Stony Brook University

Tuning fiTQun

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Introduction

- fiTQun was originally written and tuned for Super-K and SKDETSIM

- It has been updated to run on WCSim
  - We can now run on nuPRISM, Hyper-K, …

- Need to **tune** reconstruction parameters for each detector configuration
  - Photosensor response, geometry
  - Detector geometry

- The tuning procedures have been adapted to WCSim
  - Several modifications required which will be condensed into `nuPRISM/WCSim`
  - Work in progress: first attempt at full retune this week!

FiTQun reminder

$$\mathcal{L}(\mathbf{x}) = \prod_{i_{unhit}} P(unhit \mid \mathbf{x}) \prod_{i_{hit}} P(hit \mid \mathbf{x}) f_q(q_i \mid \mathbf{x}) f_t(t_i \mid \mathbf{x})$$

- Maximum $\mathcal{L}$ gives best estimate of track parameters $\mathbf{x}$:
  - Particle type, momentum, direction, vertex position and time

- For a given hypothesis $\mathbf{x}$, charge (f_q) and time (f_t) probability distributions are generated for each photosensor in the detector
  - f_t is determined by the photosensor and associated electronics' response, particle type and kinematics
  - f_q depends on:
    - μ, the predicted number of photons arriving at the photosensor (both **direct** and **scattered or reflected**)
    - response of the photosensor + electronics

FiTQun reminder

- The predicted charge from direct light is given by:

Light yield — Cherenkov emission profile — PMT angular response

$$\mu = \Phi(p) \int ds \; g(s, cos(\theta)) \, \Omega(R) \, T(R) \, \epsilon(\eta)$$

Integral over track length — PMT solid angle — Water attenuation

- Lookup tables are used for scattered and reflected light

Components to be tuned

- In `fiTQun/const`:
  - Scattered light tables
  - PMT charge response
  - Time PDFs

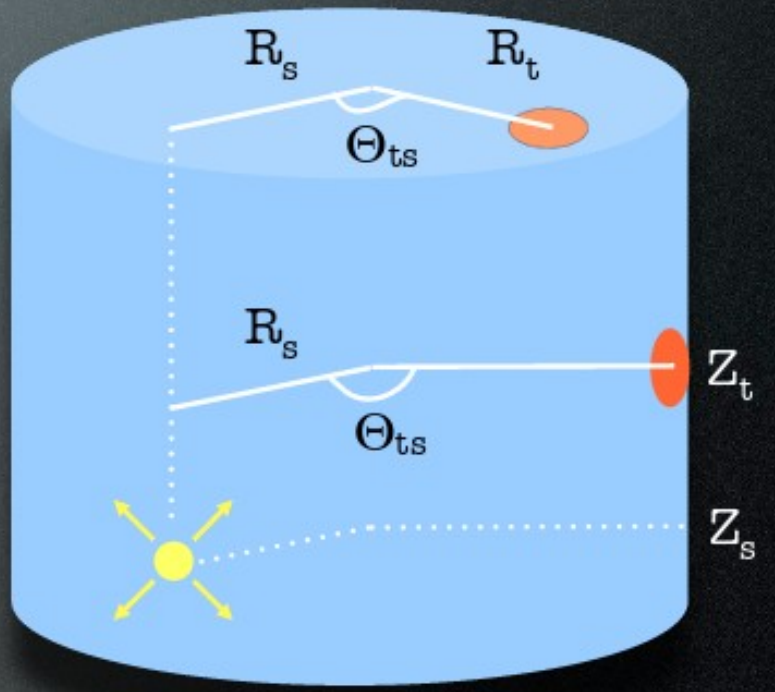
- Parameters in `parameters.dat`:
  - Water attenuation length
  - PMT quantum efficiency

