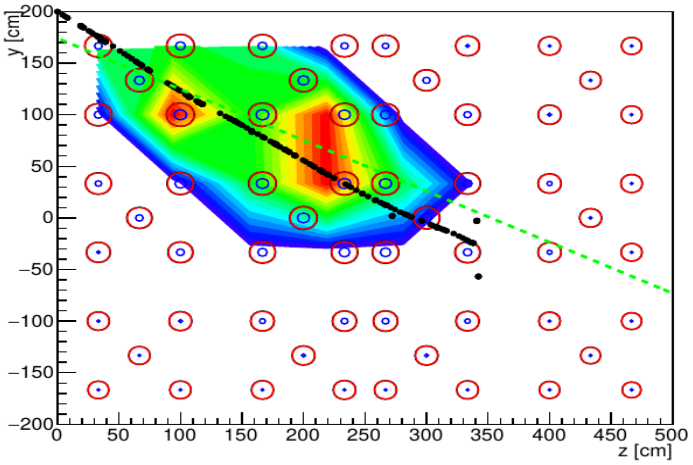
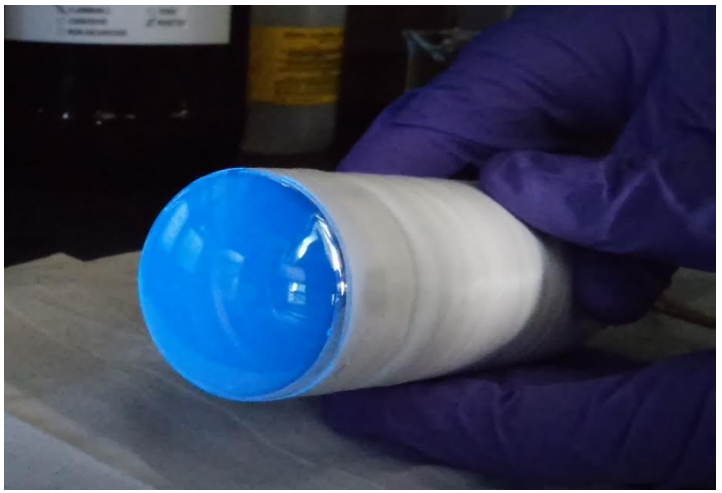
WLS coated reflector foil simulations in SBND (and LArIAT)

Andrzej Szelc

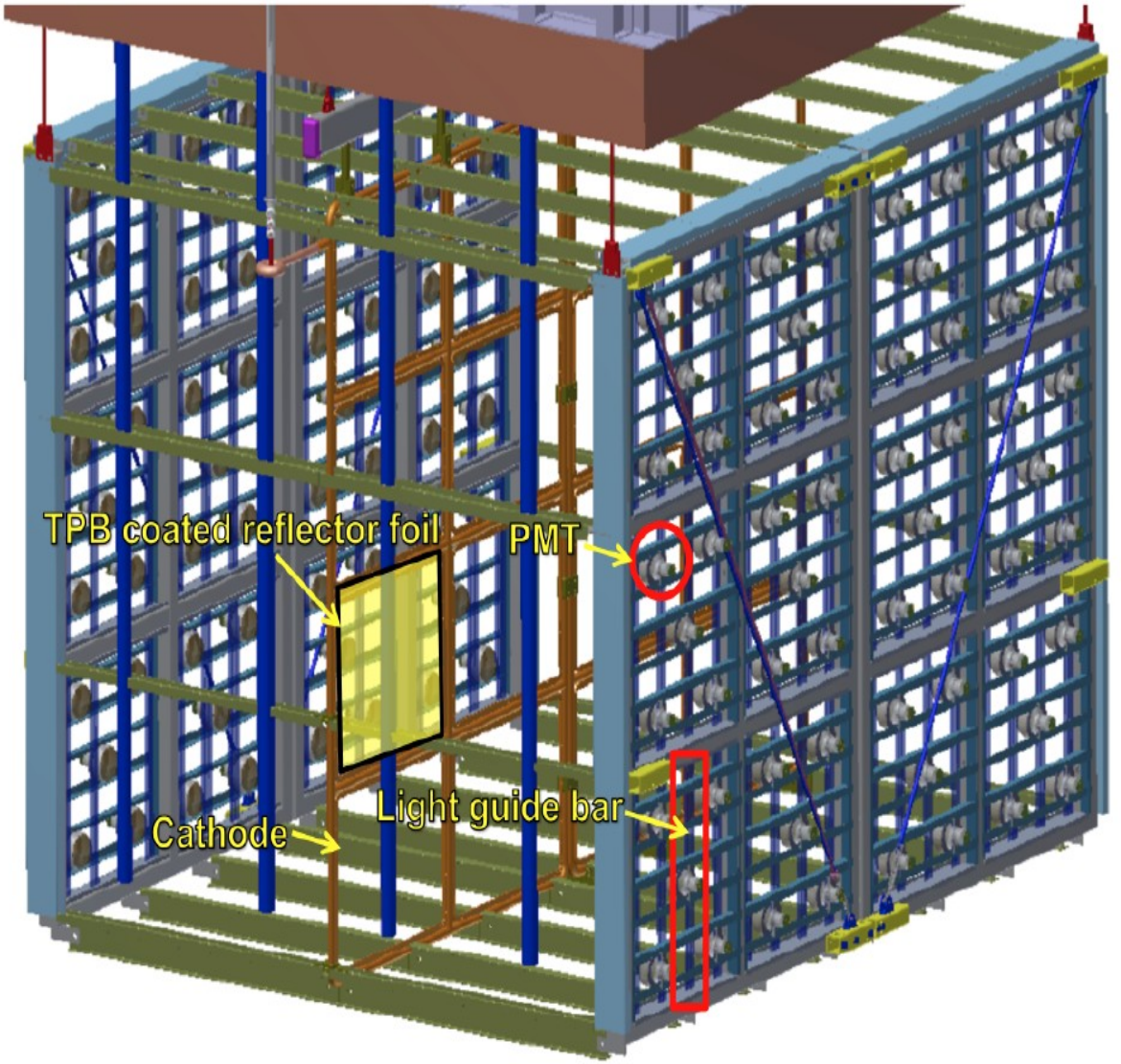
(University of Manchester)



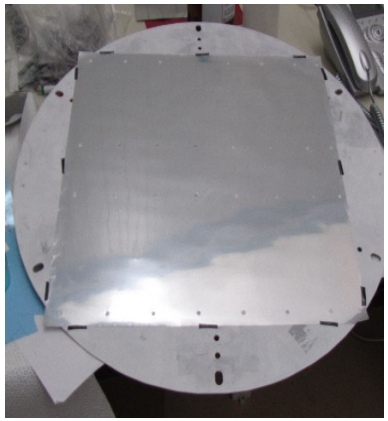


Light Detection in SBND

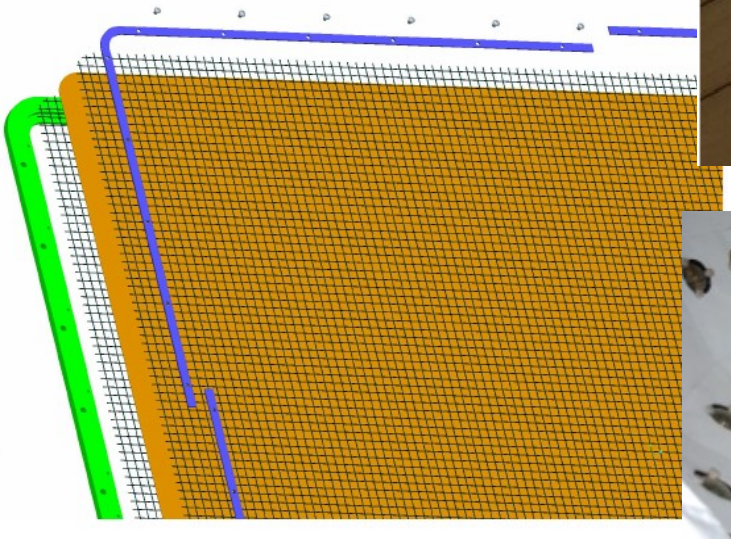
- SBND is implementing a high LY Light Detection System scheme.
- PMTs + Bars as detectors.
- Possibility of adding WLS covered reflector foils (generic R&D)
- I will present the results of simulation studies to determine the capabilities of the system and the effect of adding foils.



WLS covered reflector foils



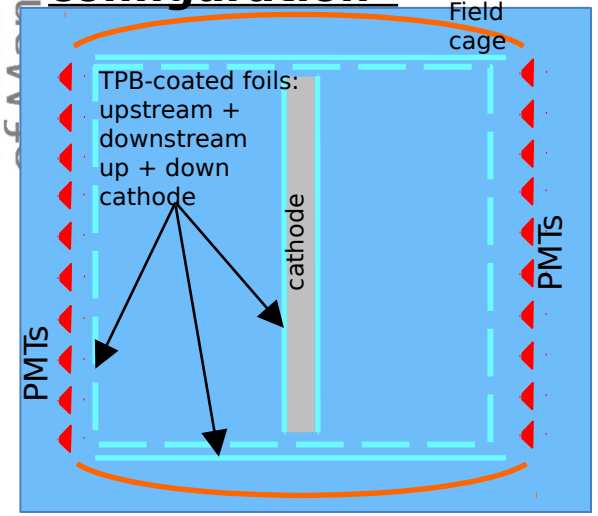
- Used in LAr DM experiments.
- di-electric reflector foils evaporated with WLS compound (TPB)
- Increase uniformity of light collection.



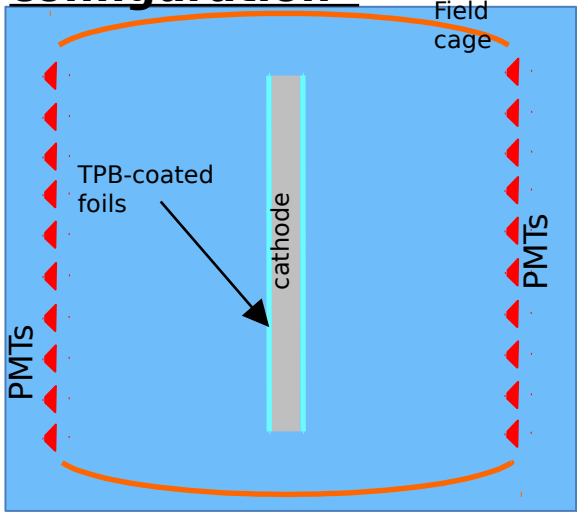
- A significant increase in collection efficiency over a setup with only PMTs.
- Uniform and enhanced light collection efficiency should help triggering and studying low energy events.

Considered configurations

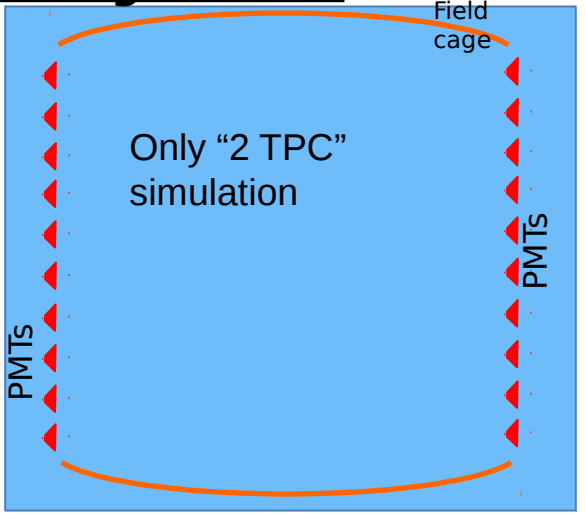
“Full coverage configuration”



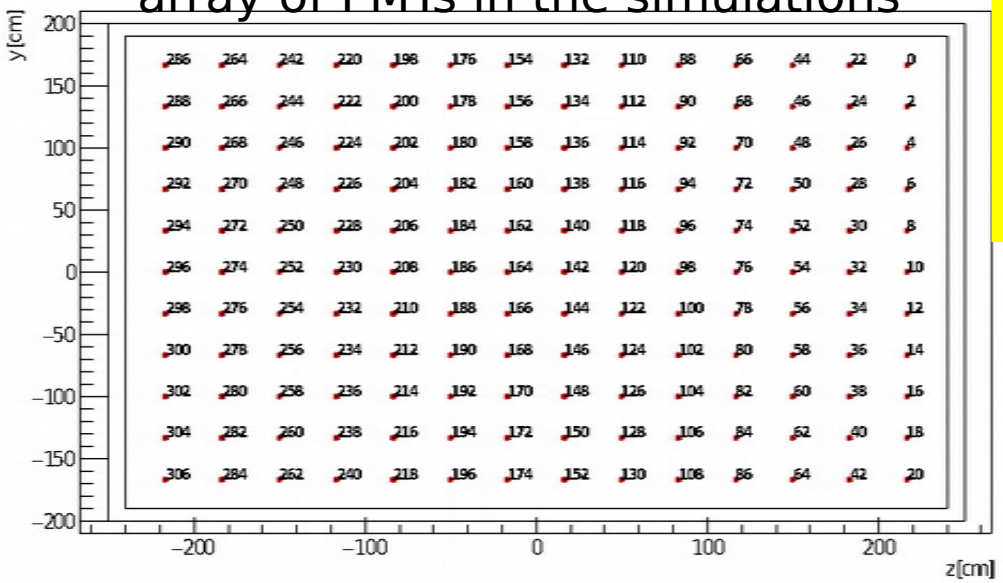
“Cathode only configuration”



“No foils/cathode configuration”



array of PMTs in the simulations

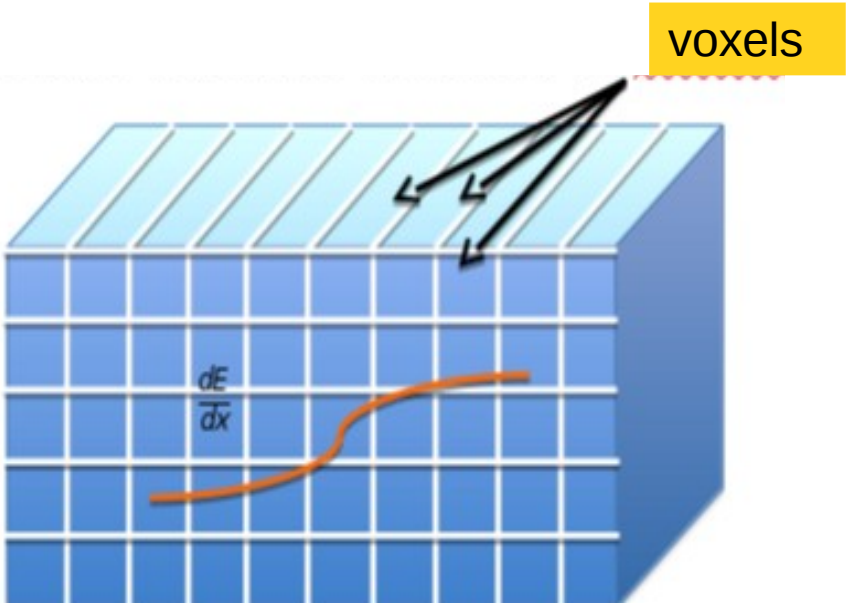


We use the symmetry of the system. Overshoot number of PMTs (11 x 14 PMTs / TPC 8’’ diameter) to be able to switch them On/Off

Note: from now on, **visible** refers To light wavelength-shifted and reflected off of the foils, while **VUV** refers to light directly hitting the PMTs.

