles in the central tile of T3B
  - Done on time of first hit distribution: The main peak corresponds to instantaneous (relativistic) particles - Peak determined with a Gaussian, set to  $t = 0$  in analysis

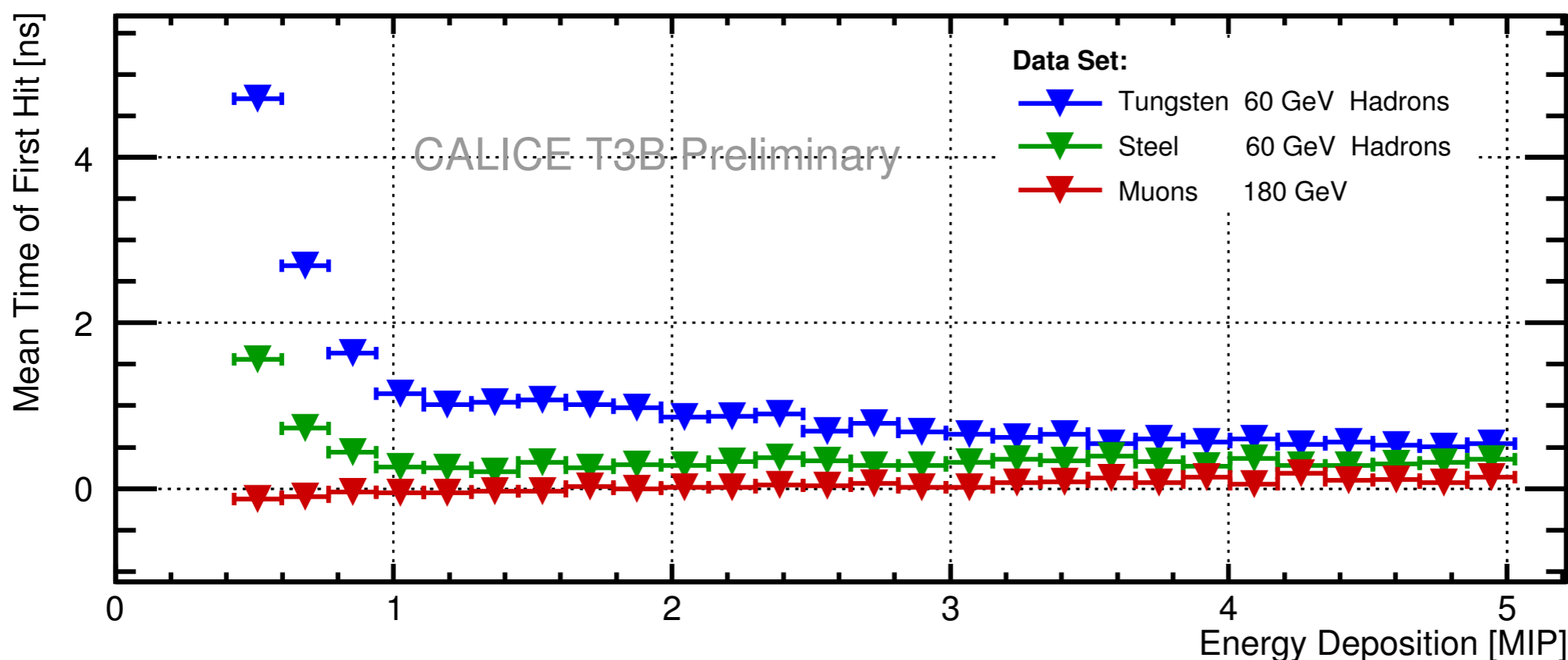
# Calibration - Time vs Energy

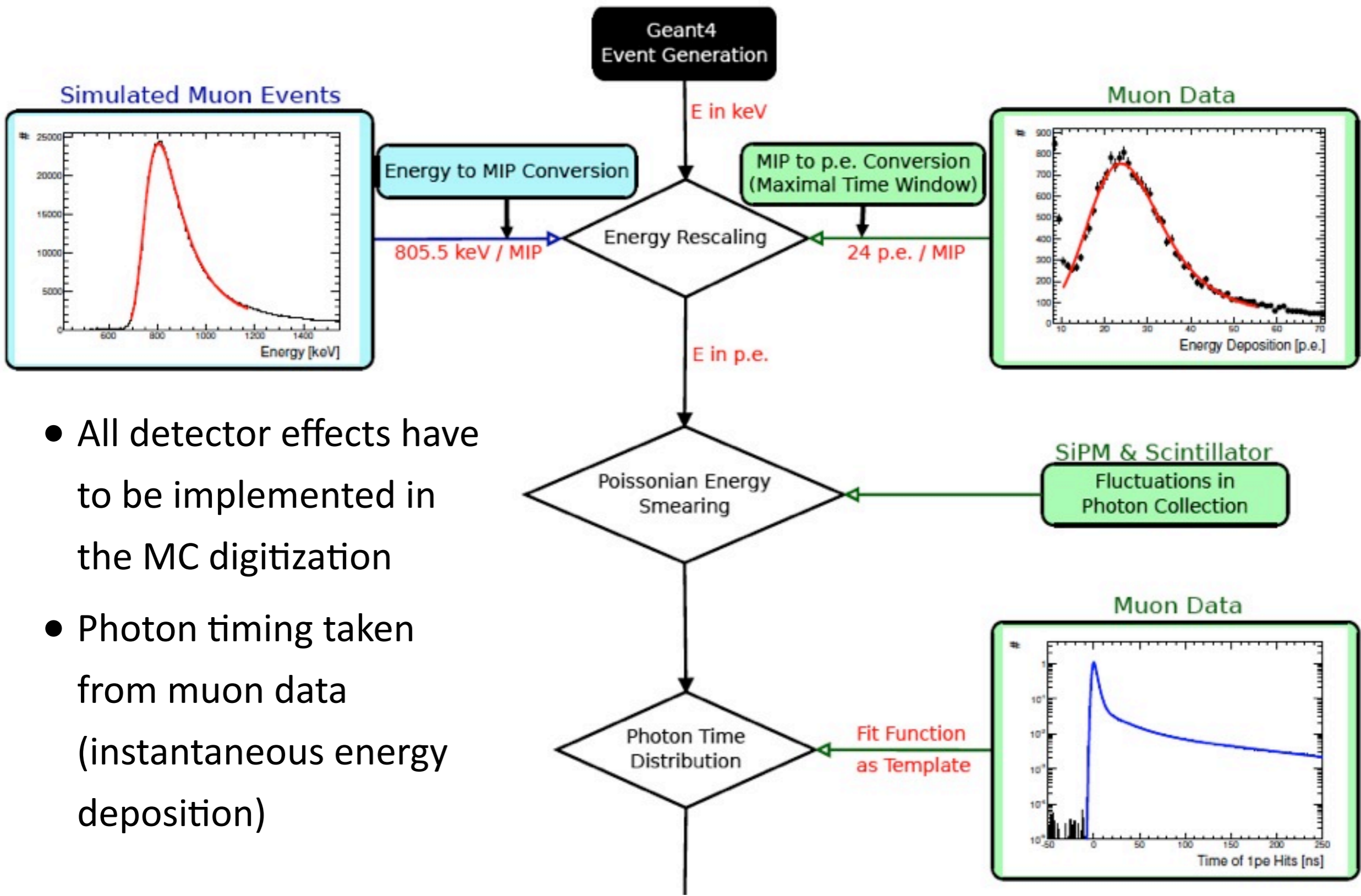
- The time of first hit is defined by the second detected photon of a pulse ( $> \sim 0.4$  MIP in 9.6 ns): Photon statistics has an influence on reconstructed time (after all, 1 MIP  $\sim 20$  p.e. , in reality lower at CERN SPS TB due to high temperature compared to CERN PS TB)
- ▶ Results in an energy-dependent time slewing - Needs to be corrected
  - ▶ done with muon runs, applied to all identified first hits in the analysis