- Hardcoded in `fiTQun.cc` (to be changed!):
  - PMT angular response

Scattered light tables

Scattering Tables

- Take advantage of **cylindrical geometry**
- A_{scat} will depend on
  - Source direction (θ_s, ϕ_s)
  - Source position (Θ_{ts}, R_s, Z_s)
  - Z_t for PMTs on the sides
    - $A_{side}(\theta_s, \phi_s, \Theta_{ts}, R_s, Z_s, Z_t)$
  - R_t for PMTs on the ends
    - $A_{end}(\theta_s, \phi_s, \Theta_{ts}, R_s, Z_s, R_t)$
- Must tabulate 6-dimensional scattering tables using the detector MC



Mike @ Hyper-K 5th

Scattered light tables

- WCSim modification by Blair allows for the optical photon history to be stored
  - `/opInfo/Enabled true`
- Generate 1 billion 3 MeV electrons all over the detector with randomized directions
- Use photons which have scattered/reflected and made a hit to build tables

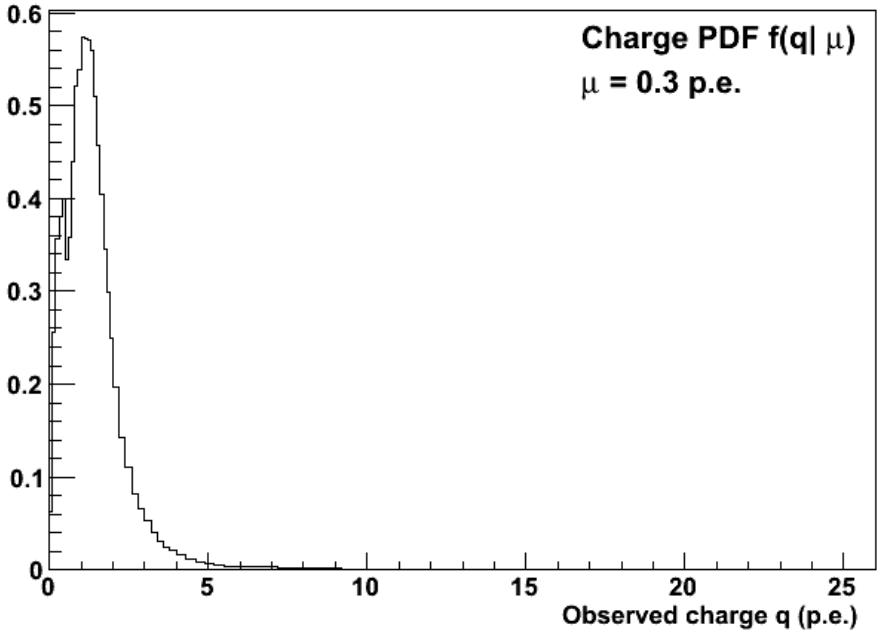
Photosensor charge response

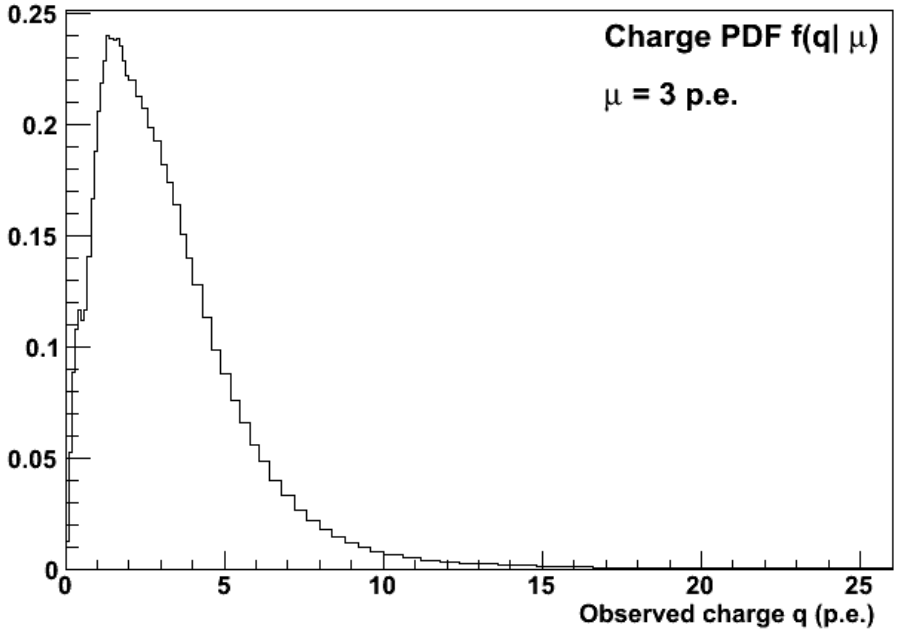
- I have modified `WCSim` by adding an option which will add to each of the PMTs in the detector a number of photoelectrons distributed according to a Poisson distribution with a mean μ:
  - `/mygen/pmtPoisson true`
  - `/mygen/poissonMean 5`
    - Used with dummy primary particles (*e.g.*, below Cherenkov threshold) and with the dark rate set to zero