Simulating light in argon (LArSoft)

- We use the optical lookup library (developed by uBooNE and used by DUNE).
- No electronics noise included.
- We split the VUV (light as is currently) and the Visible components of light.
- We've been running in a fairly ancient version of LArSoft.
- We are starting to port the tools to develop – should be available soon.



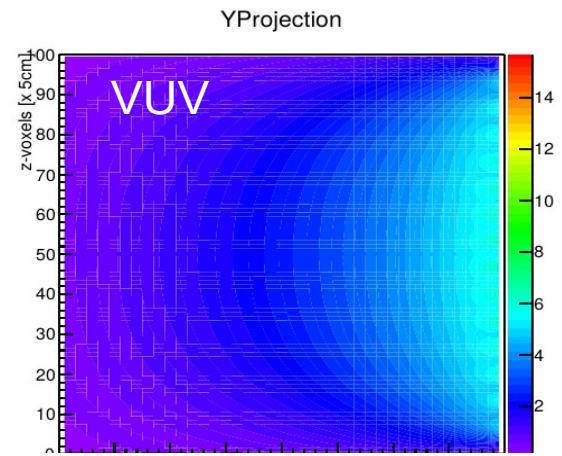
$$\langle N \rangle_{PMT-hits} = \left(\frac{dE}{dx}_{step} \cdot Length_{step} \right) \cdot LY \cdot visibility_{step}^{PMT}$$

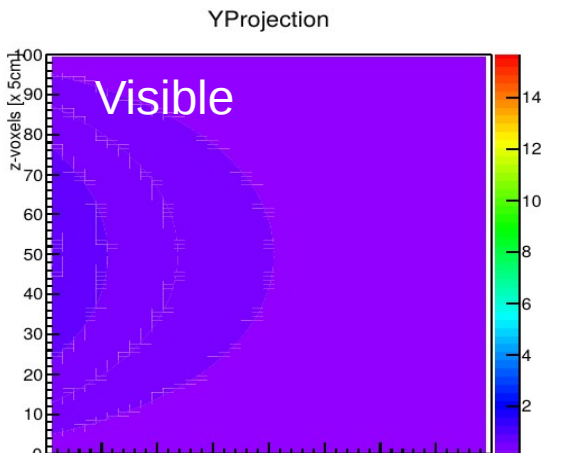
Things we were interested in the Simulation

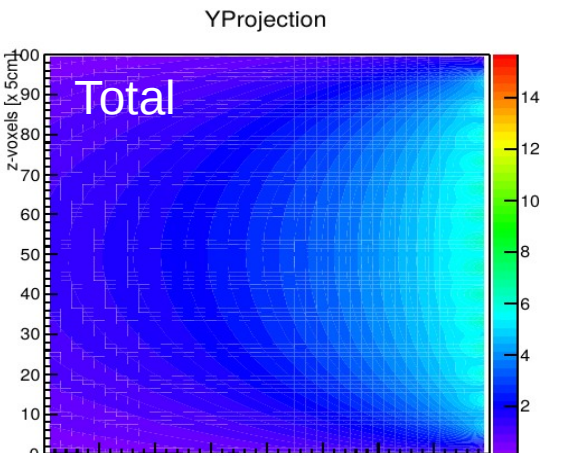
- What is the impact of a High LY setup (also with added foils) on:
  - Calorimetry
  - Timing
  - Position resolution
- What can we do with scintillation light?