# Calibration - Time vs Energy

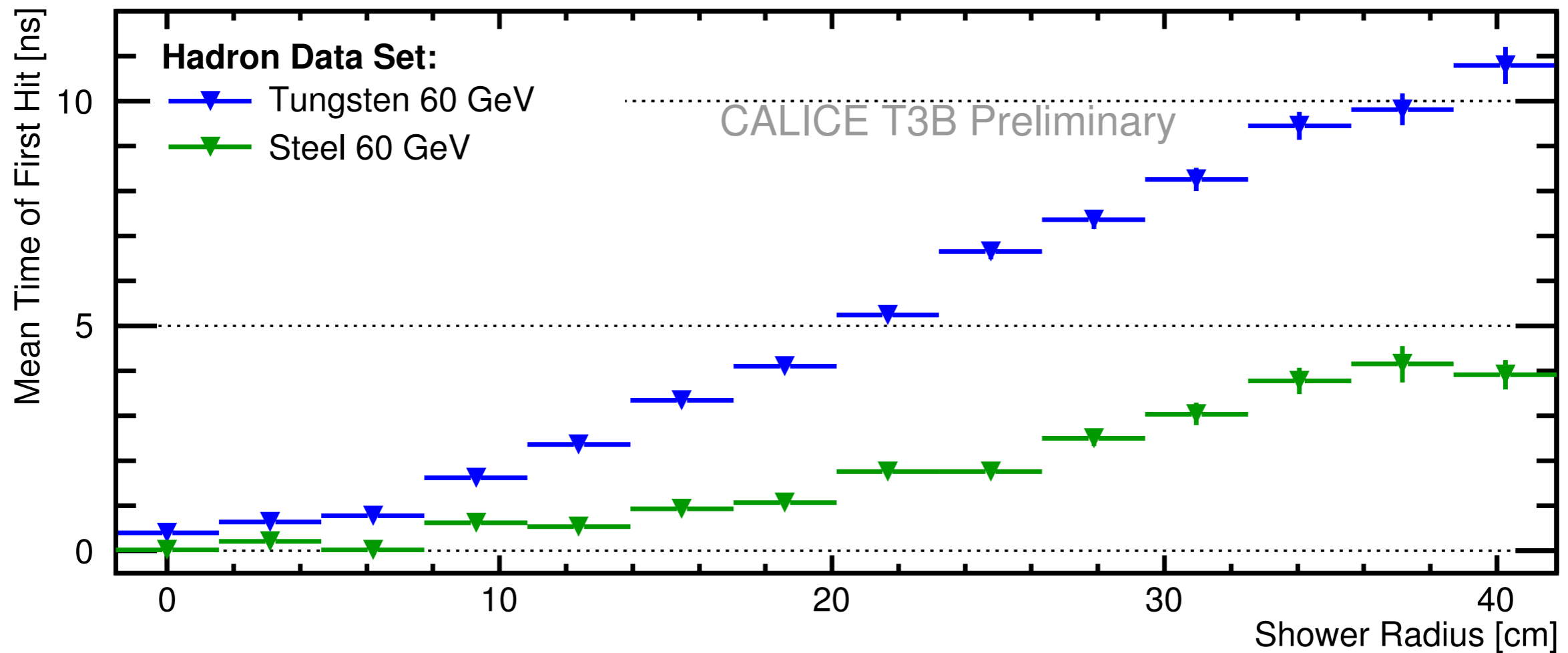
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- ▶ Results in an energy-dependent time slewing - Needs to be corrected
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- All detector effects have to be implemented in the MC digitization
- Photon timing taken from muon data (instantaneous energy deposition)

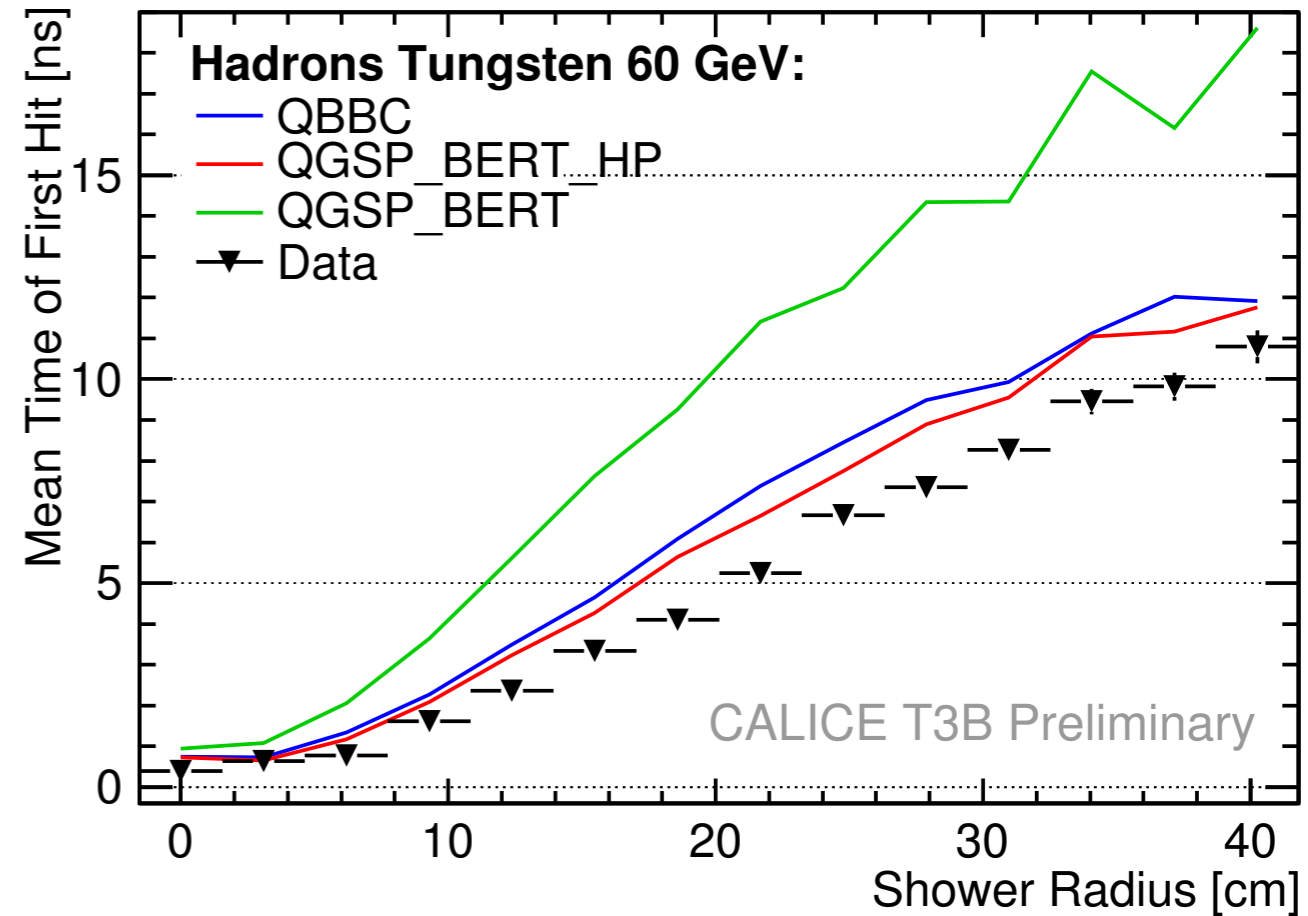
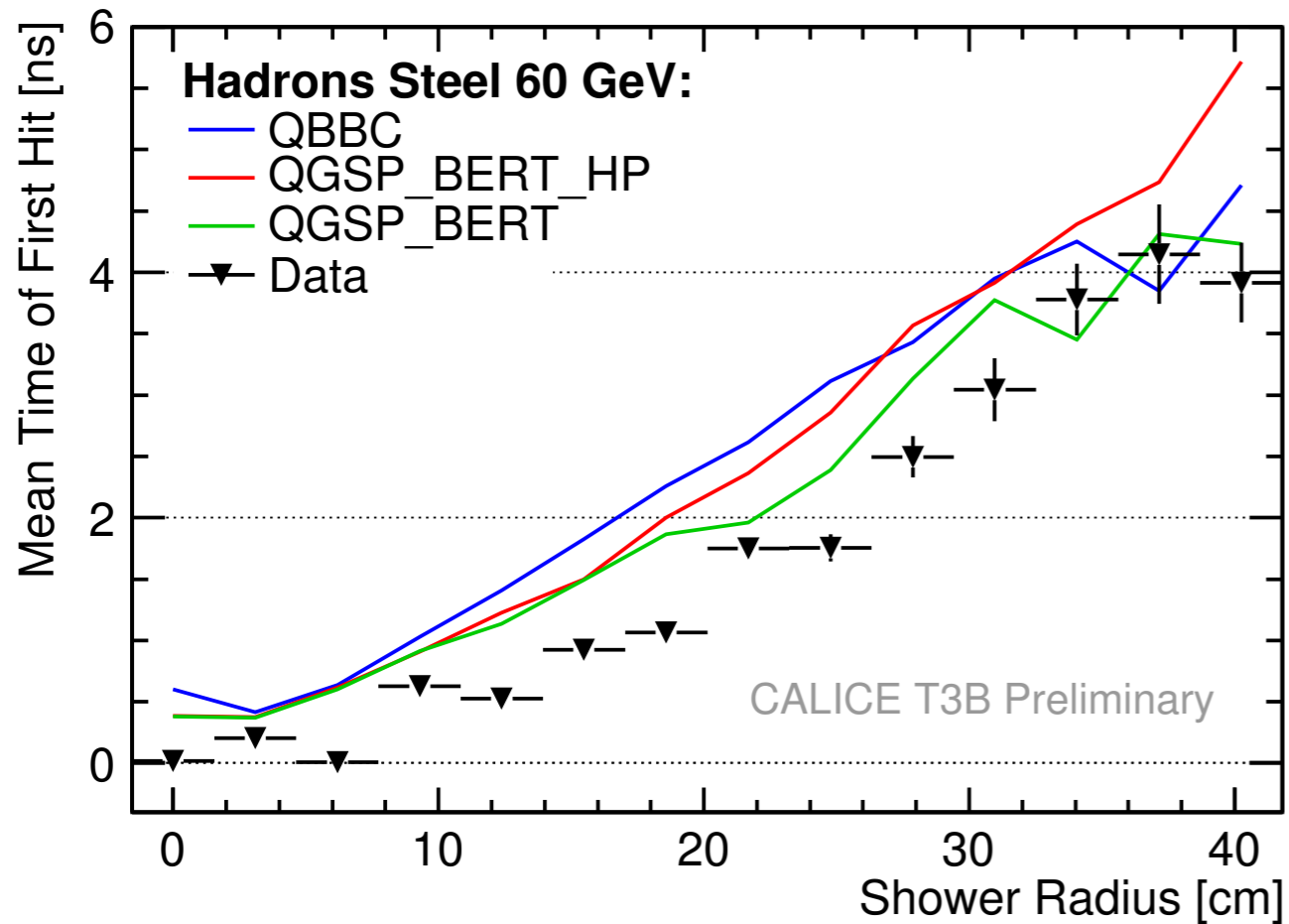
# What You get for it: Results! - One Example