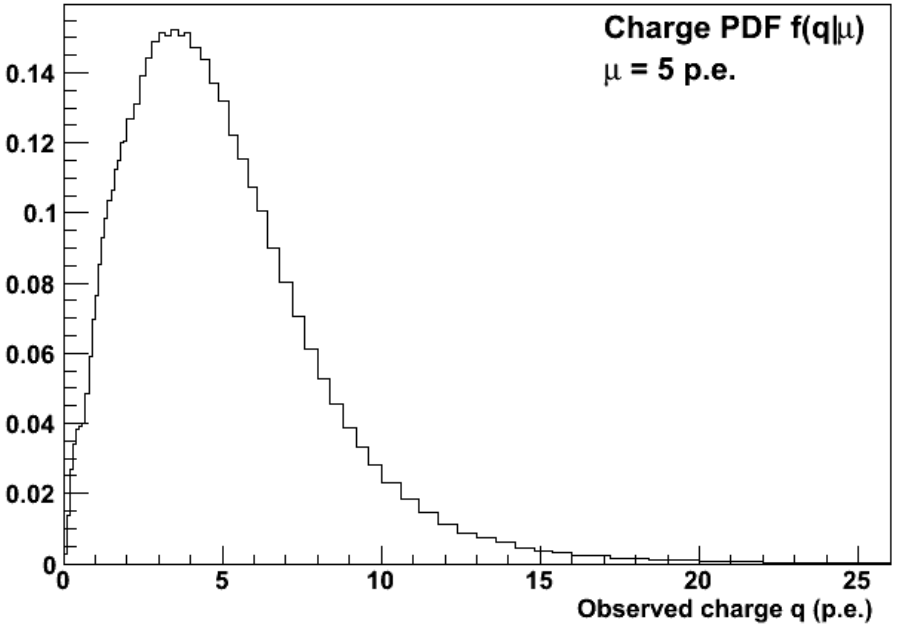
- The PMT charge response (probability distribution, P_{hit}, P_{unhit}) for a given μ can be obtained by reading out the digitised charge in the standard `WCSim` output