Next slides, largely work by
D. Garcia-Gamez, Manchester

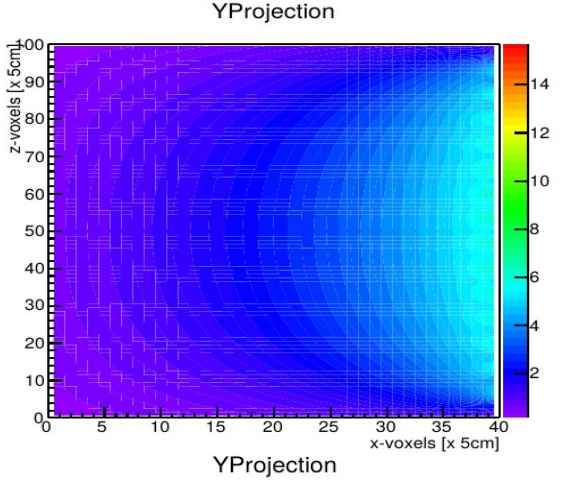
Light Yield Uniformity

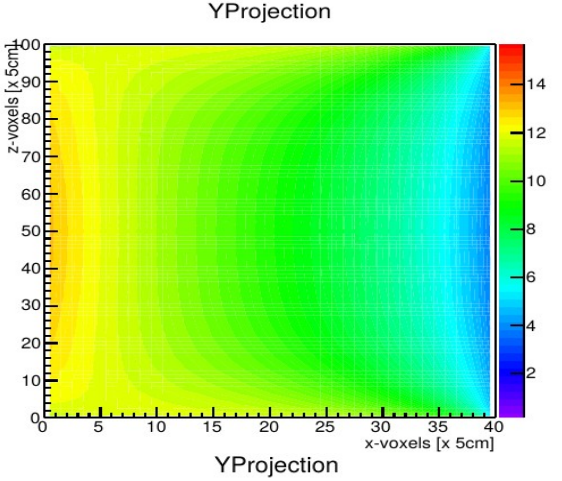


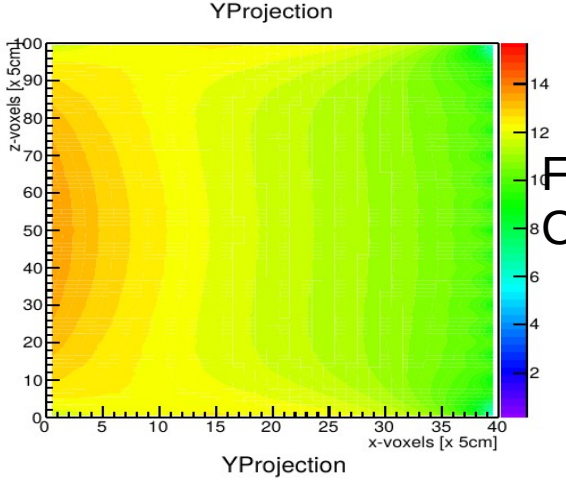




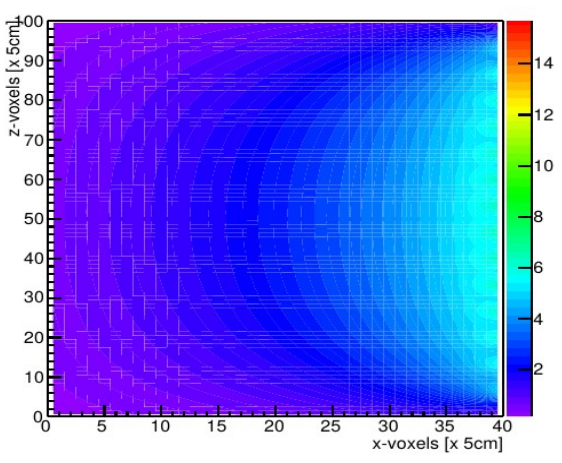
No foils

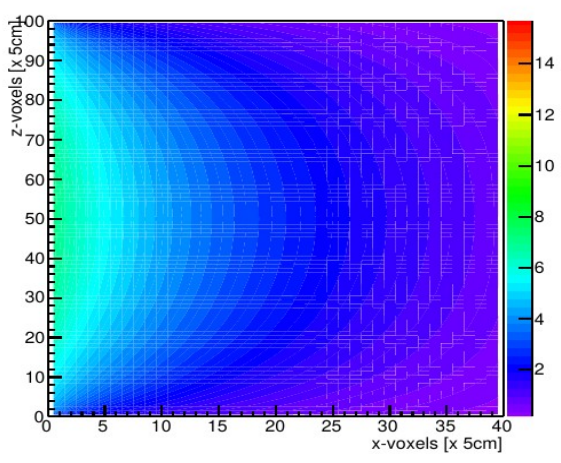


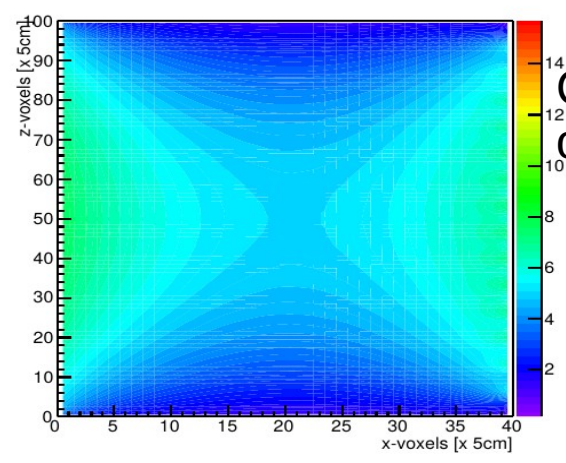




Full Coverage

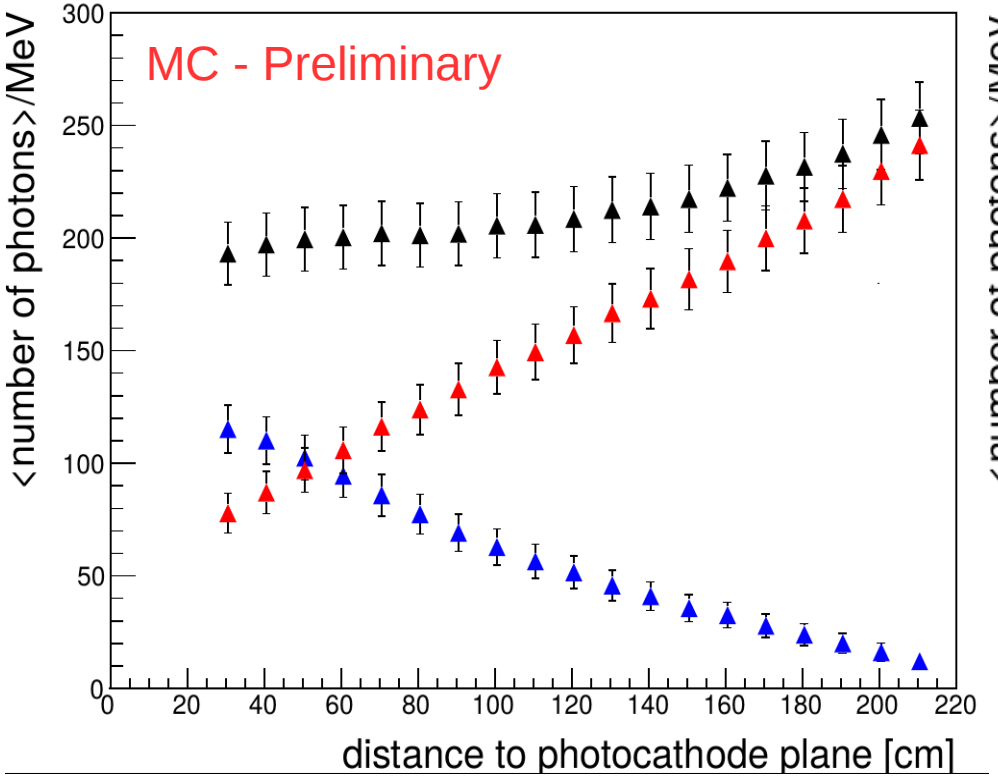


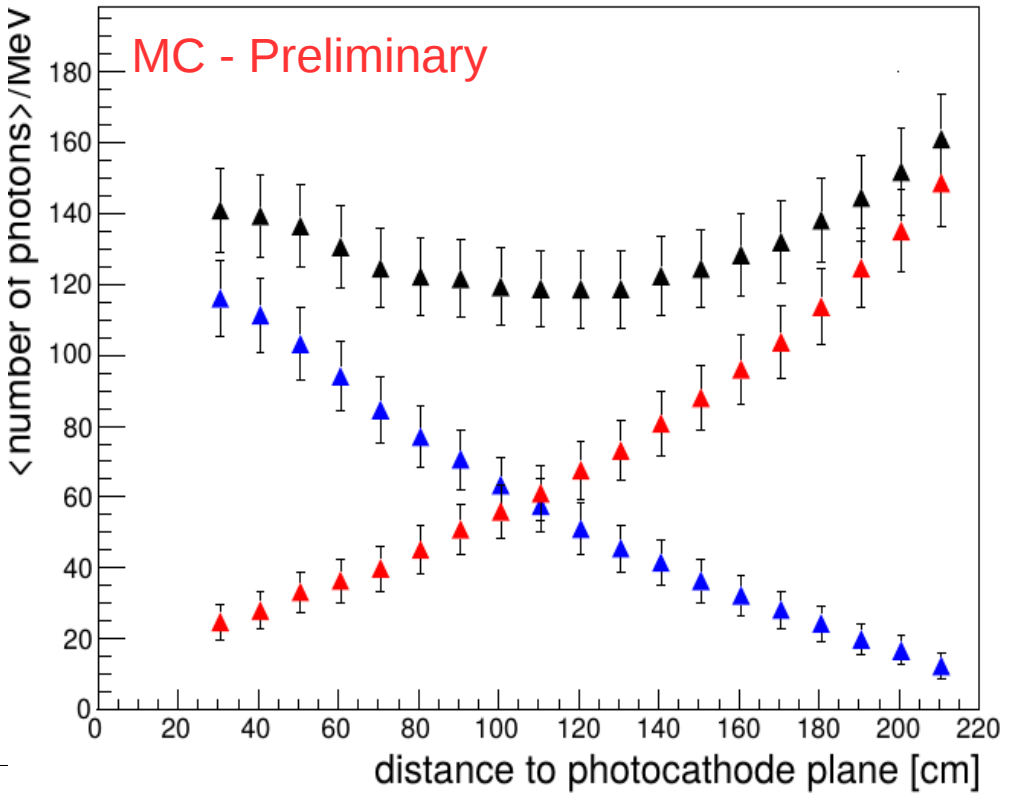




Cathode only

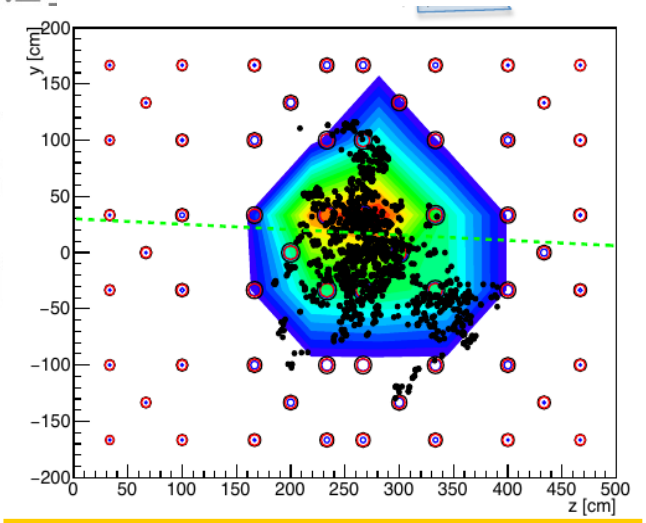
Light Yields



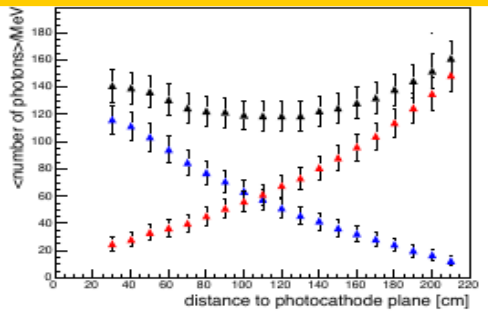


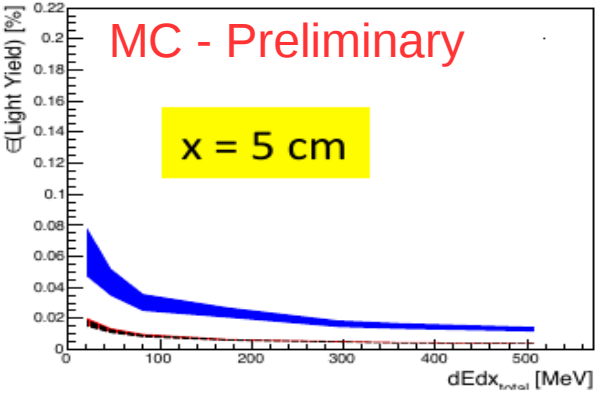
Average number of photons/event/MeV (adding the signal in all the PMTs) vs X position (drift distance to the photocathode plane)

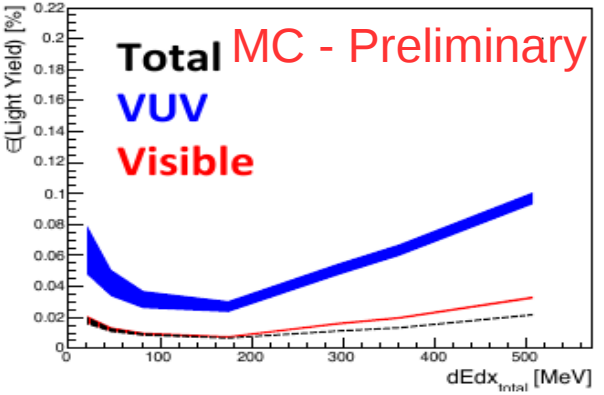
Calorimetry with Scintillation Light

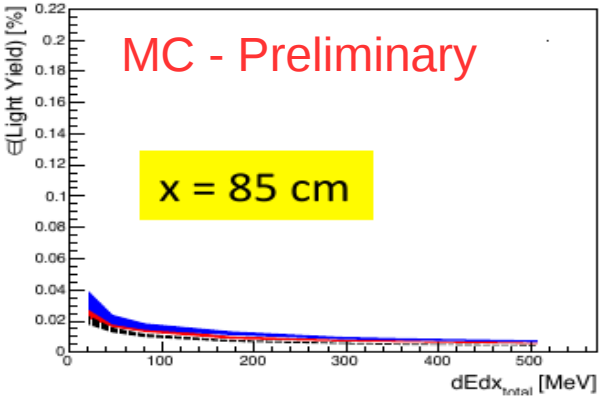


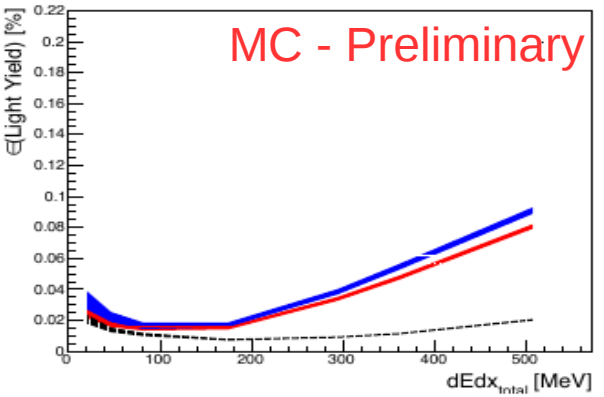
For protons interacting inelastically a large fraction of the energy is lost to the TPC. TBD how much of that we can recover some of that with light.

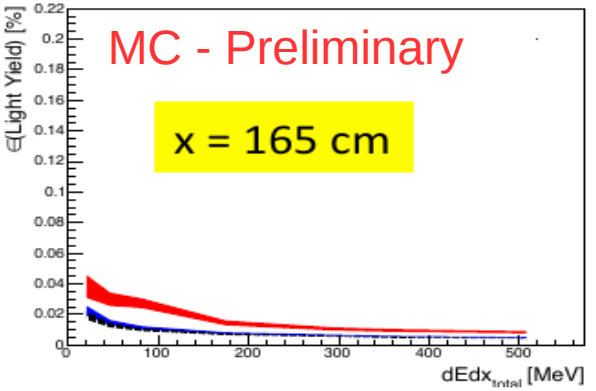


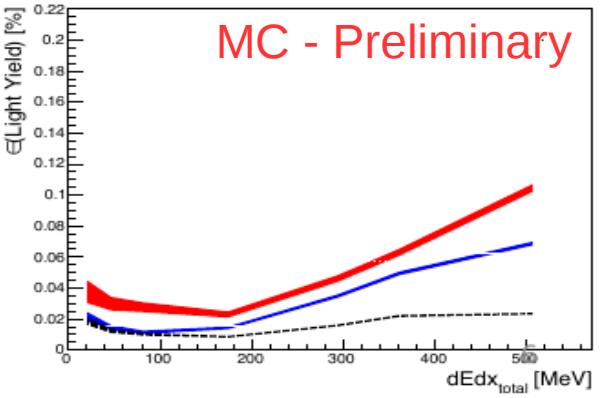






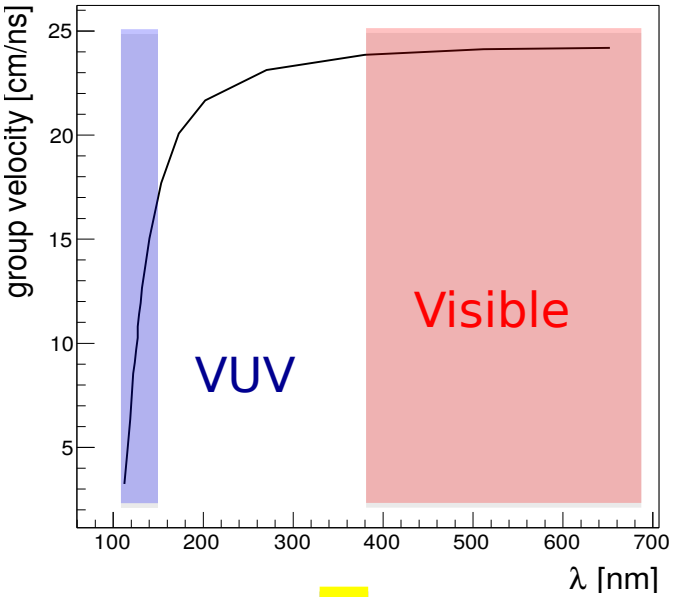


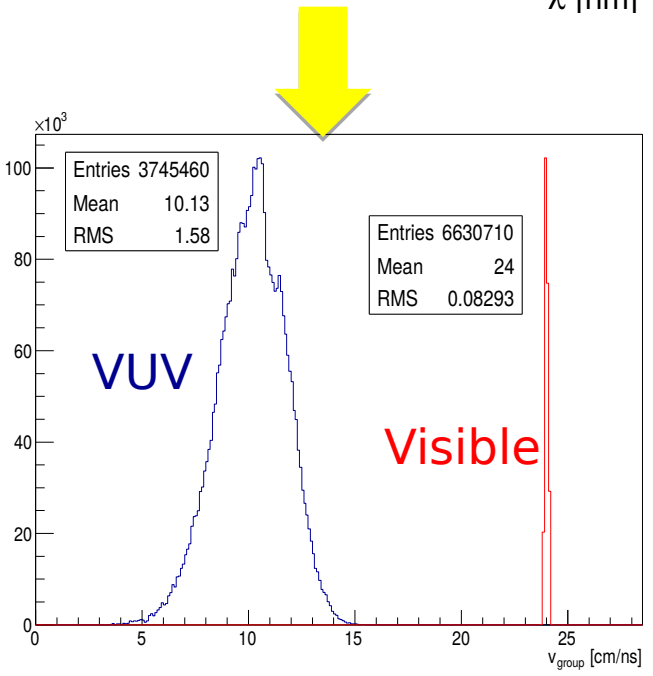




Timing

- To see if ~ns resolutions are possible needed to account for second order effects, like Rayleigh scattering ~55cm f(λ)
- Note high refractive index ~1.5 and gradient for VUV → relatively slow light.
- impossible to reproduce using a lookup library (memory) -> ***parametrization of arrival times.***
- Assume we can model arrival times of Argon Scintillation photons (in principle optimistic).



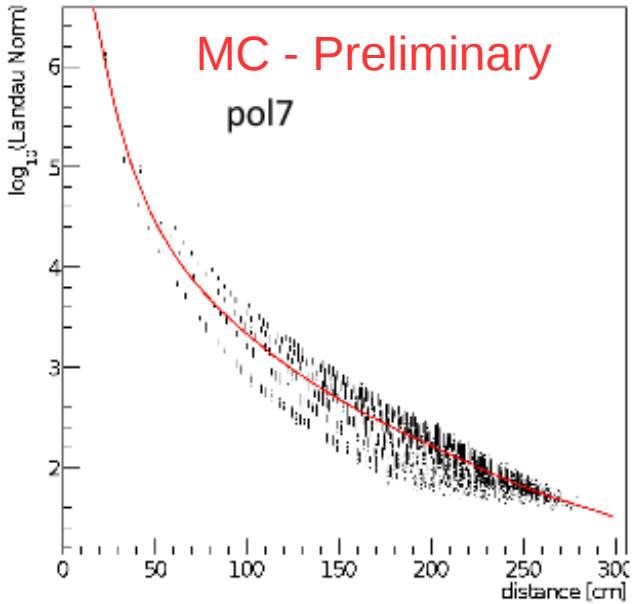


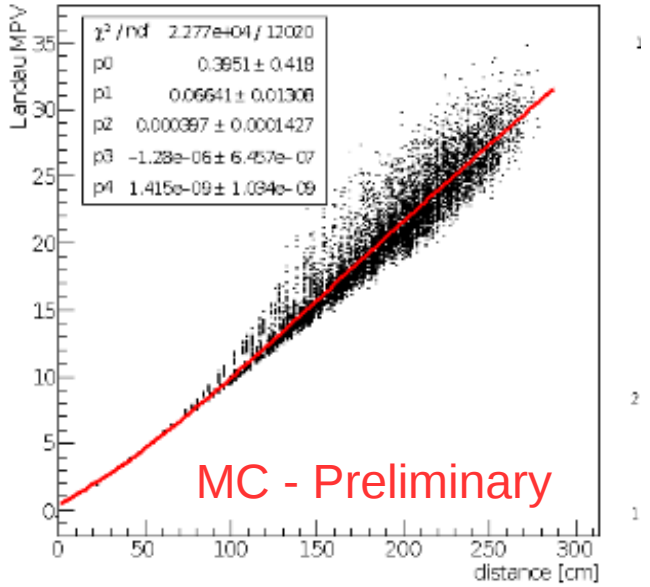
Direct light (VUV) timing parametrization:

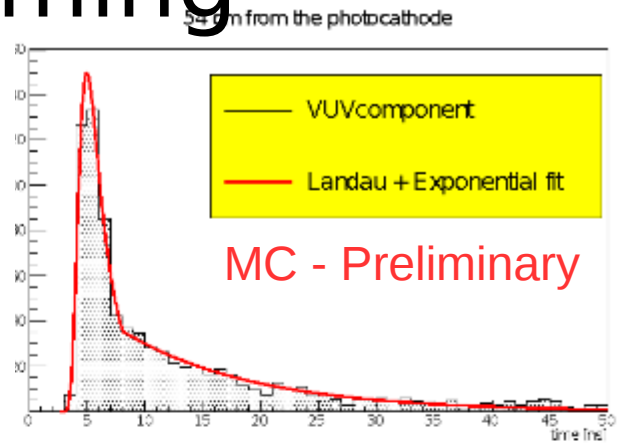
A combination of Landau and exponential functions fits practically every distribution of photon arrival times.