- Late energy deposits are more important in the outer regions of a shower
  - More pronounced effect in tungsten than in steel

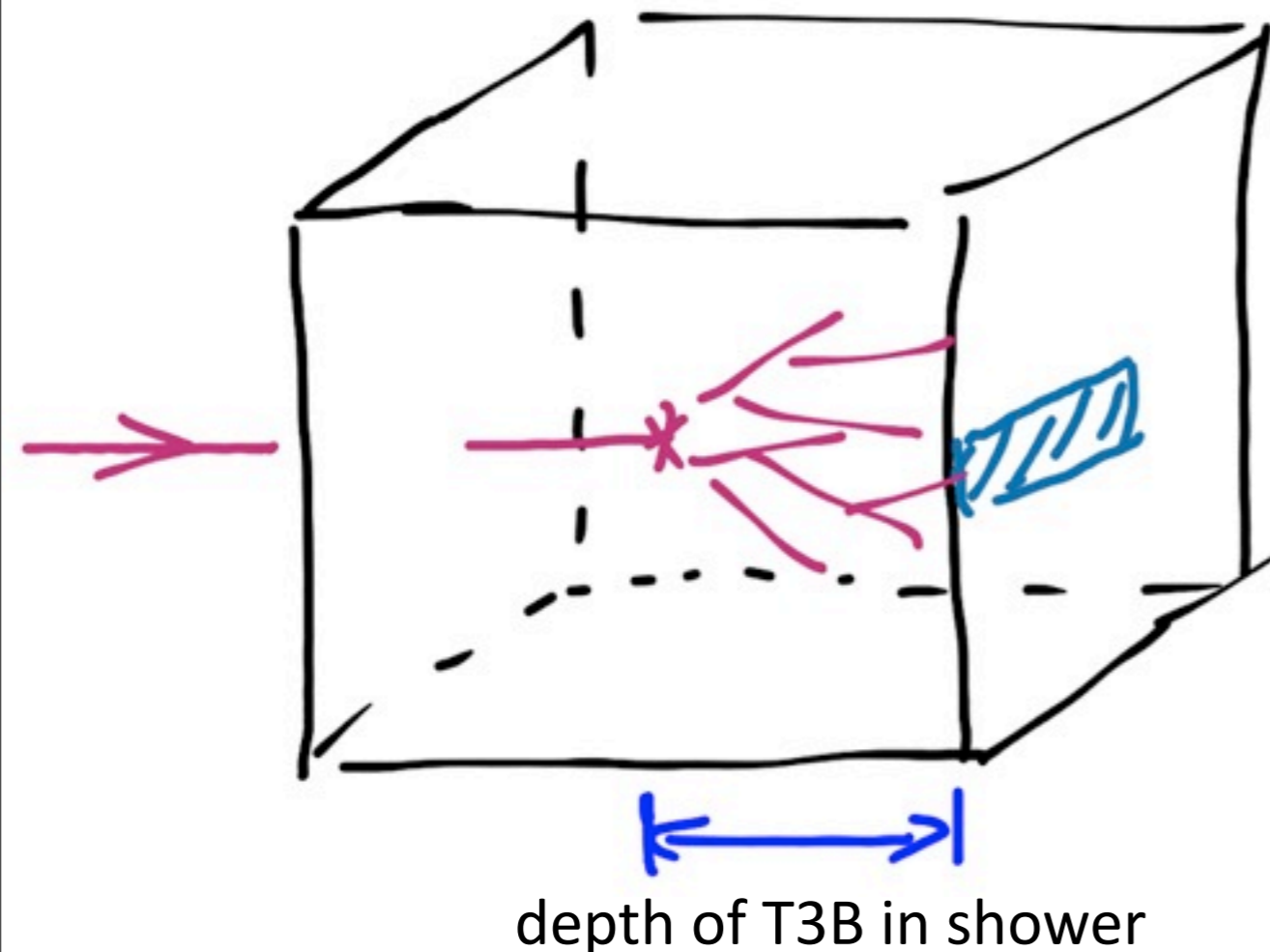


# What You get for it: Results! - One Example



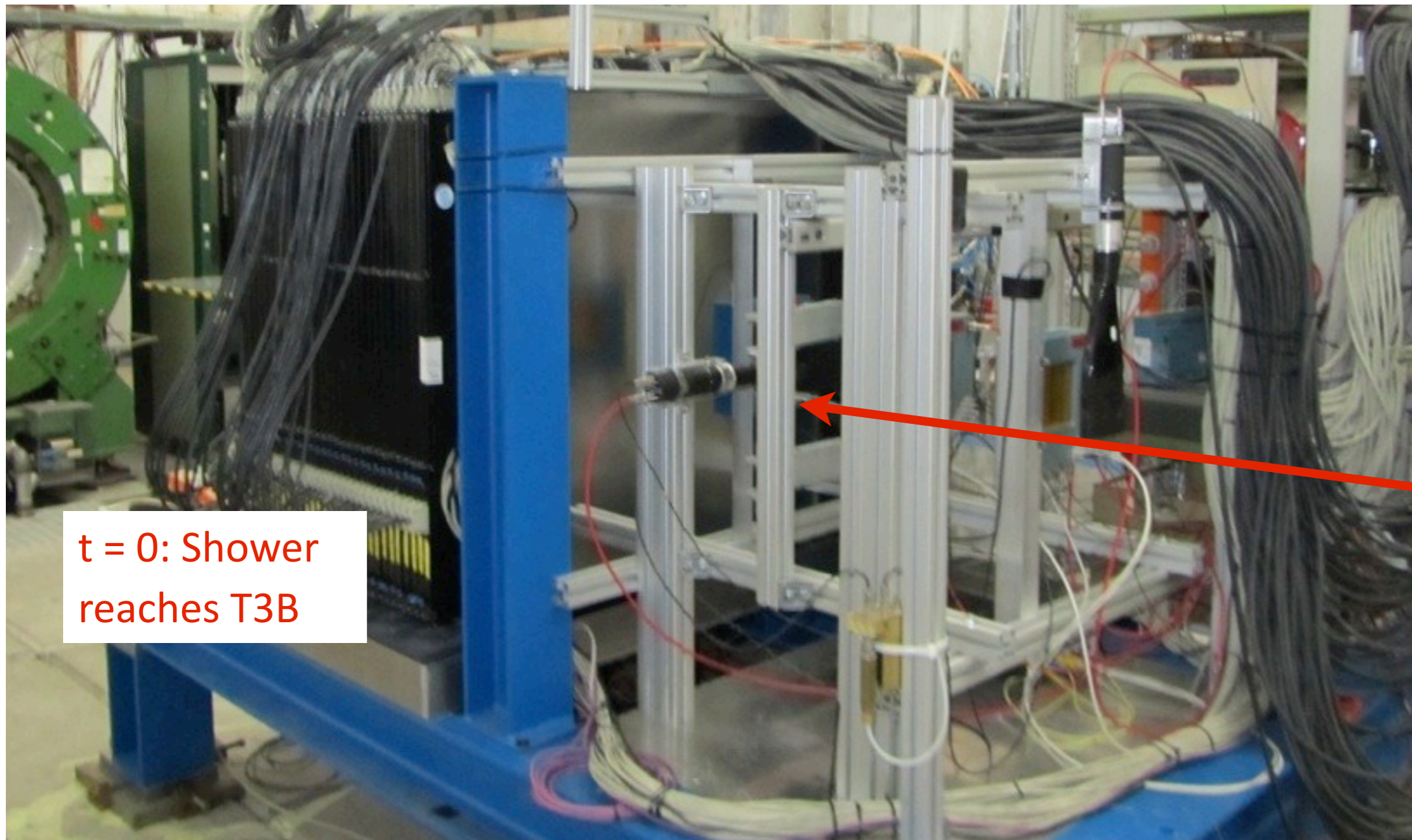
- Late energy deposits are more important in the outer regions of a shower
  - More pronounced effect in tungsten than in steel
- In steel: Good description by all physics lists (on the level of a few 100 ps)
- In tungsten: Neutrons are of key importance - only QGSP\_BERT\_HP and QBBC provide a good prediction





- Correlate T3B and WAHCAL events:  
Event-wise shower start information
- Split data set (identified first hits) into 3D - histogram:
  - radial position: T3B cell id
  - longitudinal depth in shower:  
distance of shower start and T3B  
(the number of events in the shower start bins is used as normalization basis: gets longitudinal profile right!)
  - time: measured time of first hit,  
corrected for speed of light  
propagation from shower start to T3B