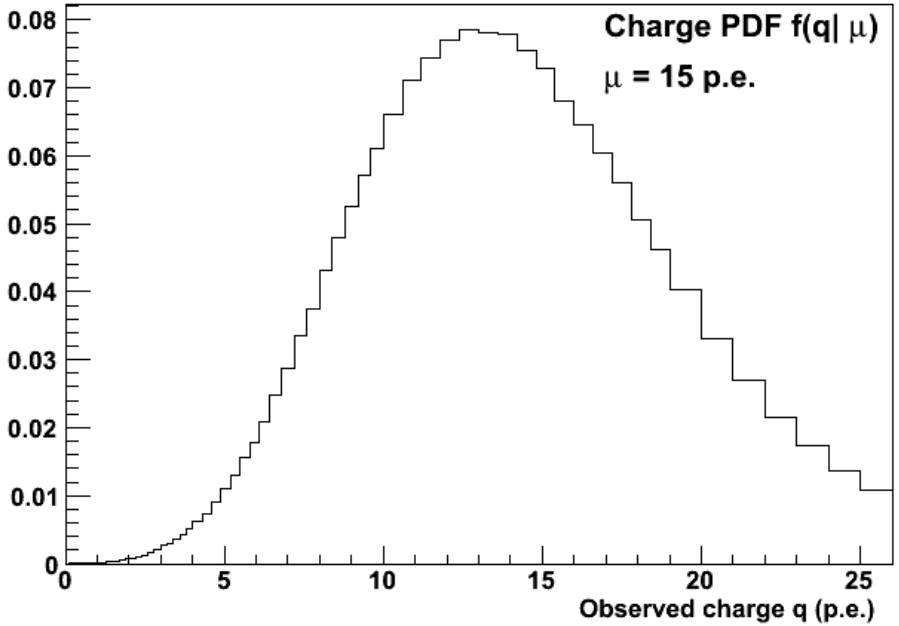
- This method treats photosensors as black-boxes and should work even if the digitisation procedures are changed significantly