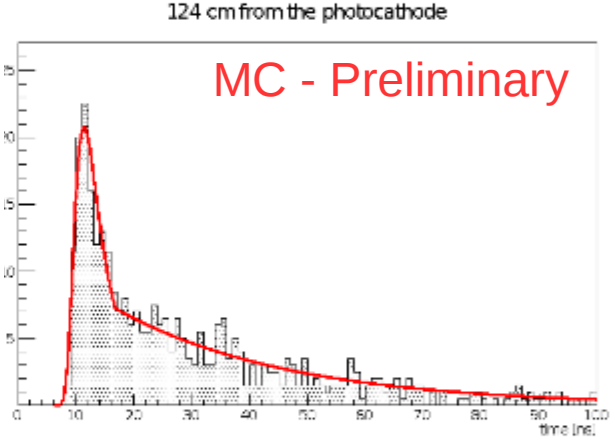
The fit parameters turn out to be monotonic functions of distance.

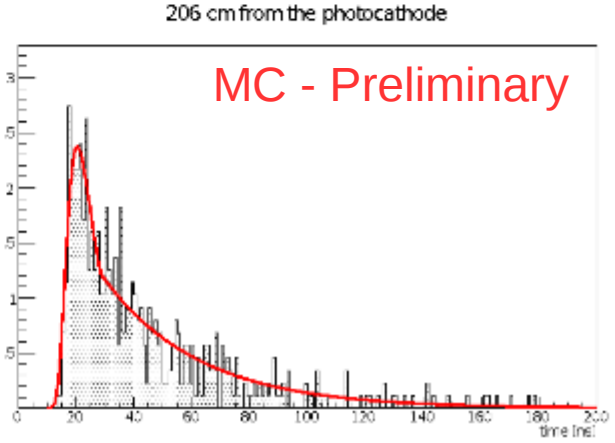
Preliminary tests show agreement also in uB geometry





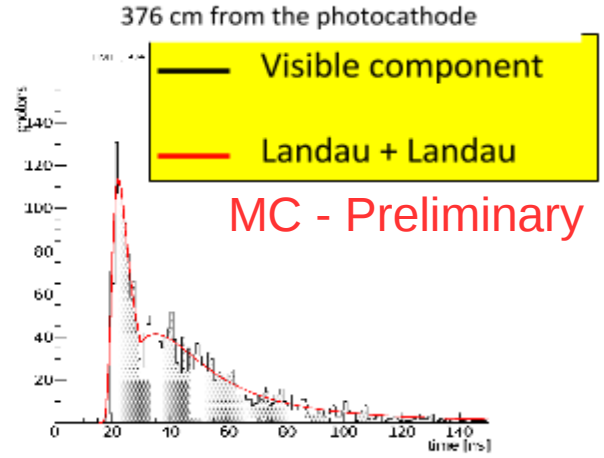






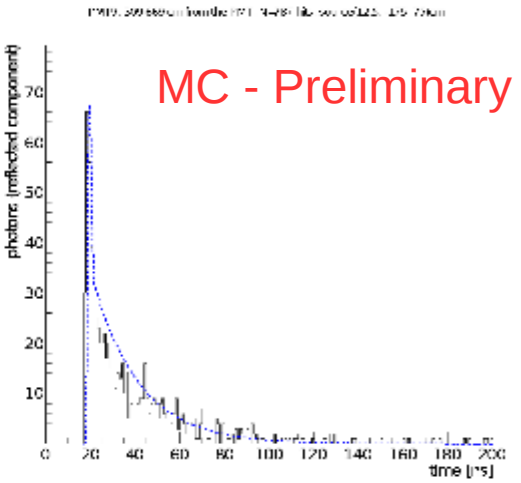
Works for Visible Light too:

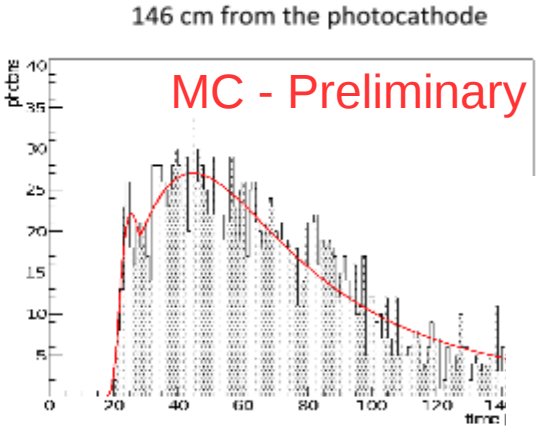
The University

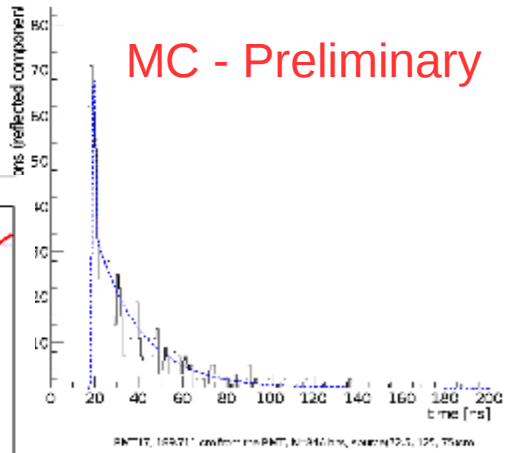


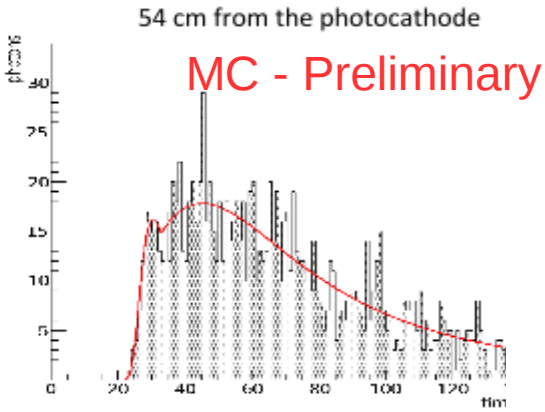
Cathode only configuration is much easier to model - path of light easier to “predict”.

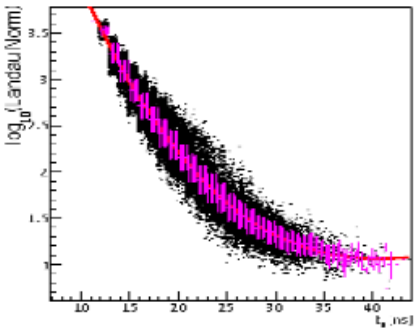
Full coverage requires an extra parameter to be saved in the lookup library.

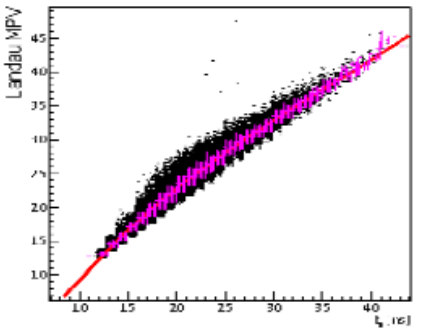


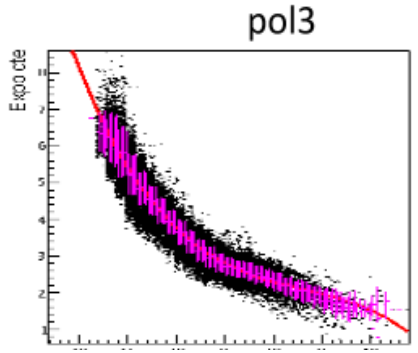


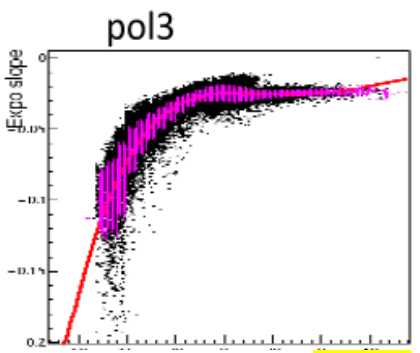


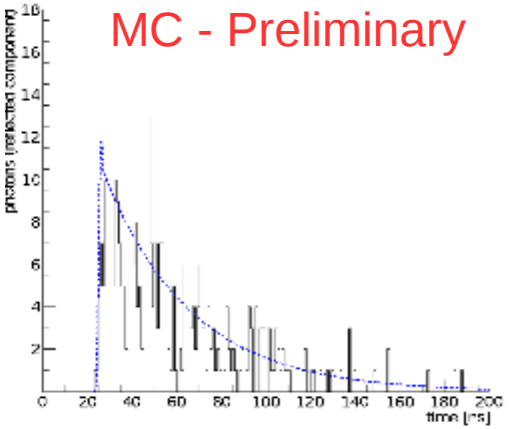




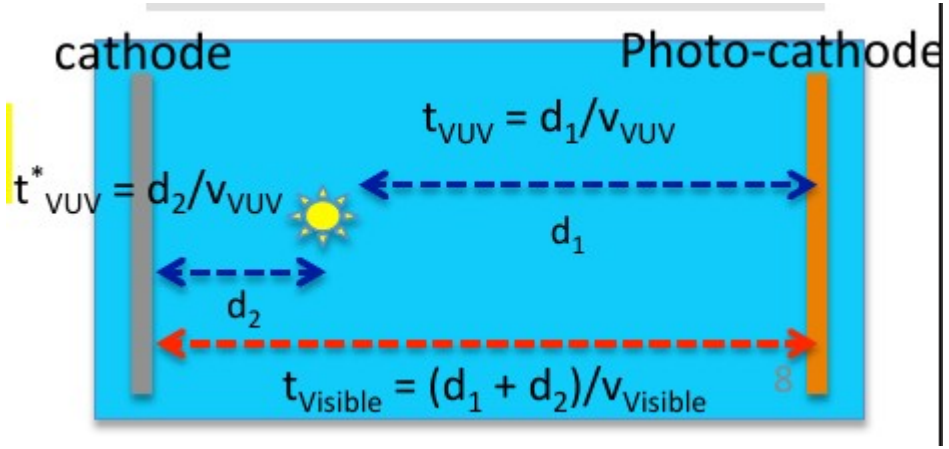


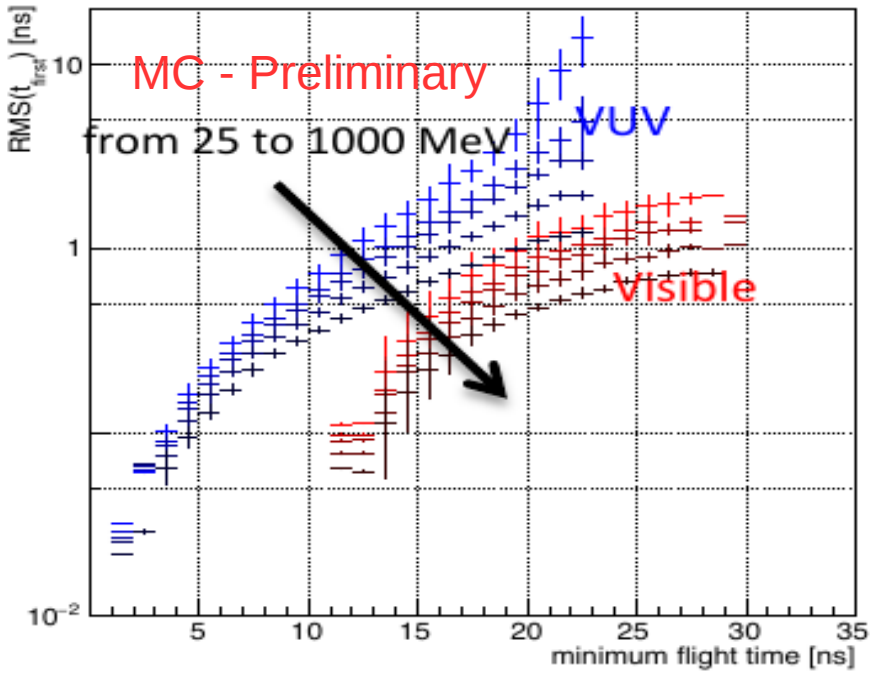


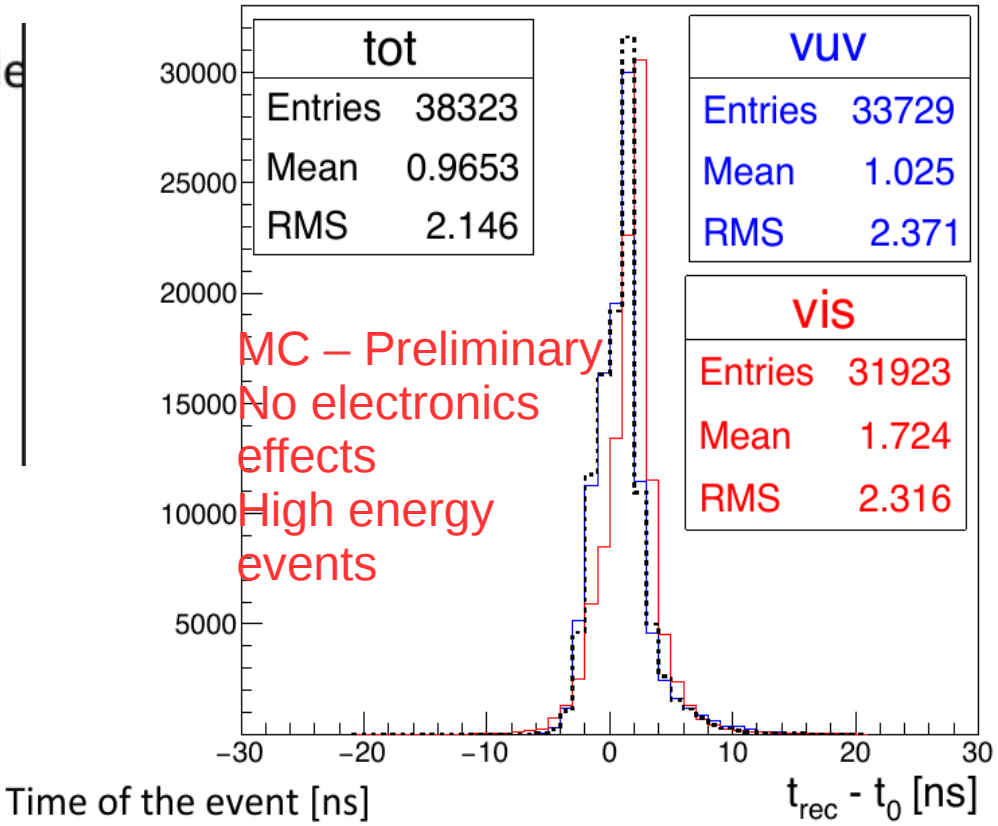




Timing







Timing resolution depends on the quantity of arriving light (smaller chance of missing photons coming in)