# The Making Of: The Movie



$t = 0$ : Shower reaches T3B

60 GeV  
pion



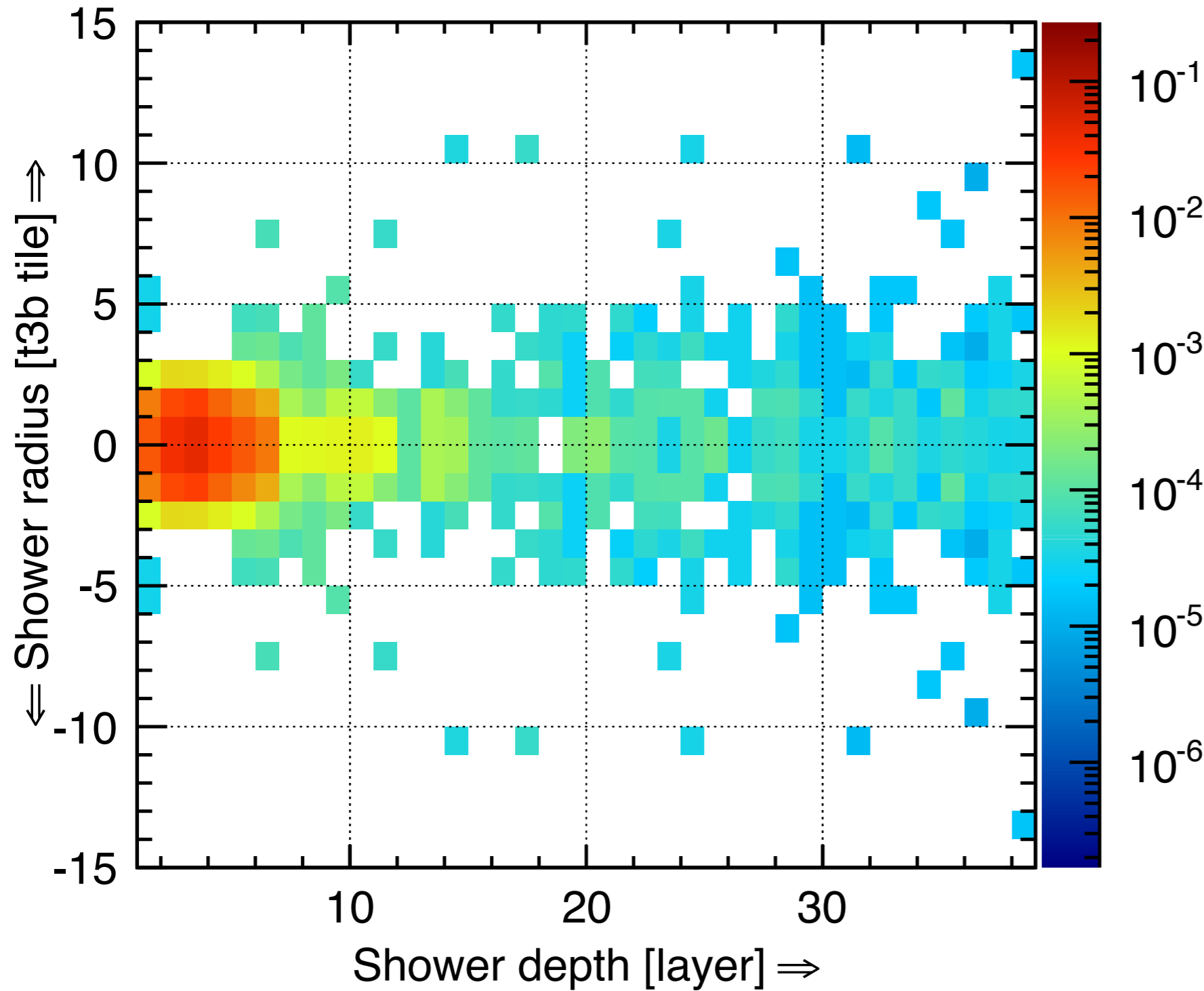


# The Movie: The Life of a Pion in the WAHCAL



Shower @ -8 to -6 ns

CALICE T3B Data



T = 0: Activity maximum in layer 39 (rear of calorimeter)

Shown: First hits in each cell only

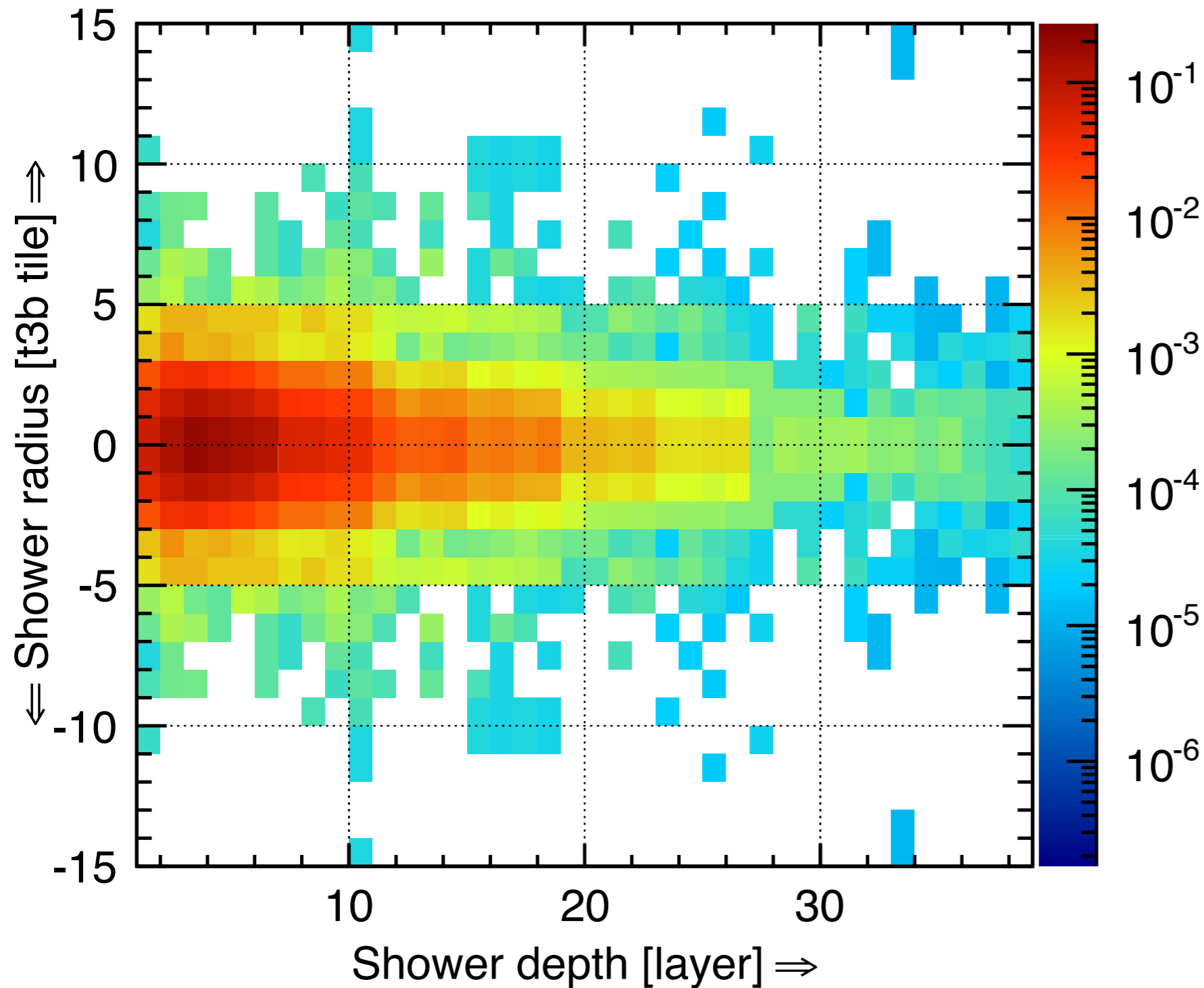


# The Movie: The Life of a Pion in the WAHCAL



Shower @ -6 to -4 ns

CALICE T3B Data



T = 0: Activity maximum in layer 39 (rear of calorimeter)