Photosensor charge response

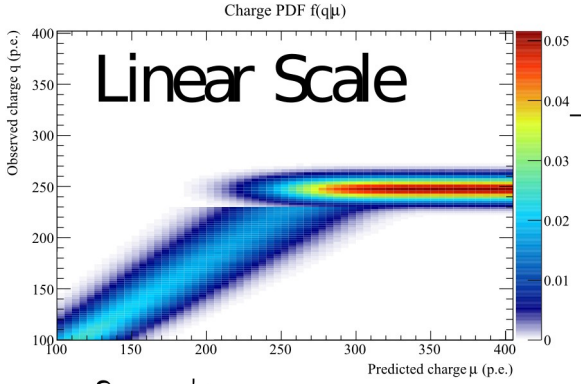




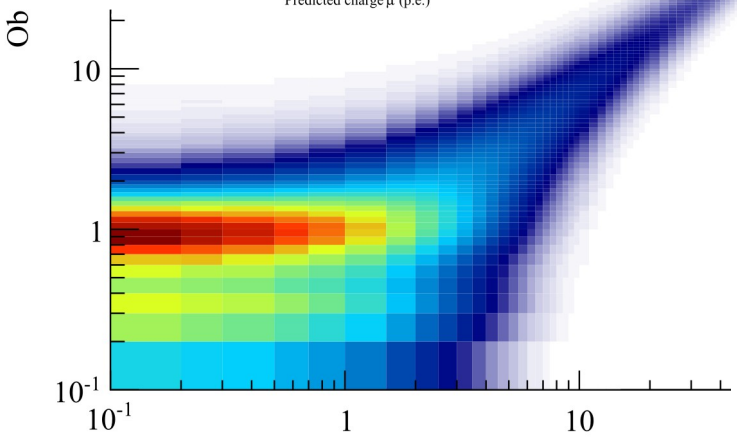




Photosensor charge response



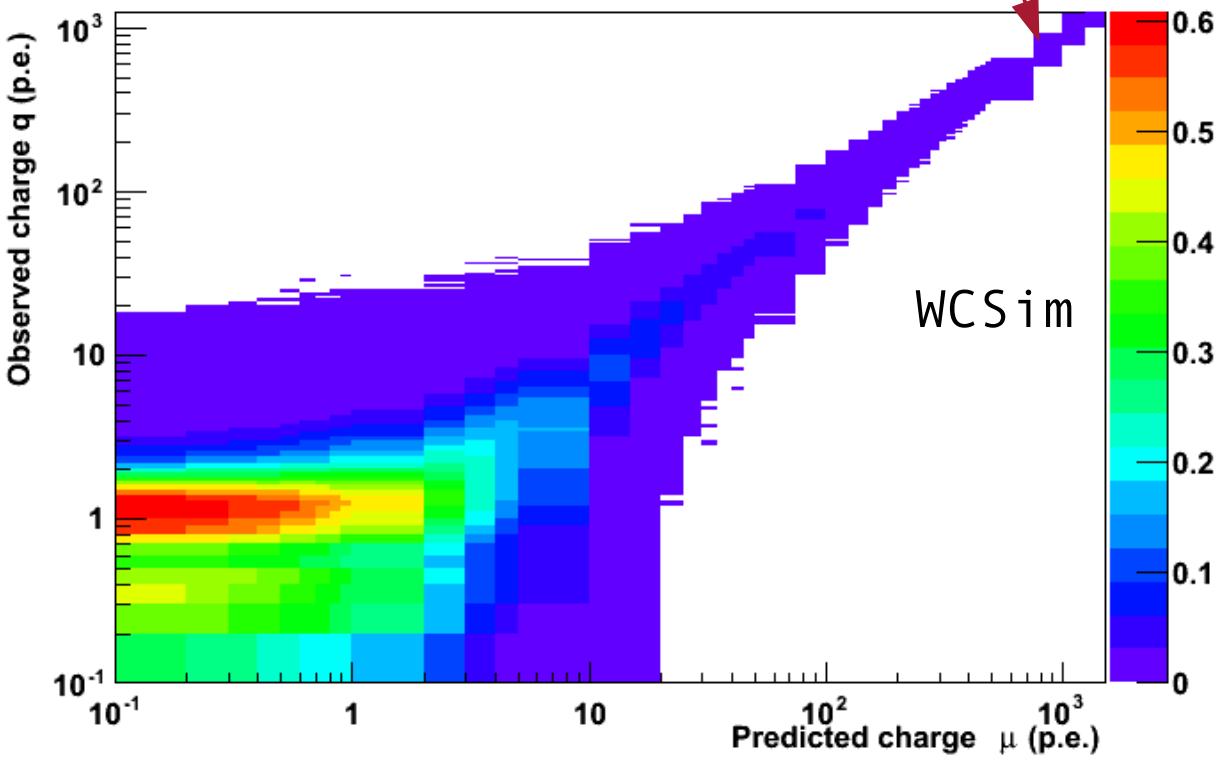
SK1



SKDETSIM
S. Tobayama

No saturation in WCSim

Discontinuity due to how ATM saturation is simulated in SKDETSIM

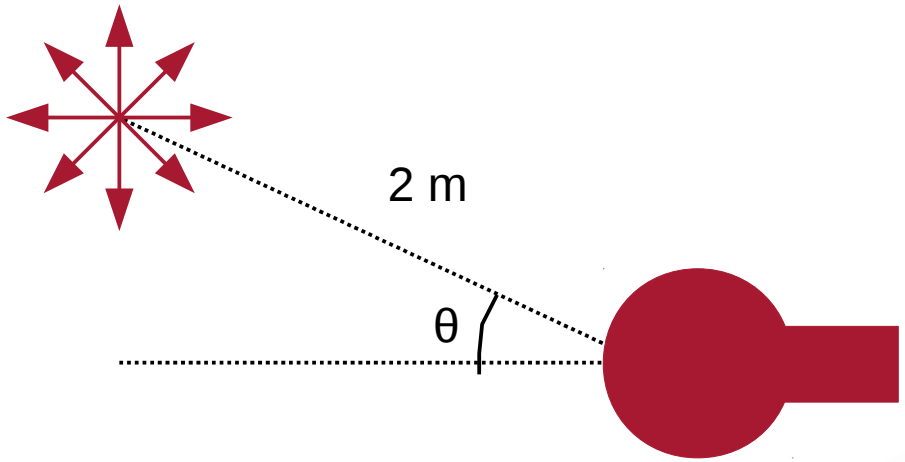


Water attenuation length and PMT QE

- For now tuning these parameters to remove bias in (rec – true)/true
- In principle we should be able to extract these parameters from the data generated to produce the scattered light tables