Effects on timing constants

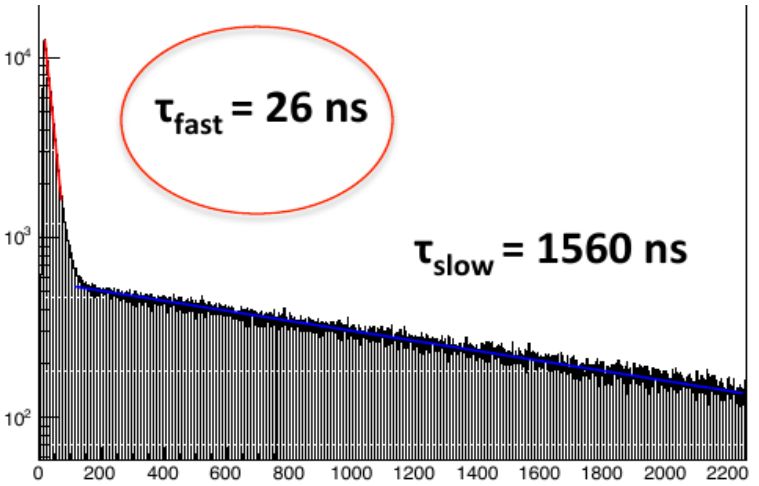
Scintillation:

$0.3 \times \tau_{fast}(6\ ns) + 0.7 \times \tau_{slow}(1590\ ns)$

+

Propagation:

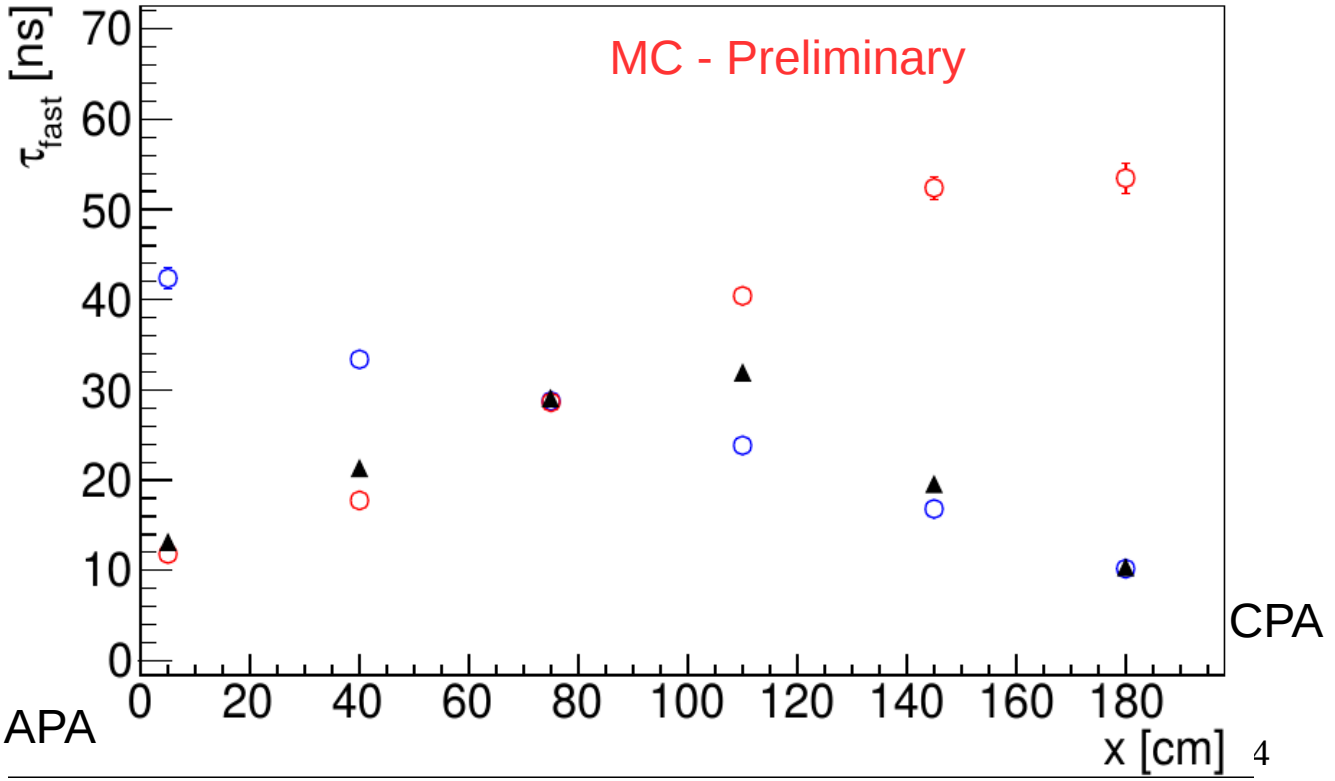
Direct transportation + Rayleight Scattering



Fast component life time changes as a function of distance.

Triggers focusing on the fast component should account for this.

TPB lifetimes not Accounted for yet.



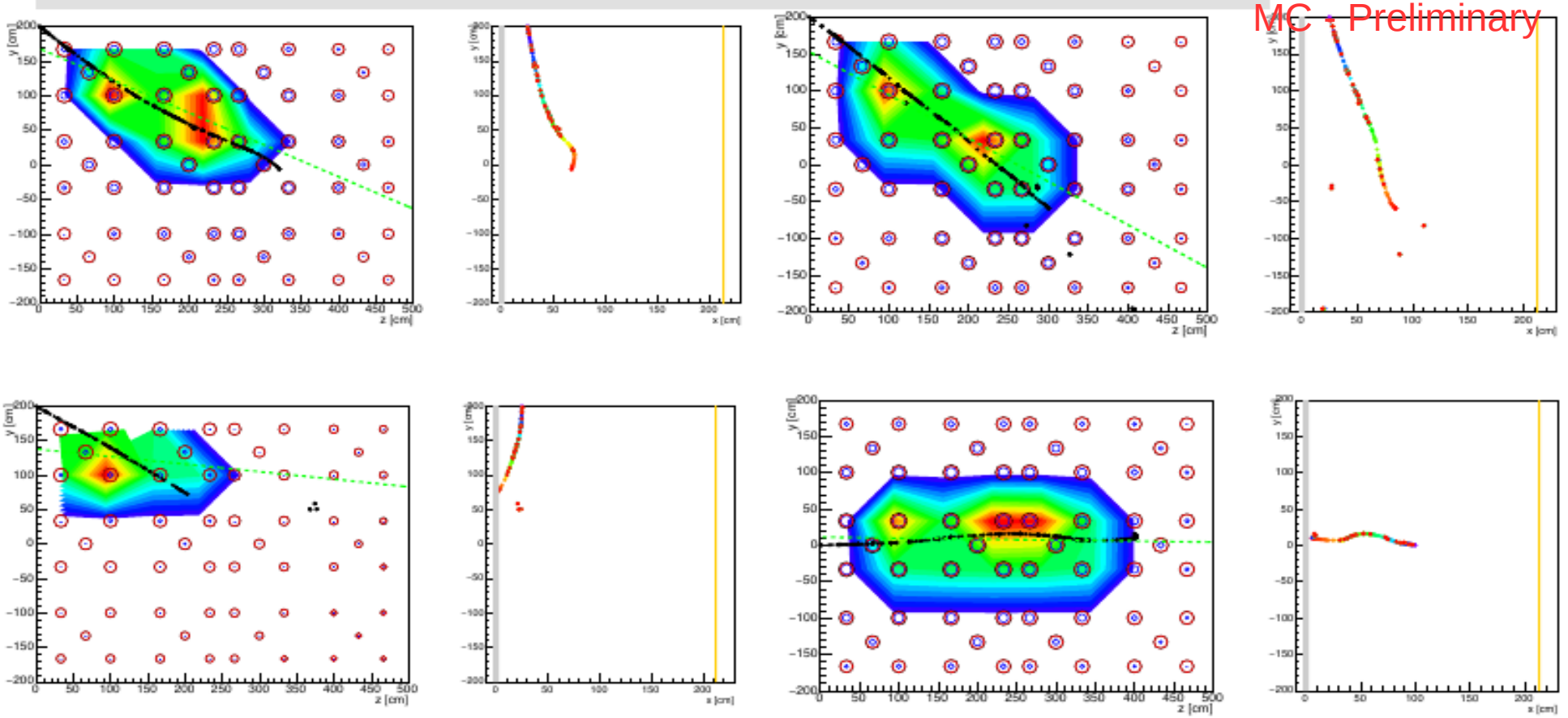
Y-Z Positional Resolution

"Tracking" the events with light: "cosmics"

1GeV muons
VUV + Visible components
Contours = hottest PMTs with the 30% of the total detected light

"Realistic" PMT system → 60 PMTs/TPC

MC - Preliminary

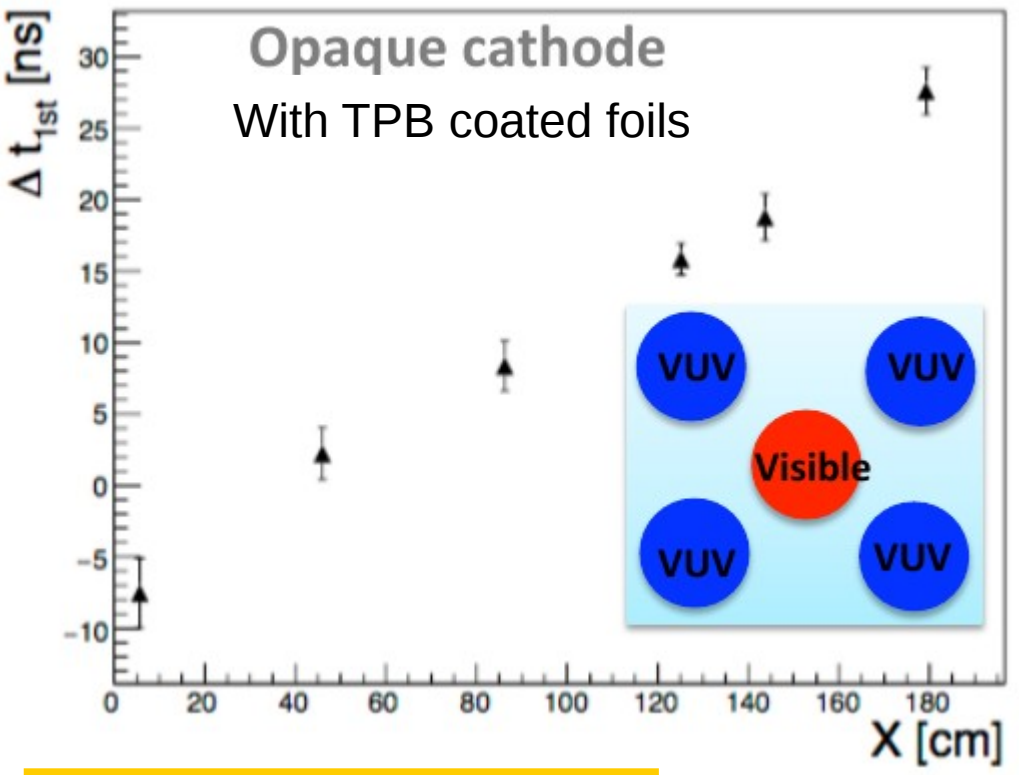


Very simple assumption → Big room for improvements!

D. Garcia-Gamez

X-drift position resolution

- If able to differentiate VUV from Visible (re-emitted) possible to get position in x “on the fly”.
- Additional information, to disentangle multiple events in the same frame.
- In principle could enable reading out just “interesting” parts of the detector.

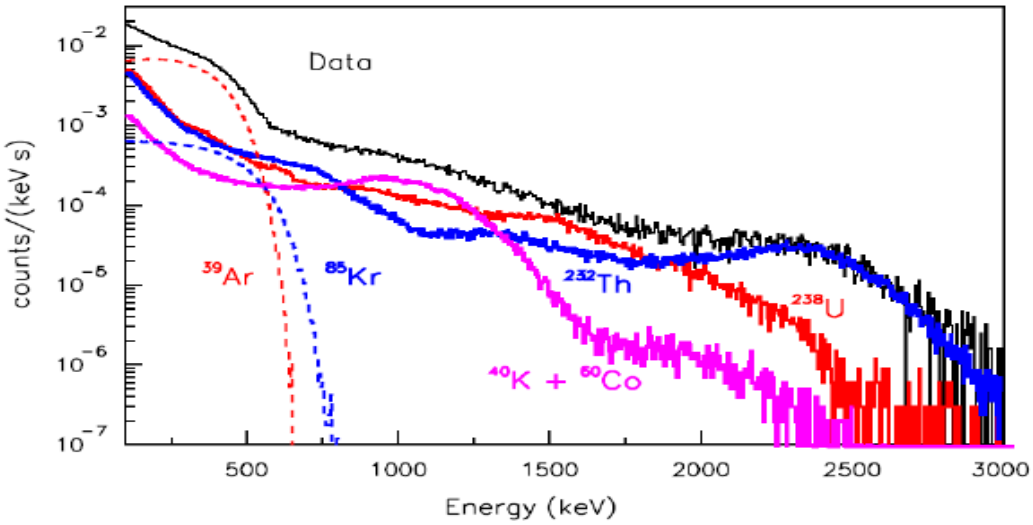


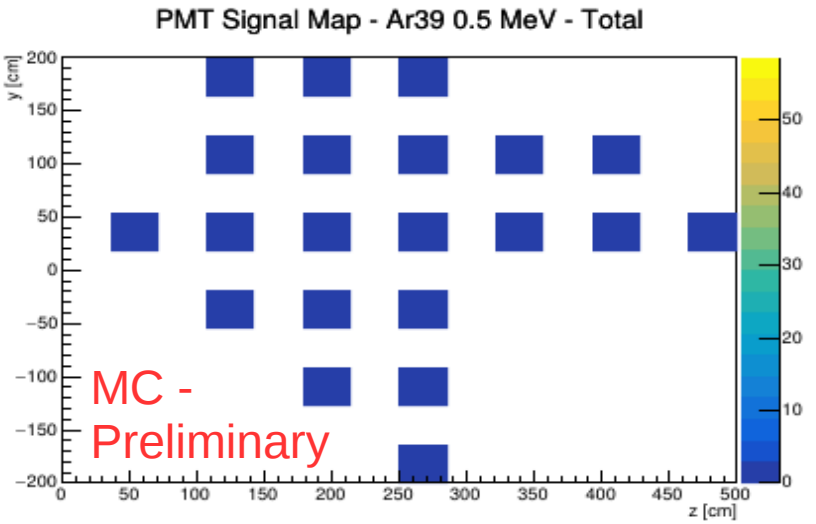
In case of PMTs can be obtained by not-coating a subset with TPB