Shown: First hits in each cell only

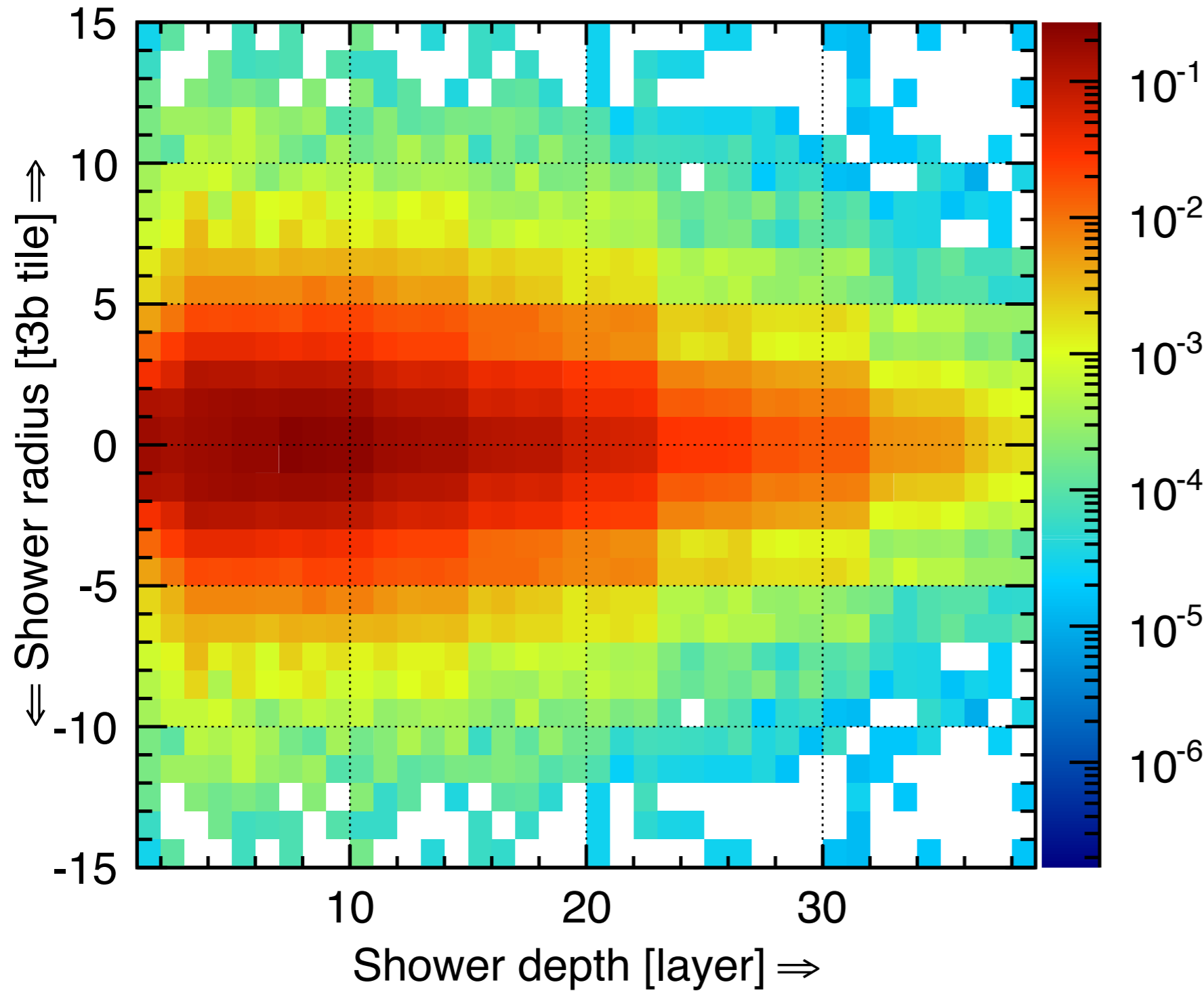


# The Movie: The Life of a Pion in the WAHCAL



Shower @ -4 to -2 ns

CALICE T3B Data



T = 0: Activity maximum in layer 39 (rear of calorimeter)

Shown: First hits in each cell only

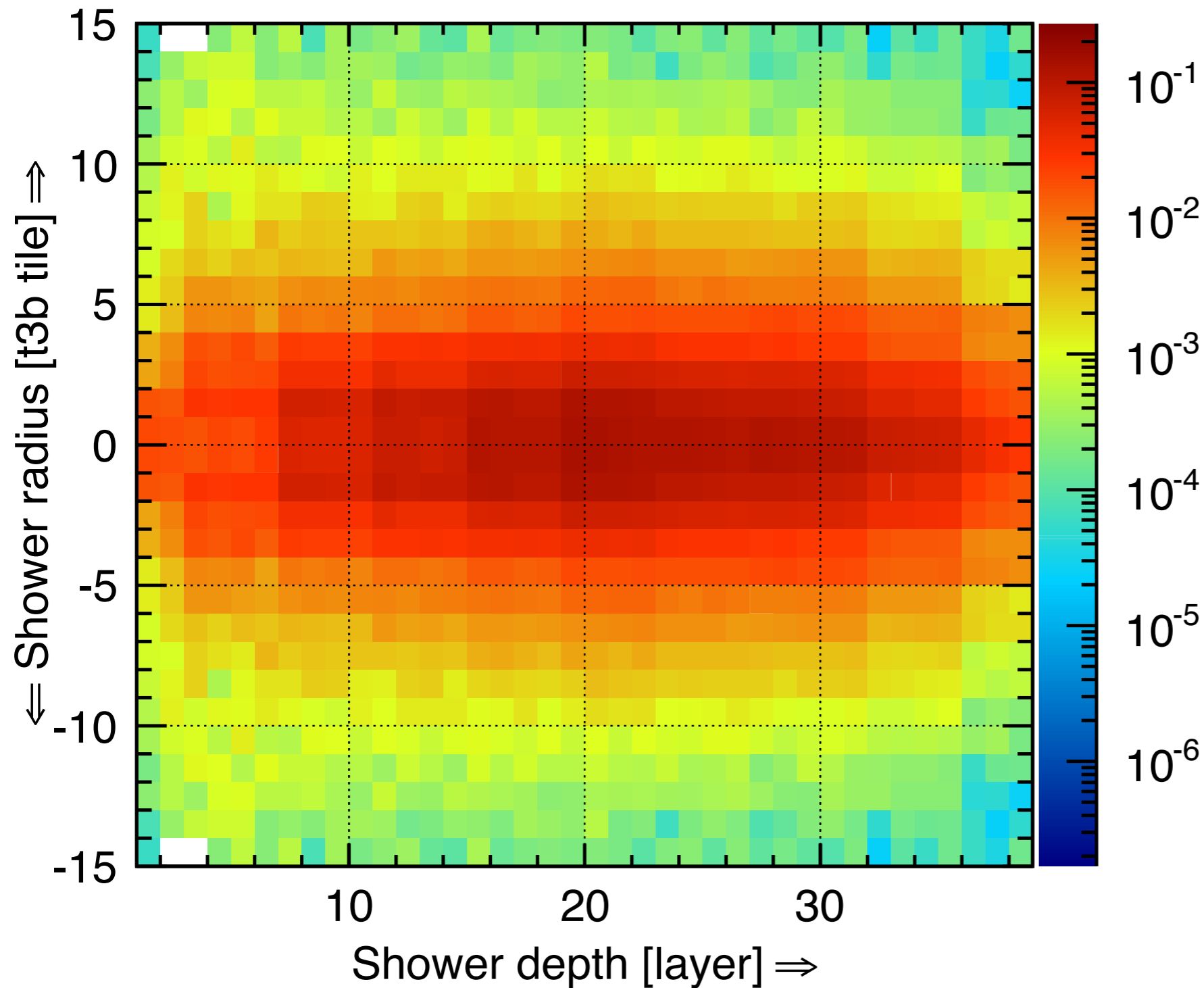


# The Movie: The Life of a Pion in the WAHCAL



Shower @ -2 to 0 ns

CALICE T3B Data



T = 0: Activity maximum in layer 39 (rear of calorimeter)