PMT angular response

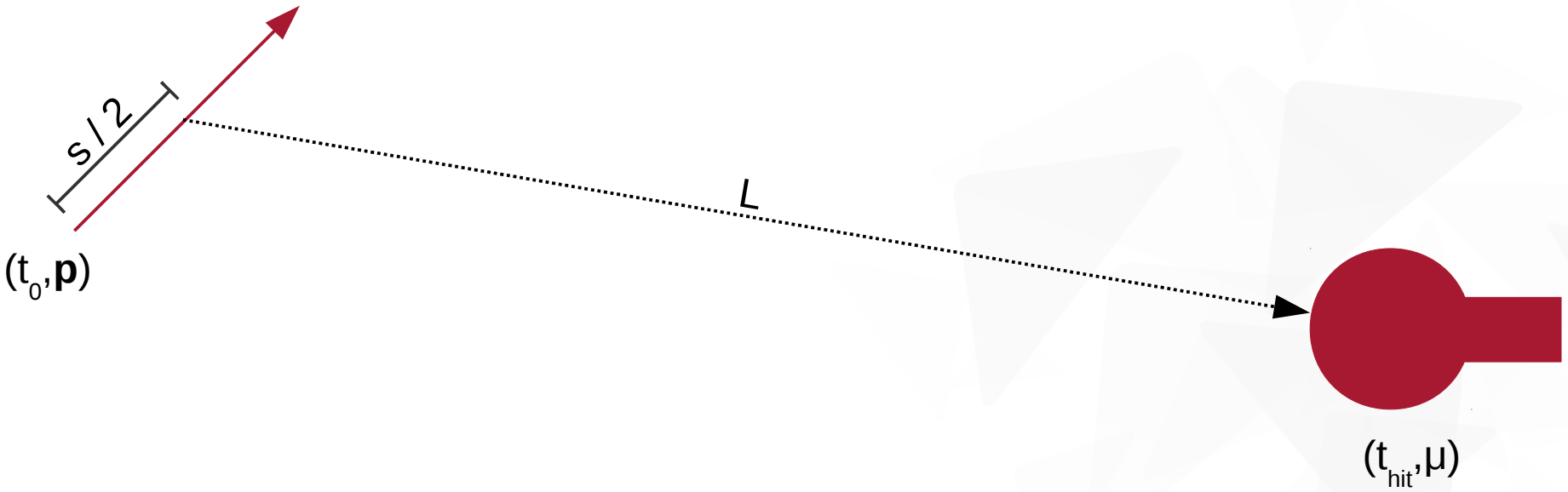
- Using direct light only, generate 3 MeV electrons with the vertex position spanning a range of angles to the PMT axis
- Extract observed charge and plot against angle