Other questions

- The light reflected from the foils does not seem to increase electronics saturation (light is diffuse enough).
- ^{39}Ar can be mitigated with relatively simple majority cuts. (uniformity allows applying essentially an energy cut)

arXiv:astro-ph/0603131v2

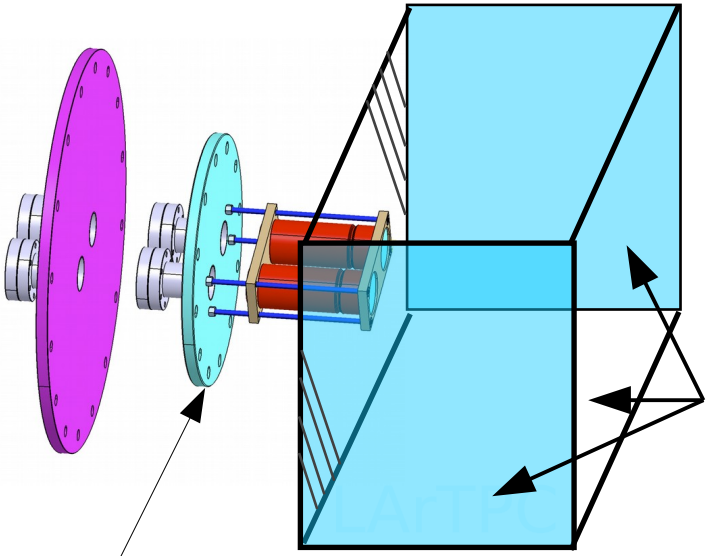




C. Hill, Manchester

Foils in LArIAT

- LArIAT is already testing how foils affect light collection efficiency.



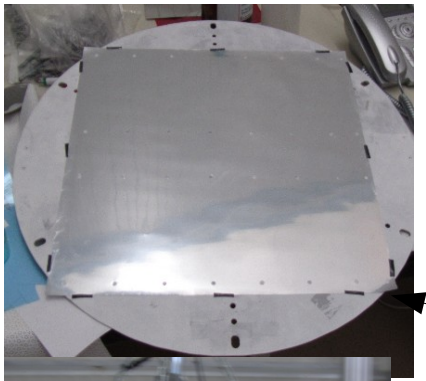
Two cryogenic PMTS
- one 3” high QE (30%)
- one 2” standard QE (20%)

+3 SiPMs

Wavelength shifting reflector foil

Hamamatsu R11065

ETL D757KFL (2”)

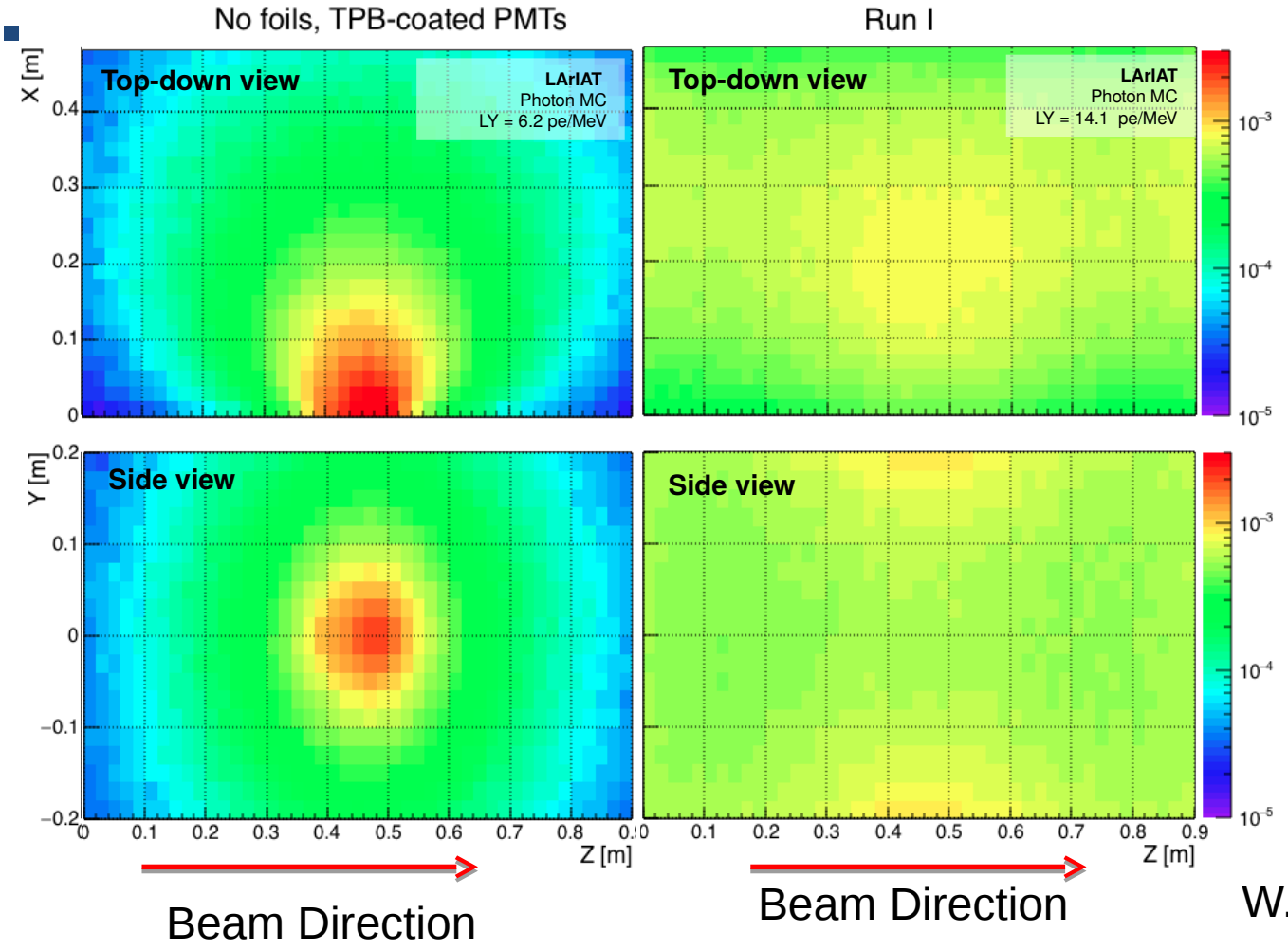


Applying TPB to the reflective foil that will line the inside of the LArIAT TPC

- *Different foil configuration than proposed for SBND, but same simulation methods.*

Using the same simulation tools as SBND

- In fact, the tools were developed for LArIAT first, and adapted for SBND and developed further.



Excellent uniformity in the detector.

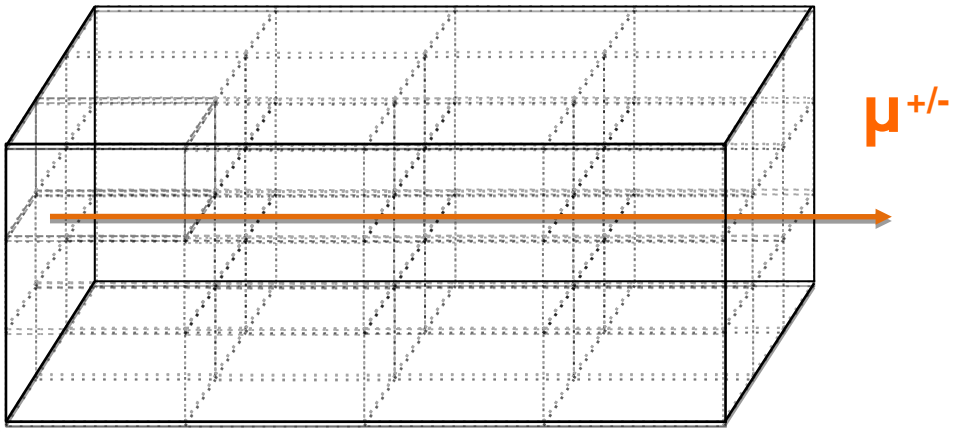
Two full runs completed (Not all PMTs were always on).

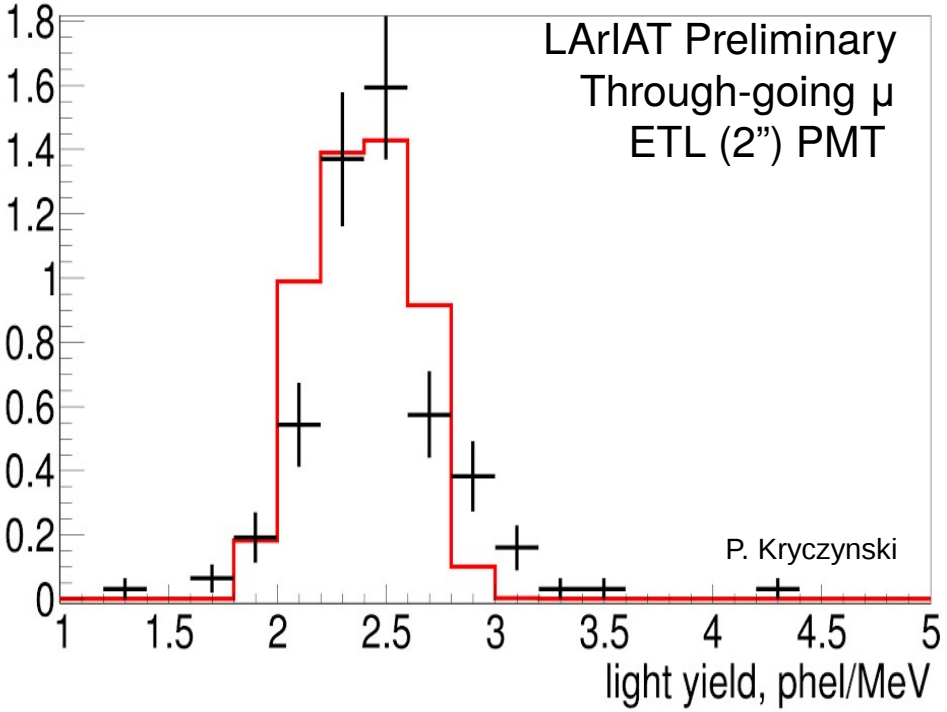
Data analysis in progress.

W. Foreman

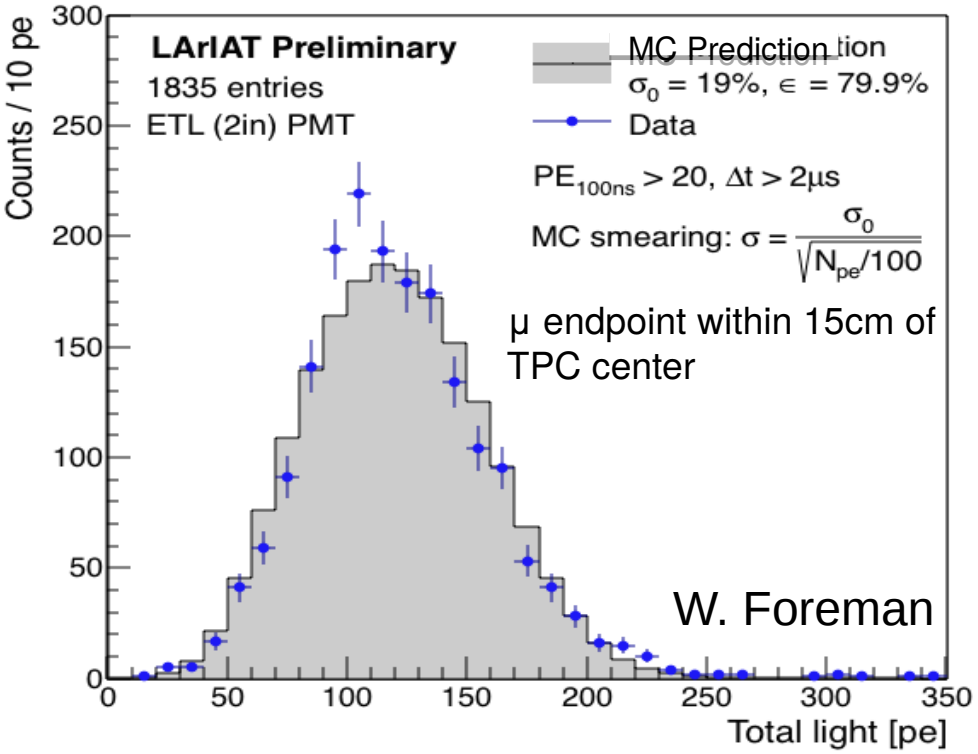
Validating the Simulation in LArIAT data

- Through going mu:





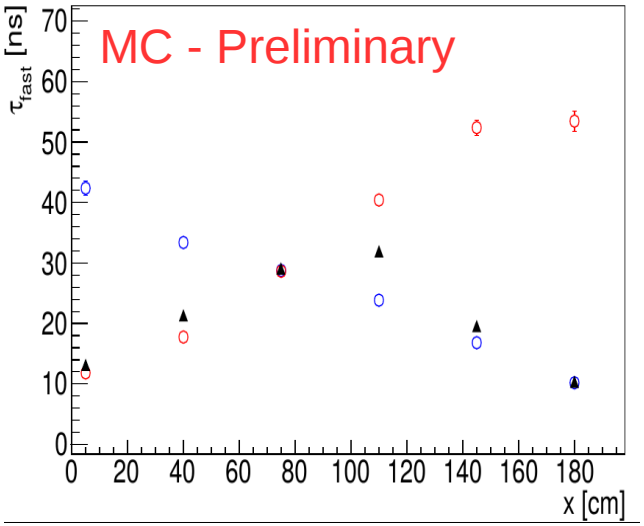
- Michel electrons:

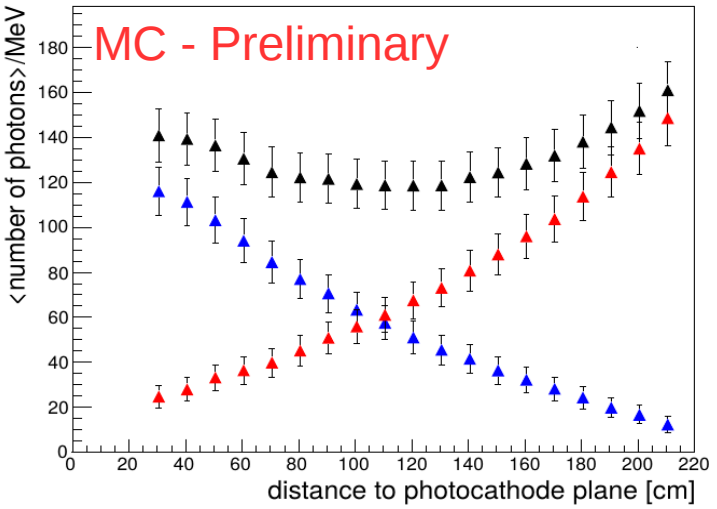


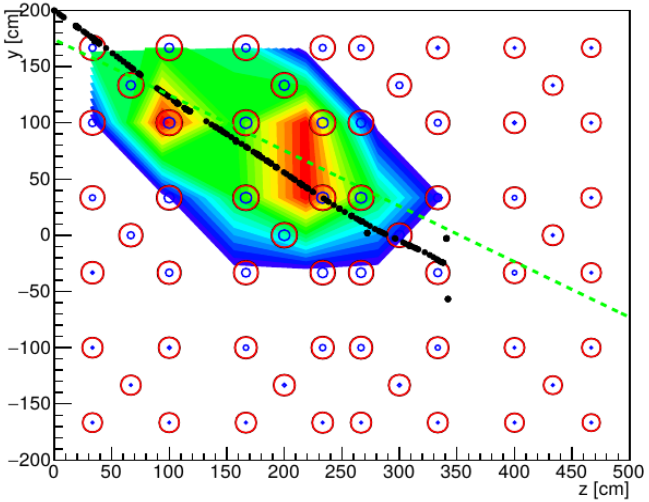
- predicted LY: 2.4 pe/MeV for 2" ETL PMT (Run I)

Summary

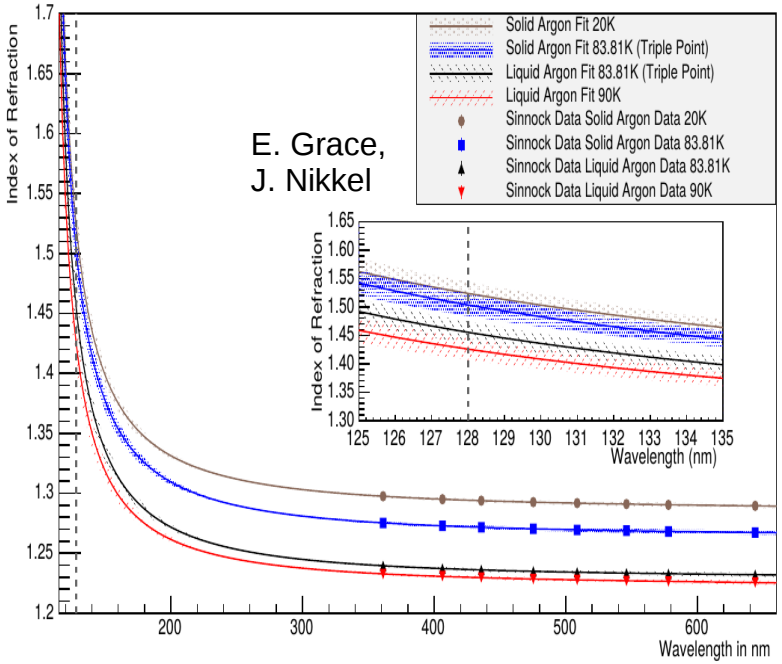
- SBND simulations of a high LY light detection system show that it can help determine timing, calorimetry and position resolution.
- Adding WLS-covered reflector foils improves the overall performance of the system.
- LY increased without raising number of channels. Rough 3D and calorimetric reconstruction “on the fly” could be possible.
- Potentially useful for DUNE.
- Getting code into current LArSoft is in progress.
- SBN technote #1155. Working on making it public.