Shown: First hits in each cell only

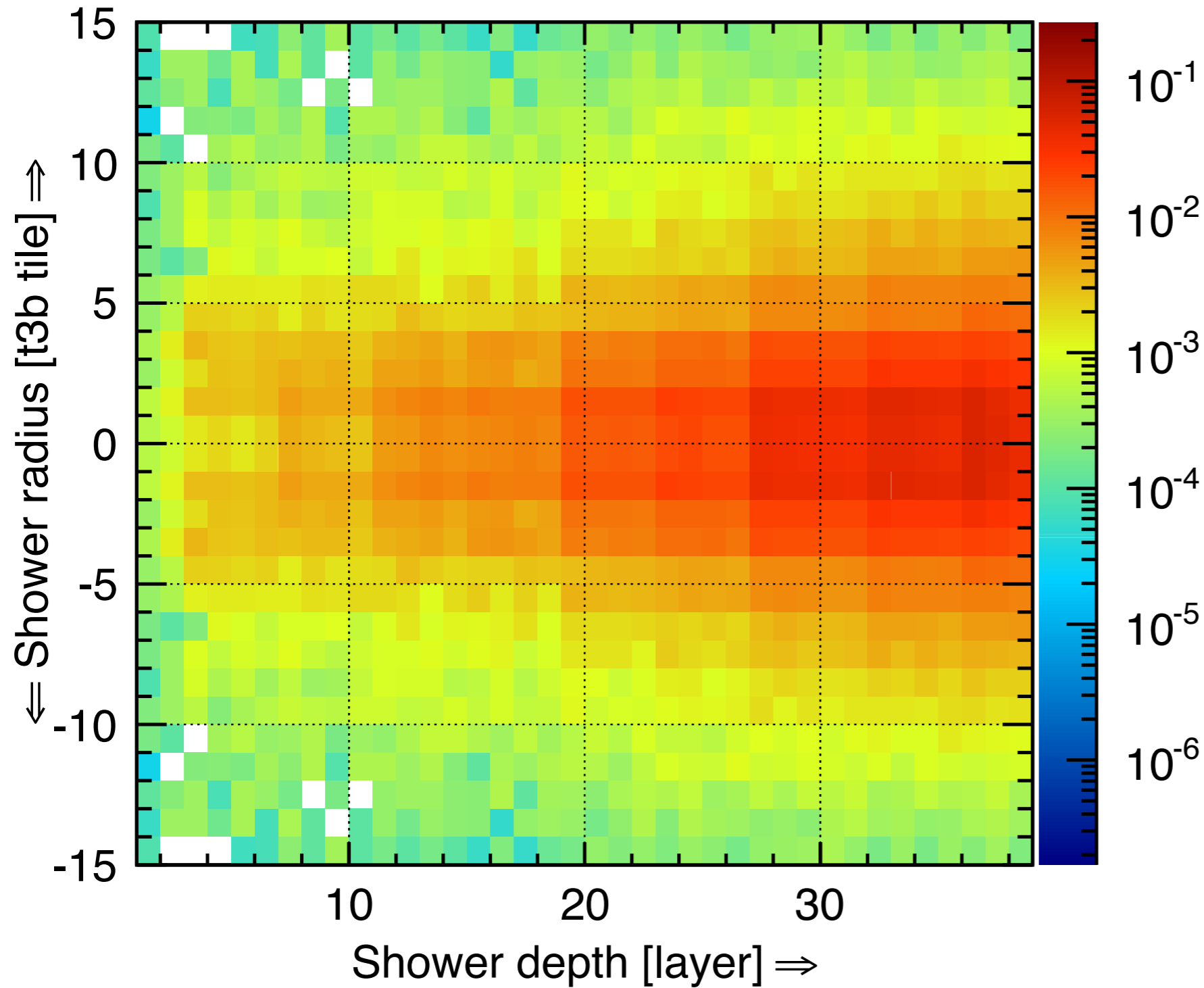


# The Movie: The Life of a Pion in the WAHCAL



Shower @ 0 to 2 ns

CALICE T3B Data



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only

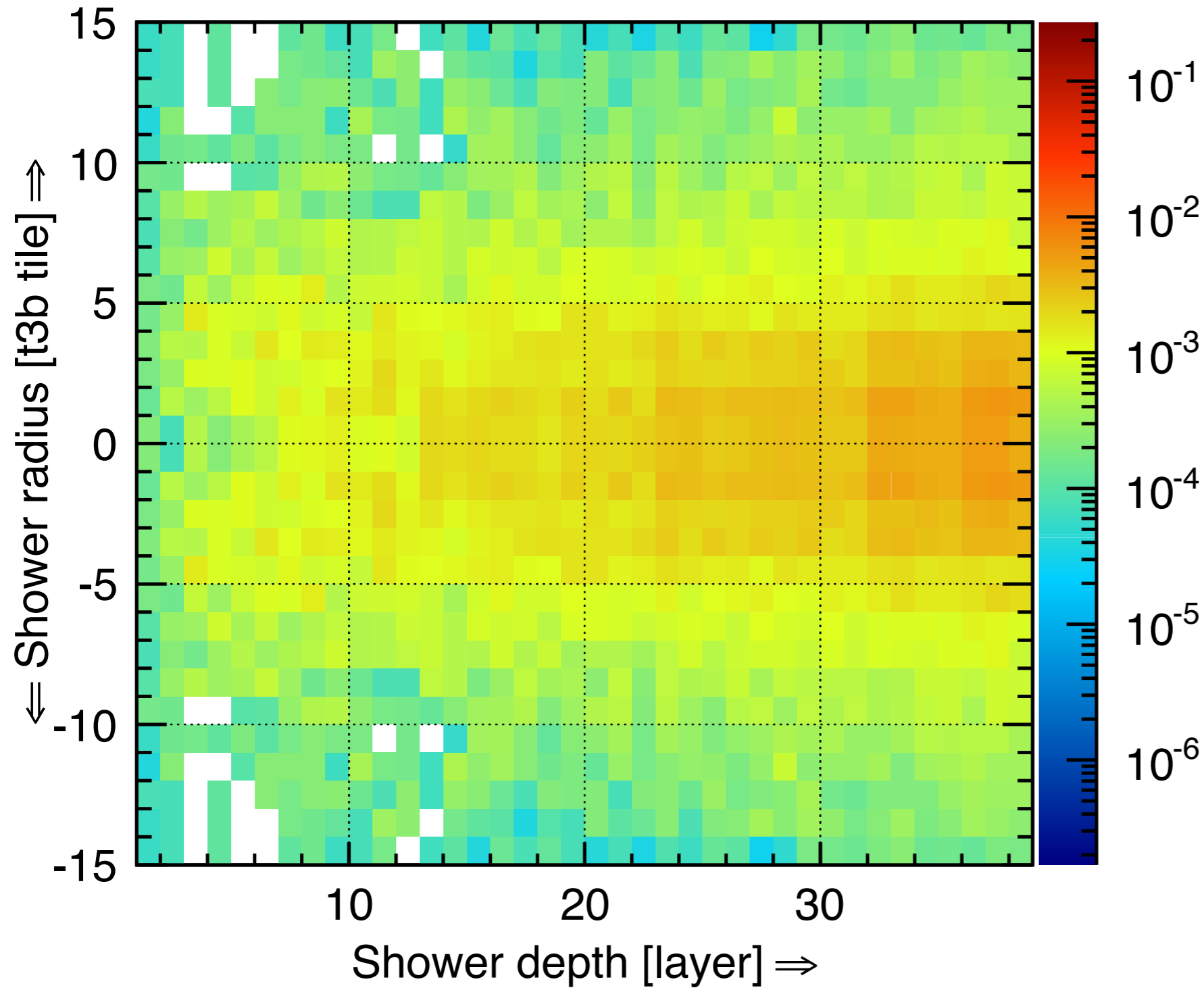


# The Movie: The Life of a Pion in the WAHCAL



Shower @ 2 to 4 ns

CALICE T3B Data



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only

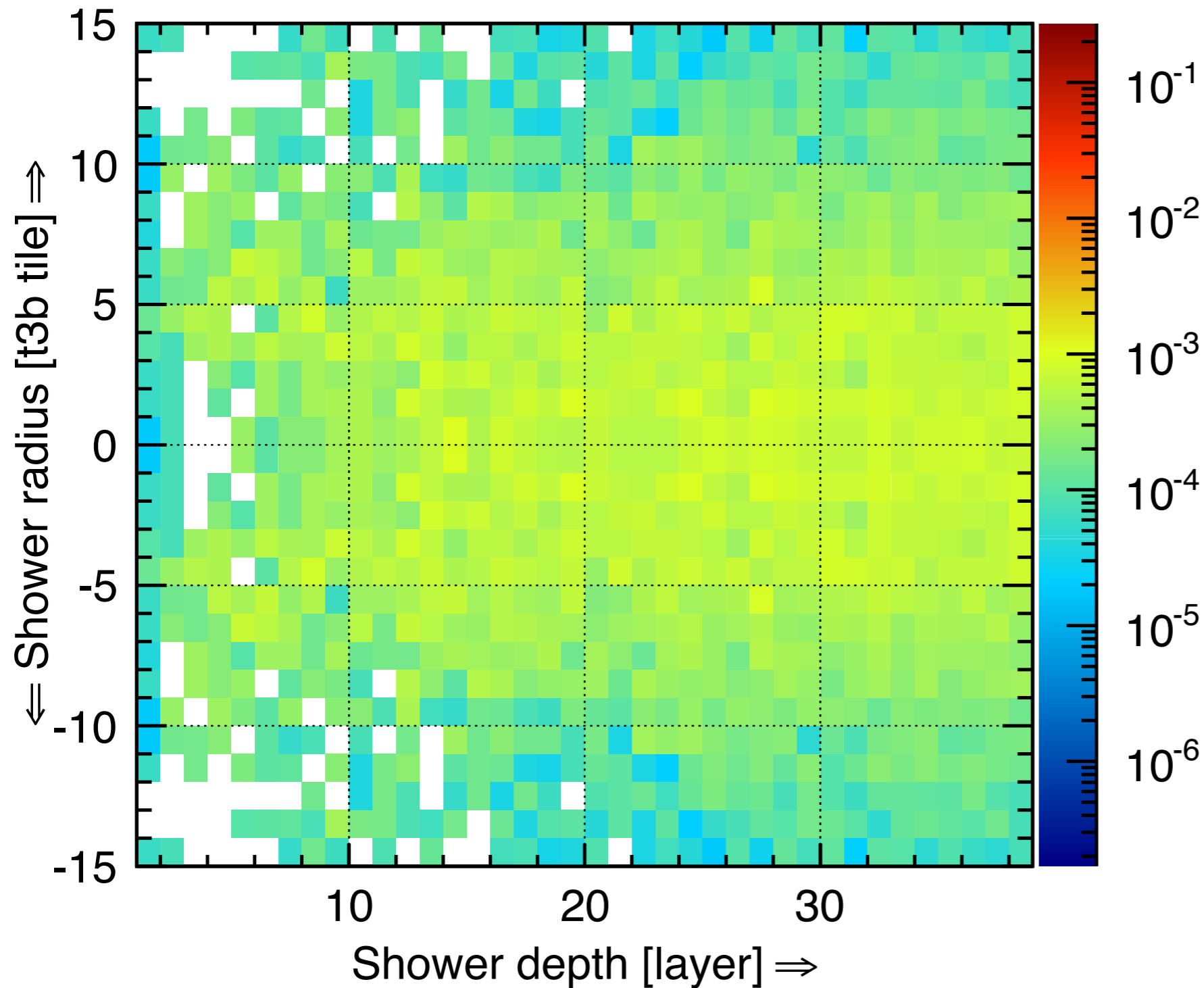


# The Movie: The Life of a Pion in the WAHCAL



Shower @ 6 to 8 ns

CALICE T3B Data