- In principle can be extracted from scattered light table data

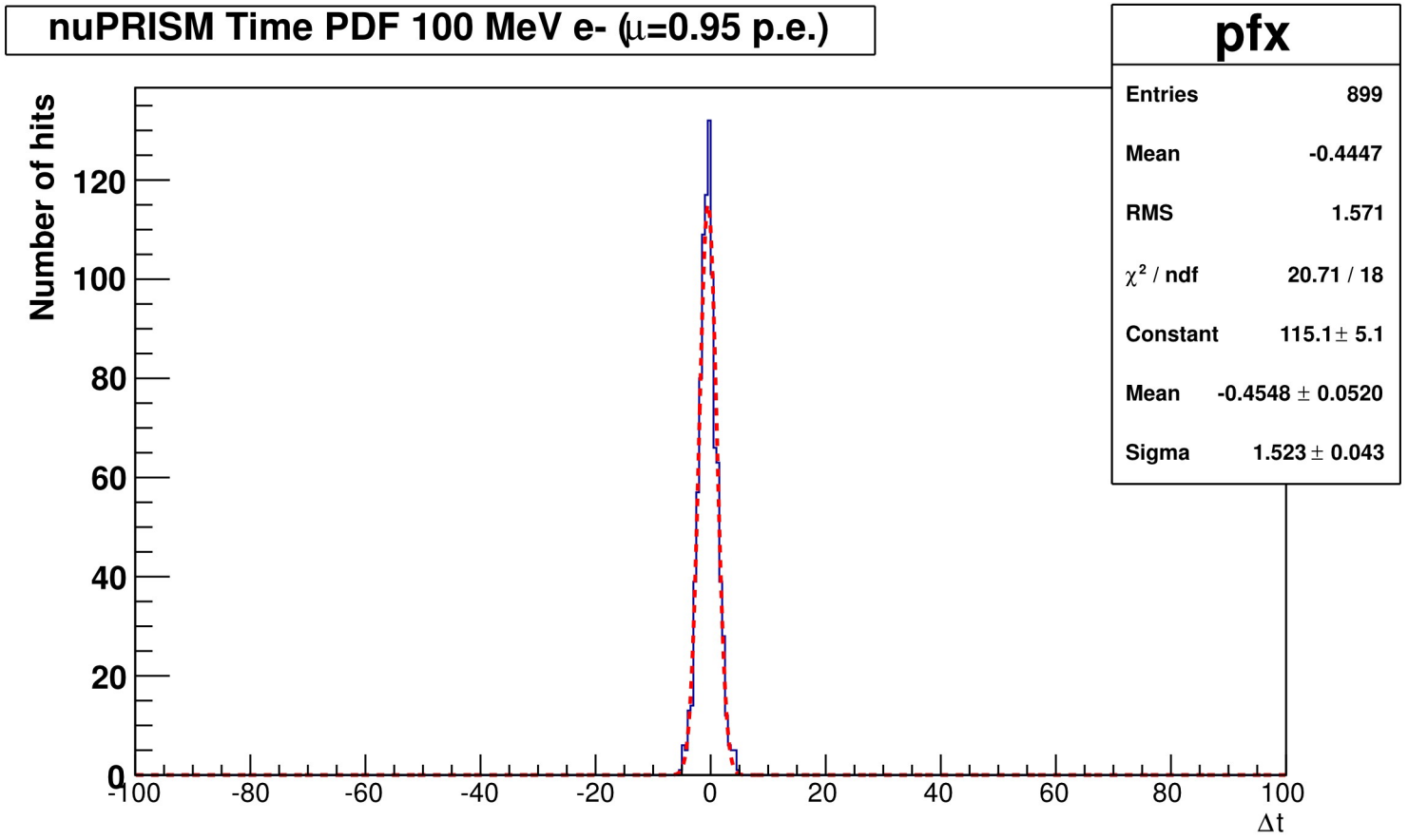
Time PDFs for direct light

- Blair's WCSim modification allows running in a mode where only direct photons produce hits
  - `/opInfo/KillScatterRef true`
- For each particle type generate particle gun events with randomised position and direction scanning over a range of momenta
- Time PDFs are the distribution of $t_0 - \left(t_{hit} - \frac{Ln}{c} - \frac{s}{2c} \right)$ binned in μ – need charge pdf part tuned!



Time PDFs for direct light

- Fit distributions with gaussians
- Fit gaussian parameters as a function of p and μ



Summary and status

- Tools to tune fiTQun to SKDETSIM have been translated for WCSim
  - Soon all these tools will be placed in the fiTQun github repository
  - Modifications to WCSim will be in the nuPRISM repository, at least for now

- nuPRISM is the first WCSim re-tune of fiTQun
  - Work in progress . . .
  - A few issues to iron out