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only

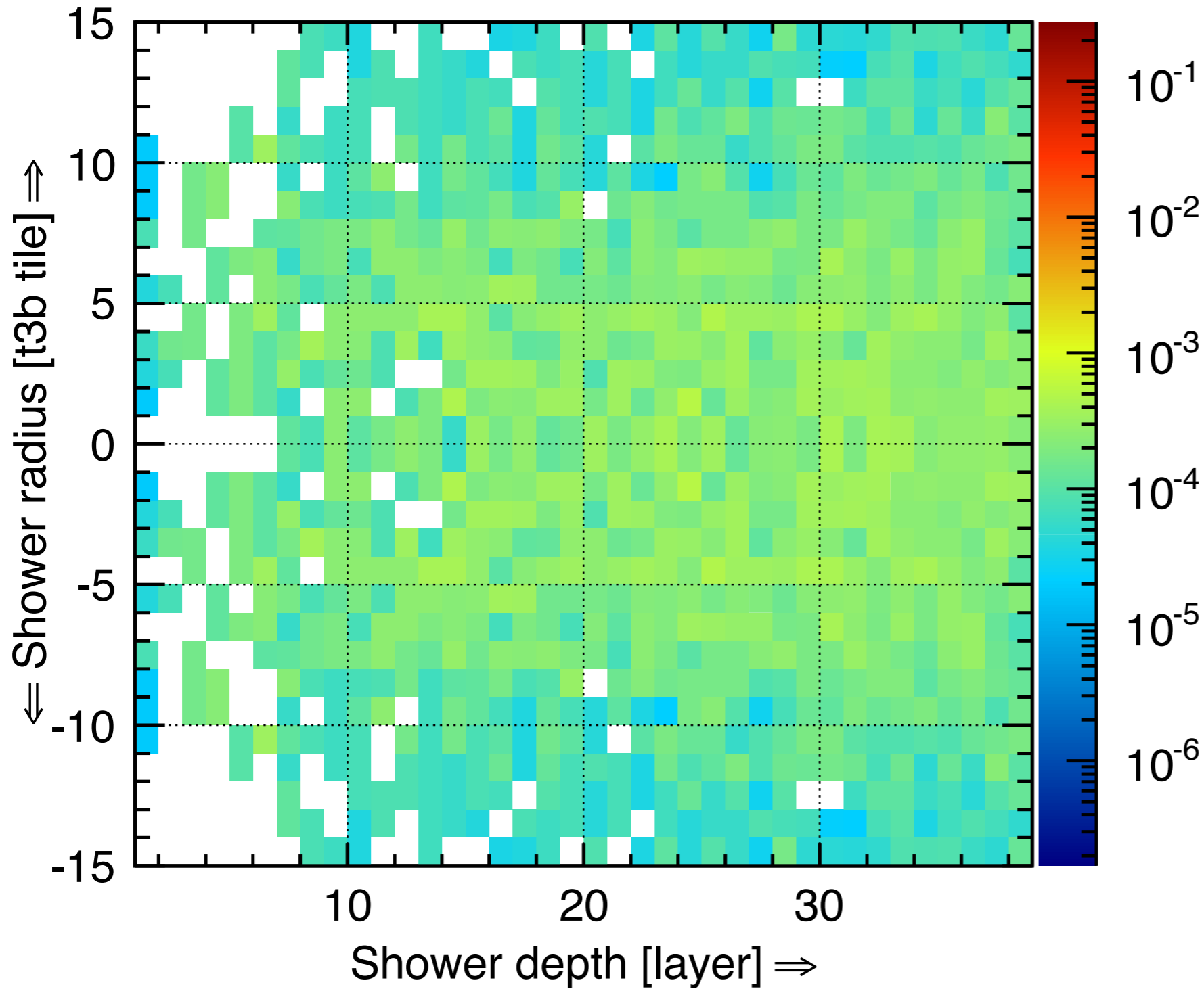


# The Movie: The Life of a Pion in the WAHCAL



**Shower @ 10 to 12 ns**

*CALICE T3B Data*



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only



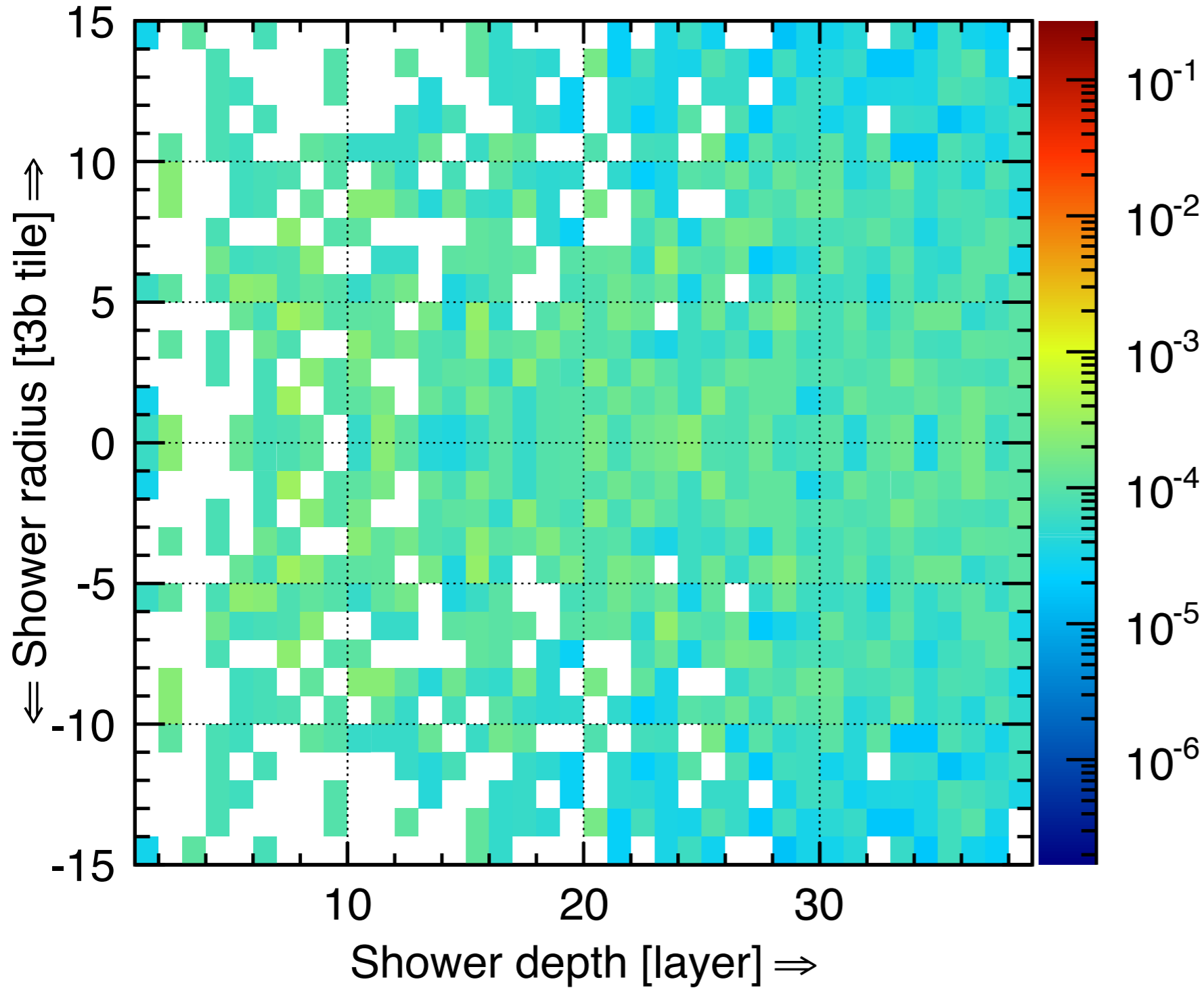


# The Movie: The Life of a Pion in the WAHCAL



**Shower @ 16 to 18 ns**

*CALICE T3B Data*



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only

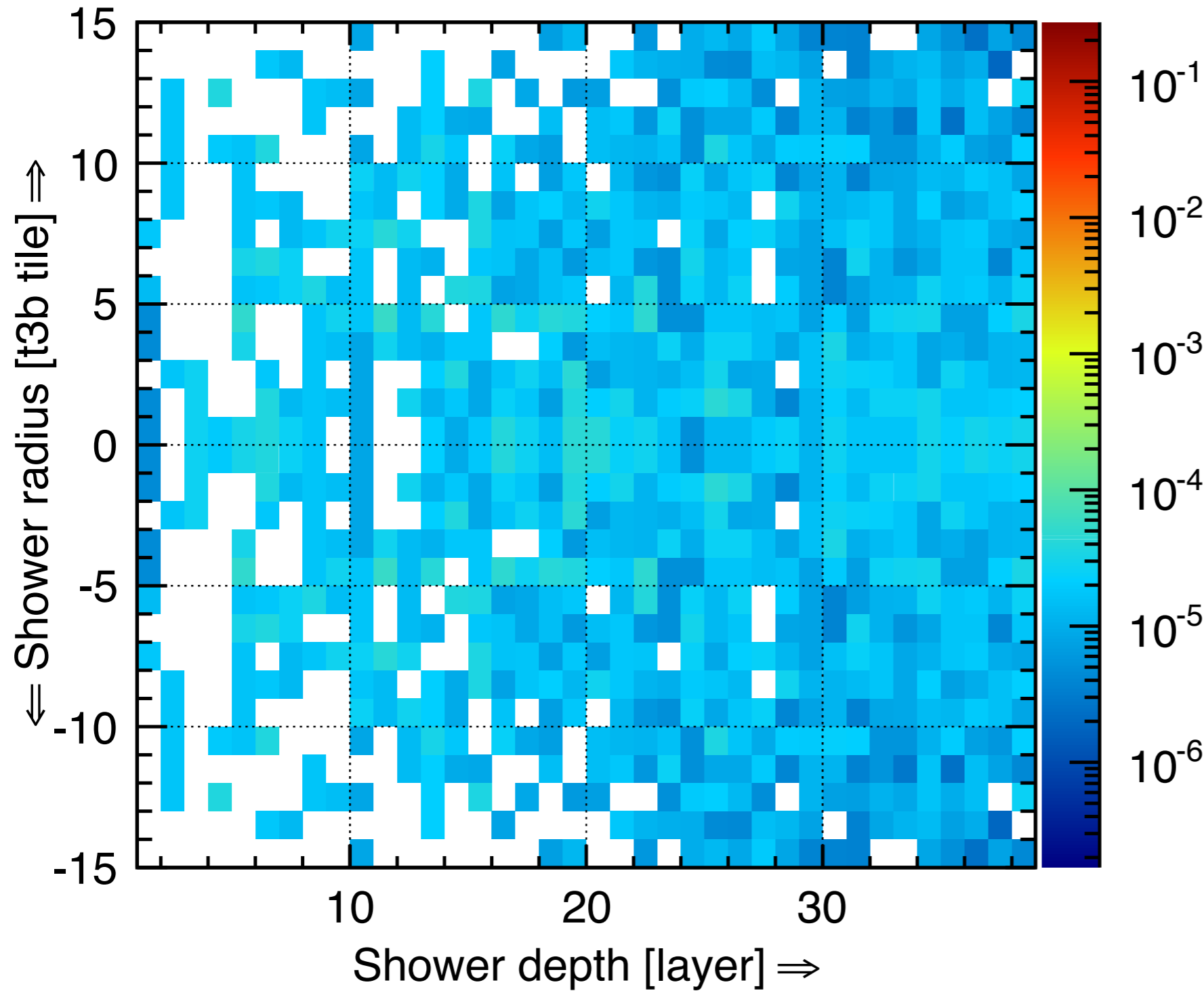


# The Movie: The Life of a Pion in the WAHCAL



Shower @ 30 to 40 ns

CALICE T3B Data



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only

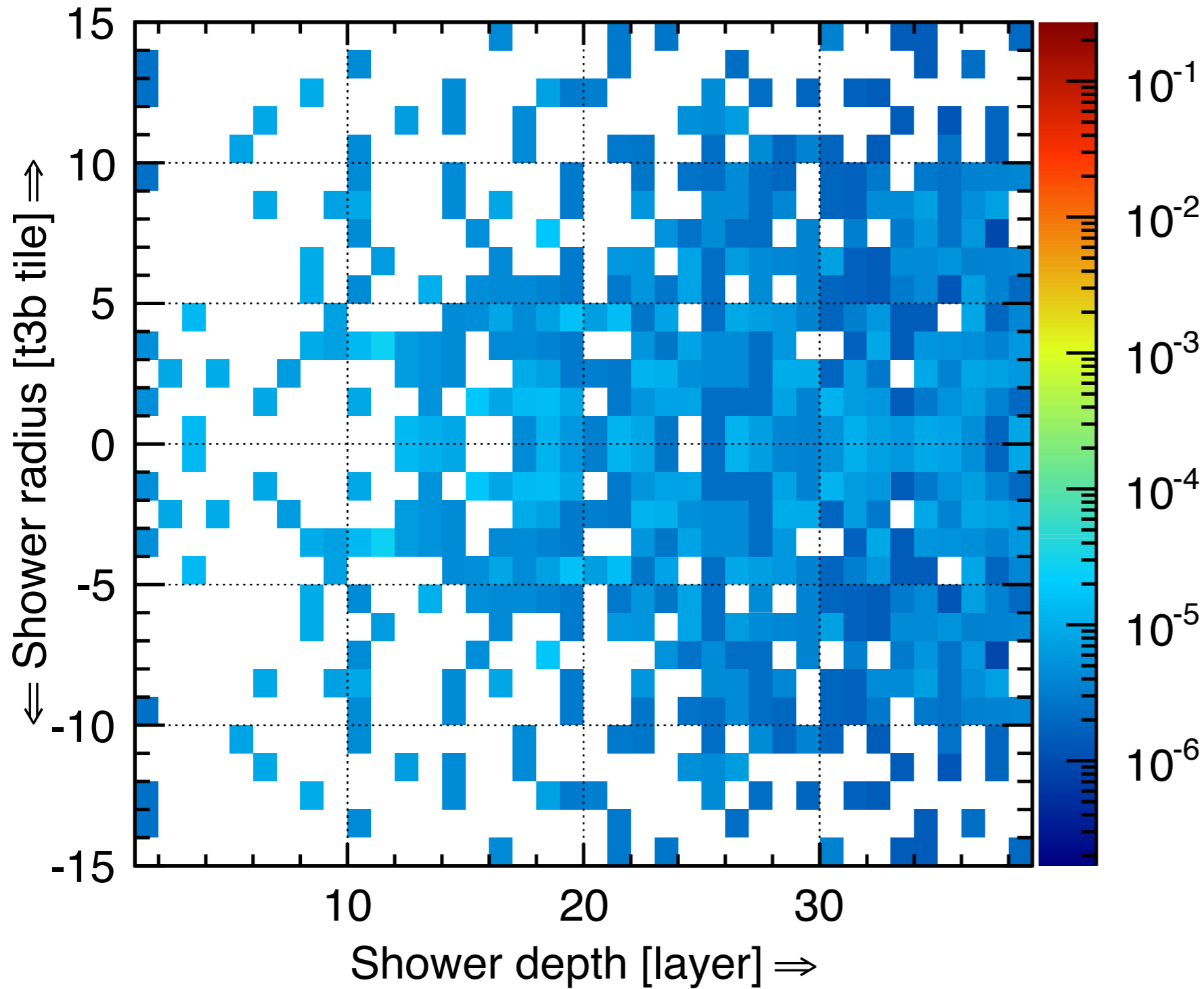


# The Movie: The Life of a Pion in the WAHCAL



Shower @ 60 to 80 ns

CALICE T3B Data



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only

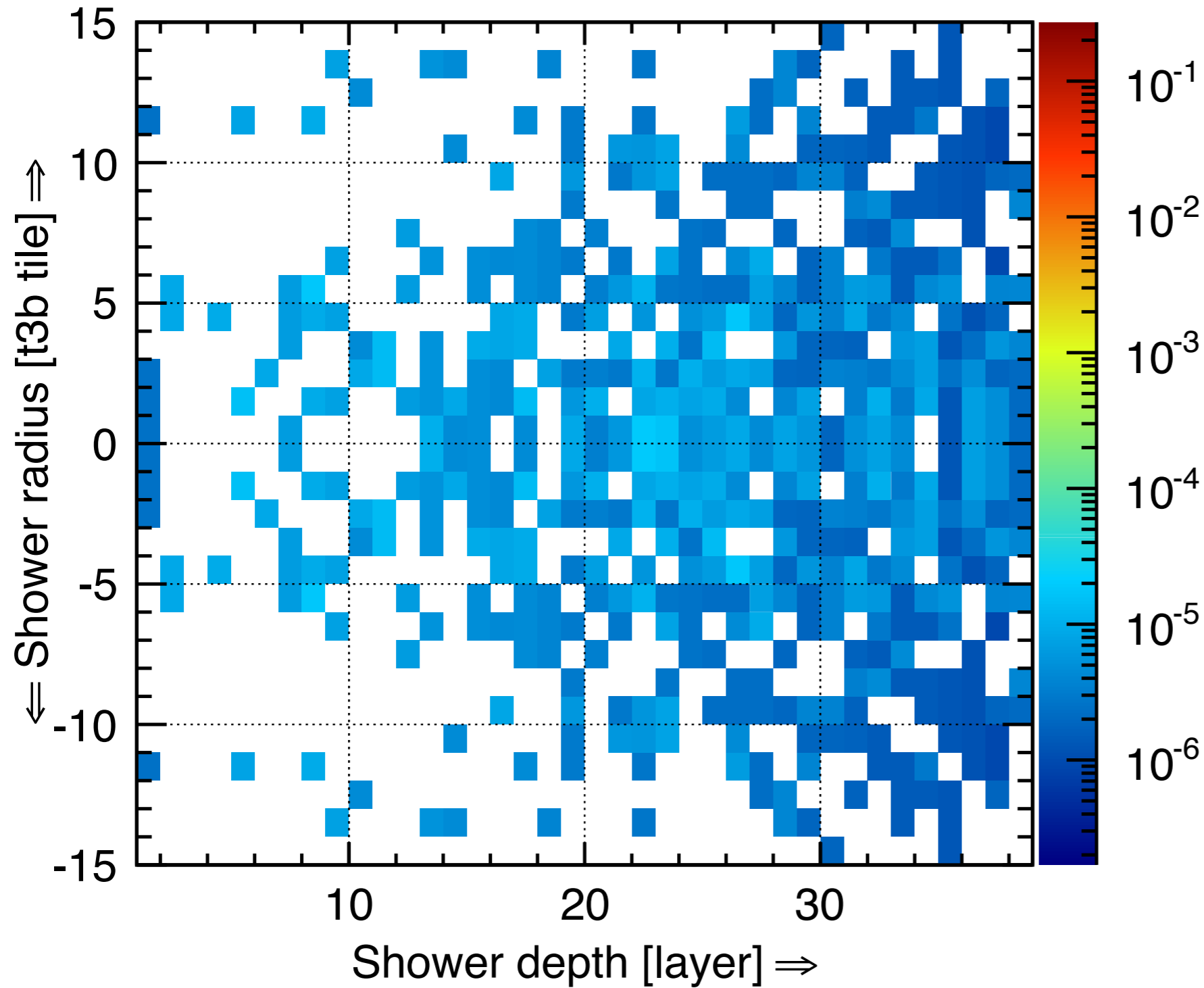


# The Movie: The Life of a Pion in the WAHCAL



**Shower @ 80 to 100 ns**

*CALICE T3B Data*



T = 0: Activity  
maximum in layer 39  
(rear of calorimeter)

Shown: First hits in  
each cell only