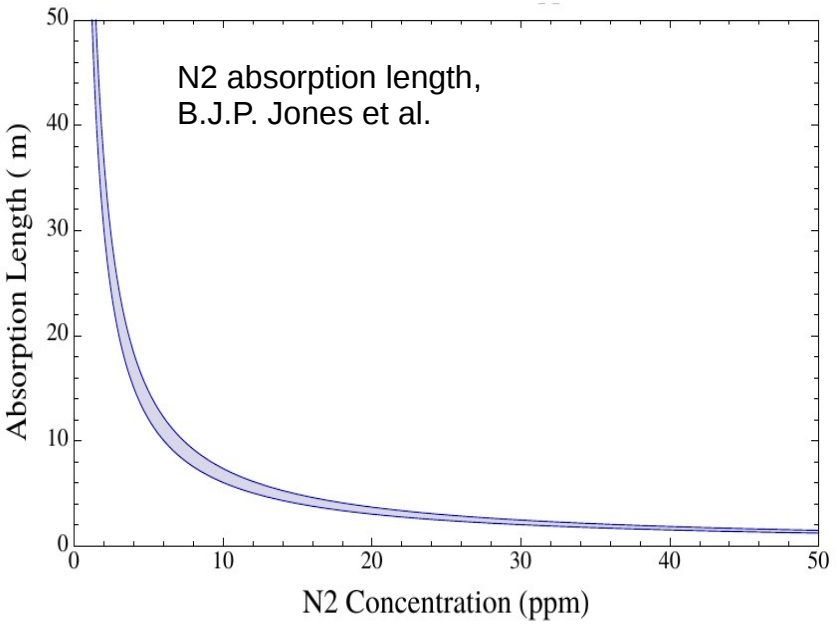




Back up slides

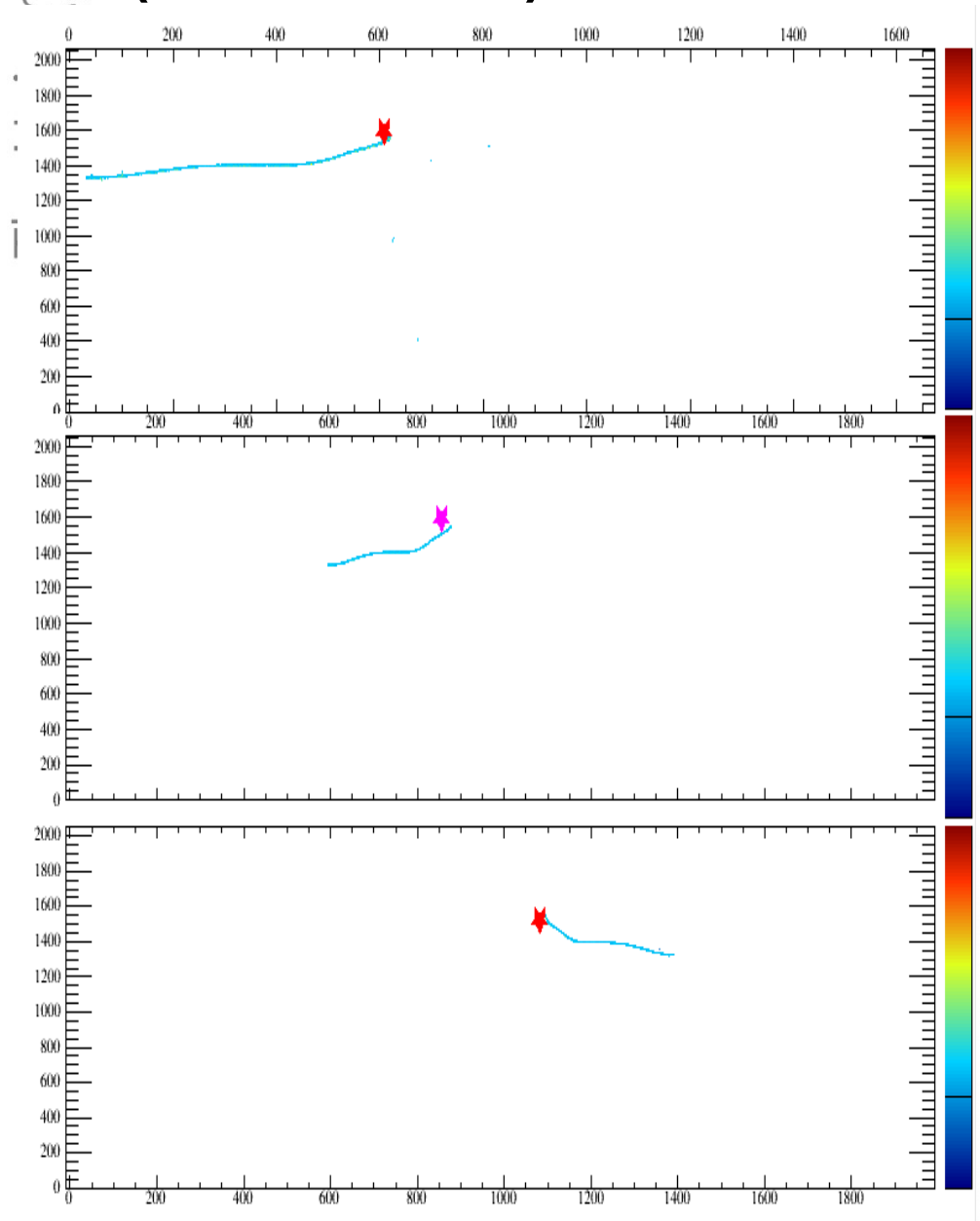


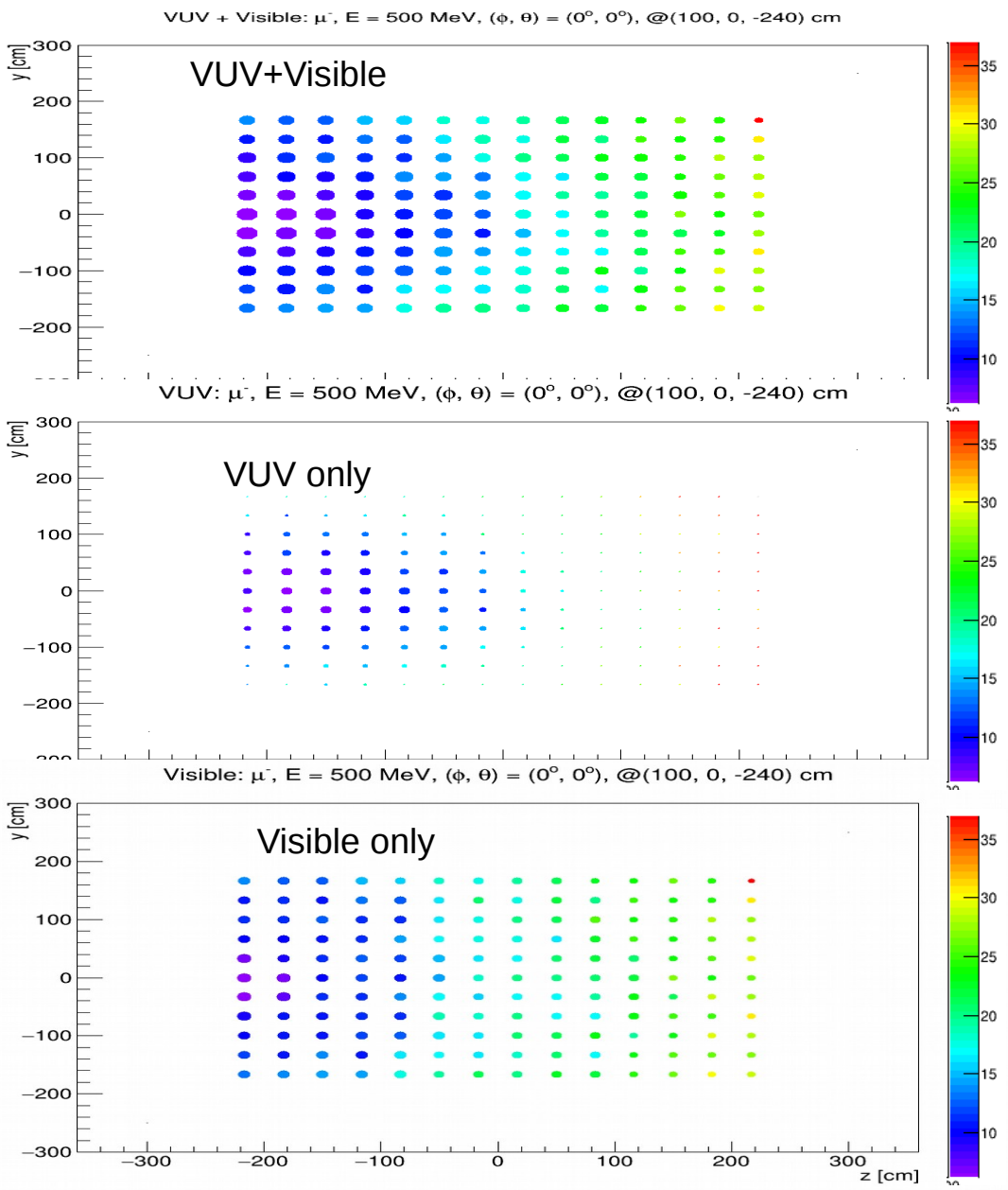
E. Grace,
J. Nikkel



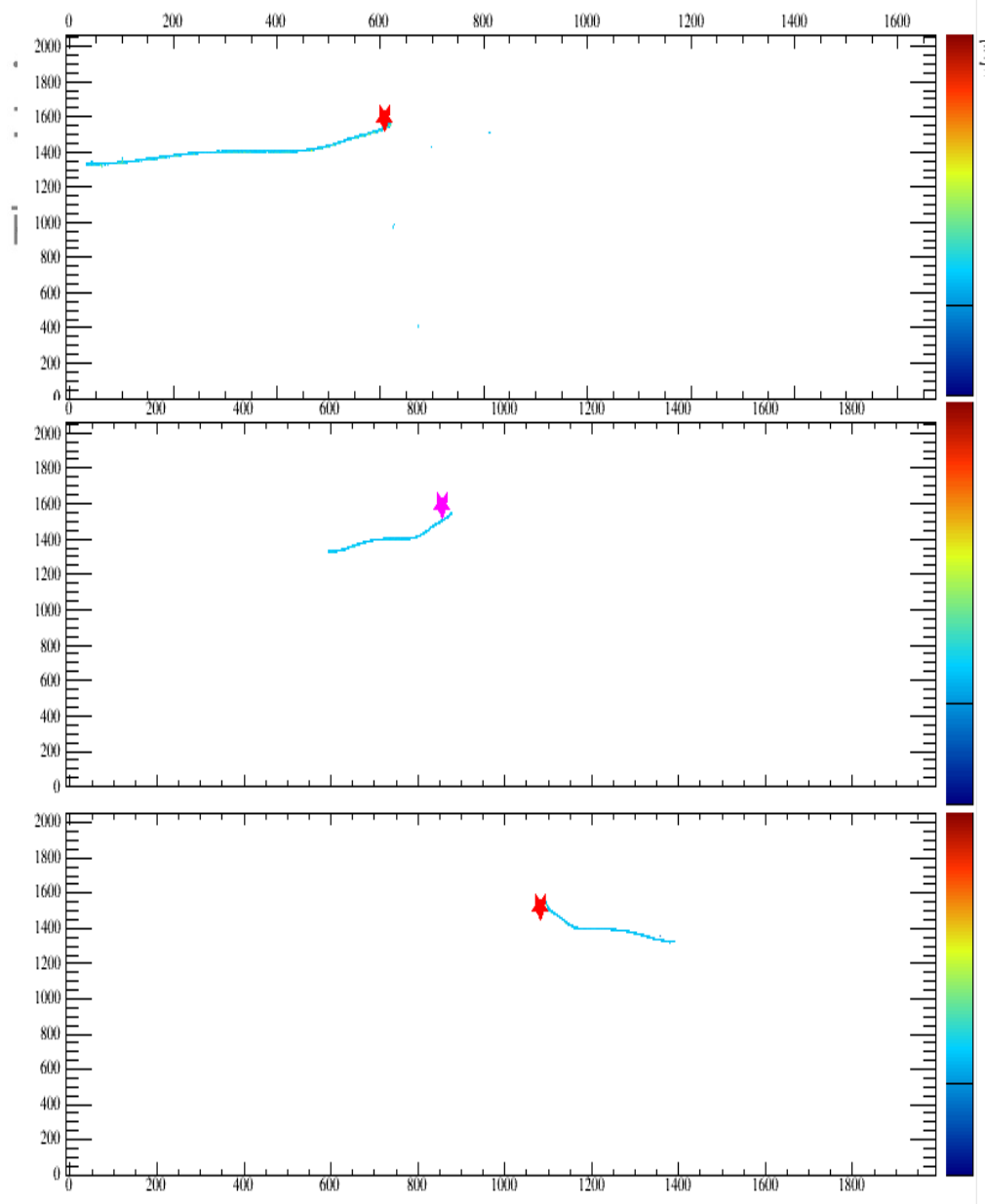
N2 absorption length,
B.J.P. Jones et al.

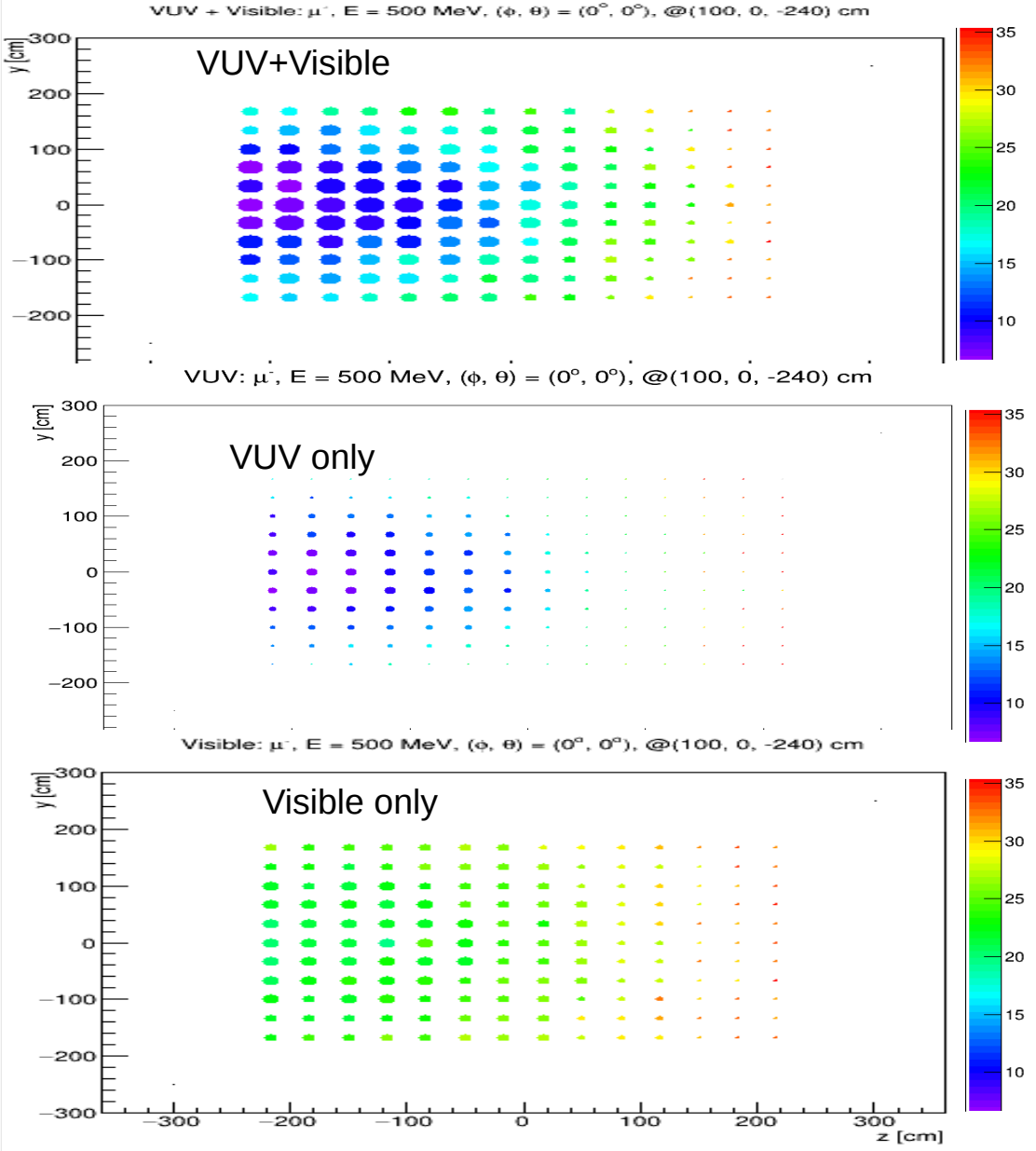
Stopping Muon (500 MeV)



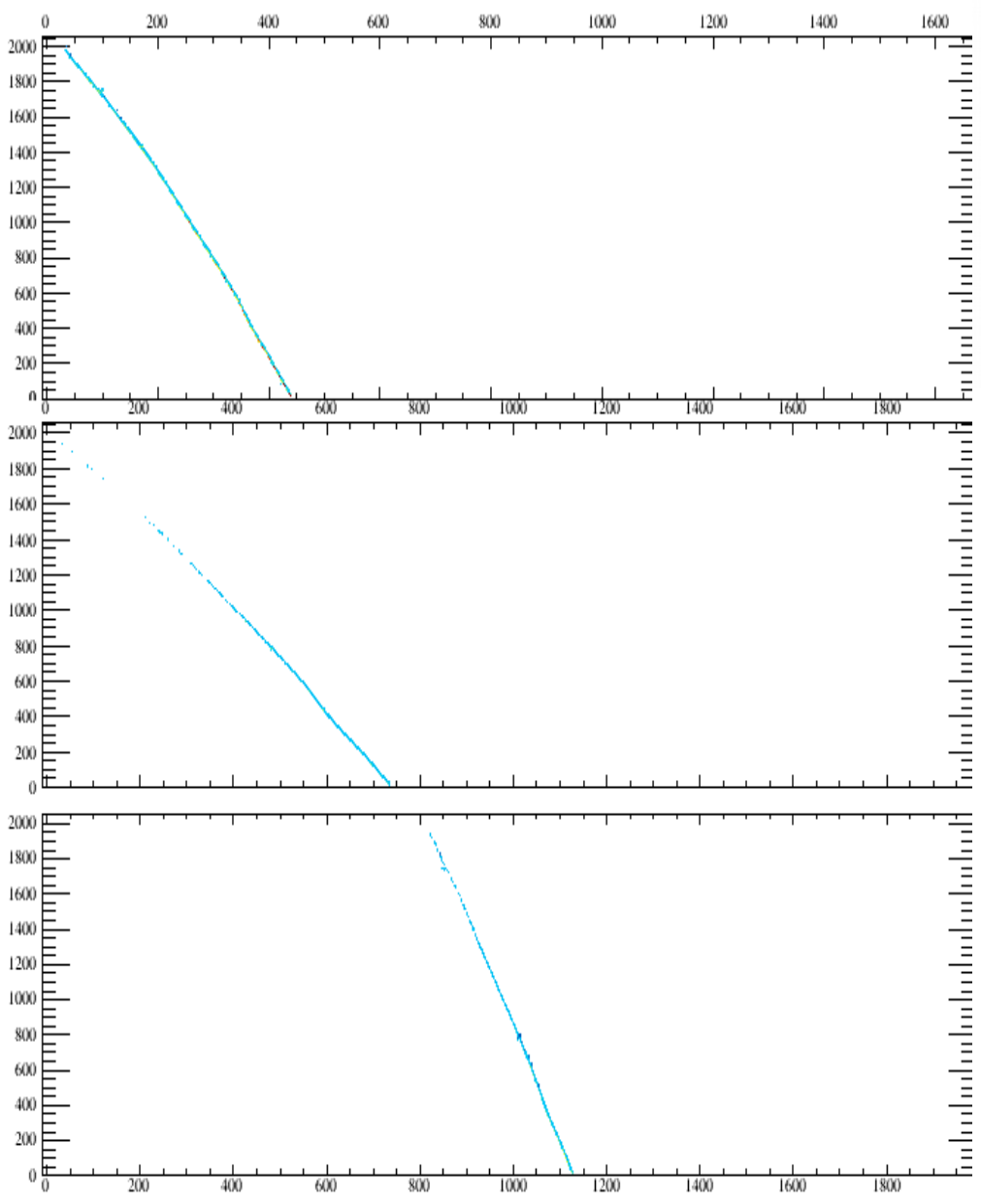


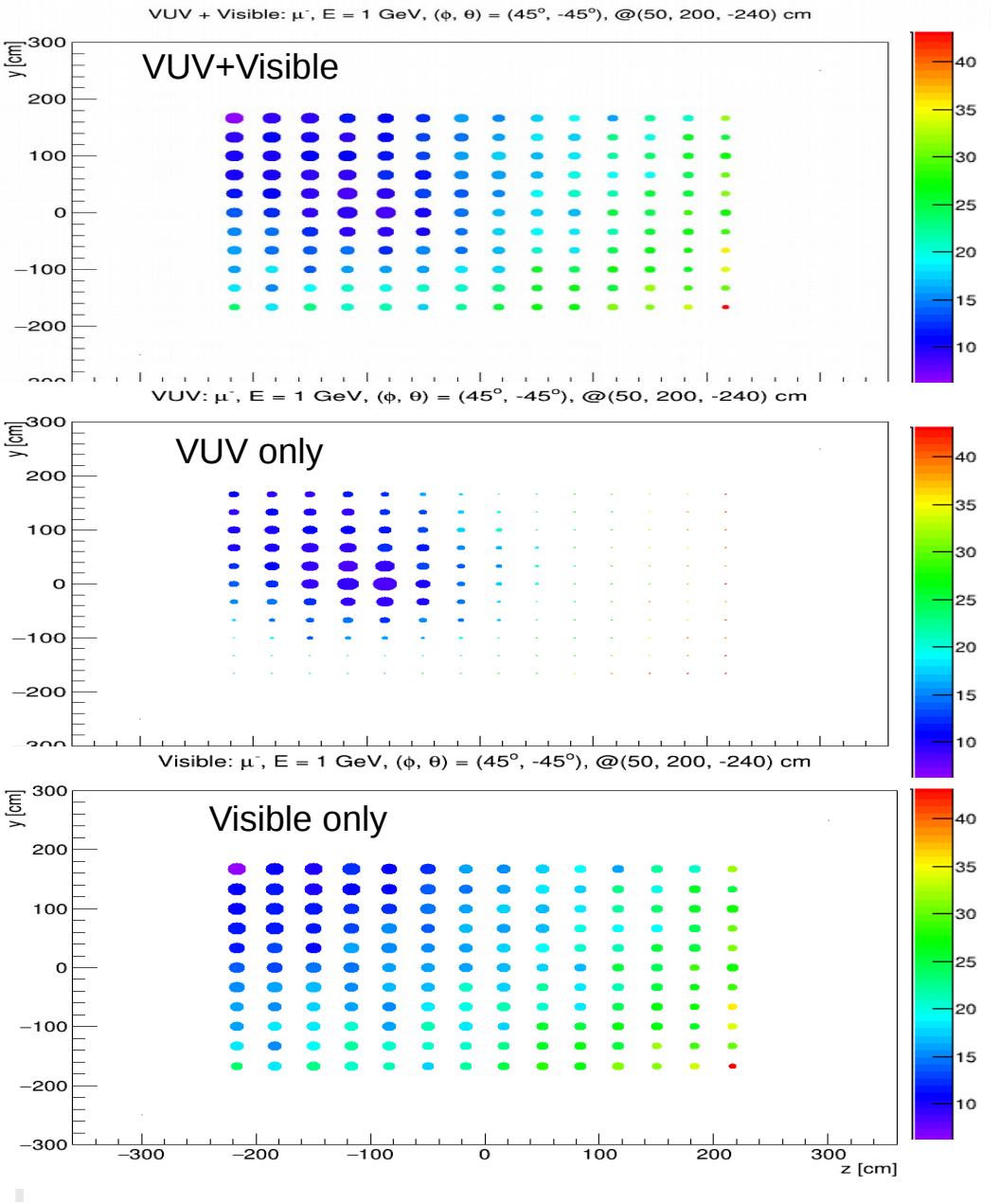
Stopping Muon (cathode only coverage)



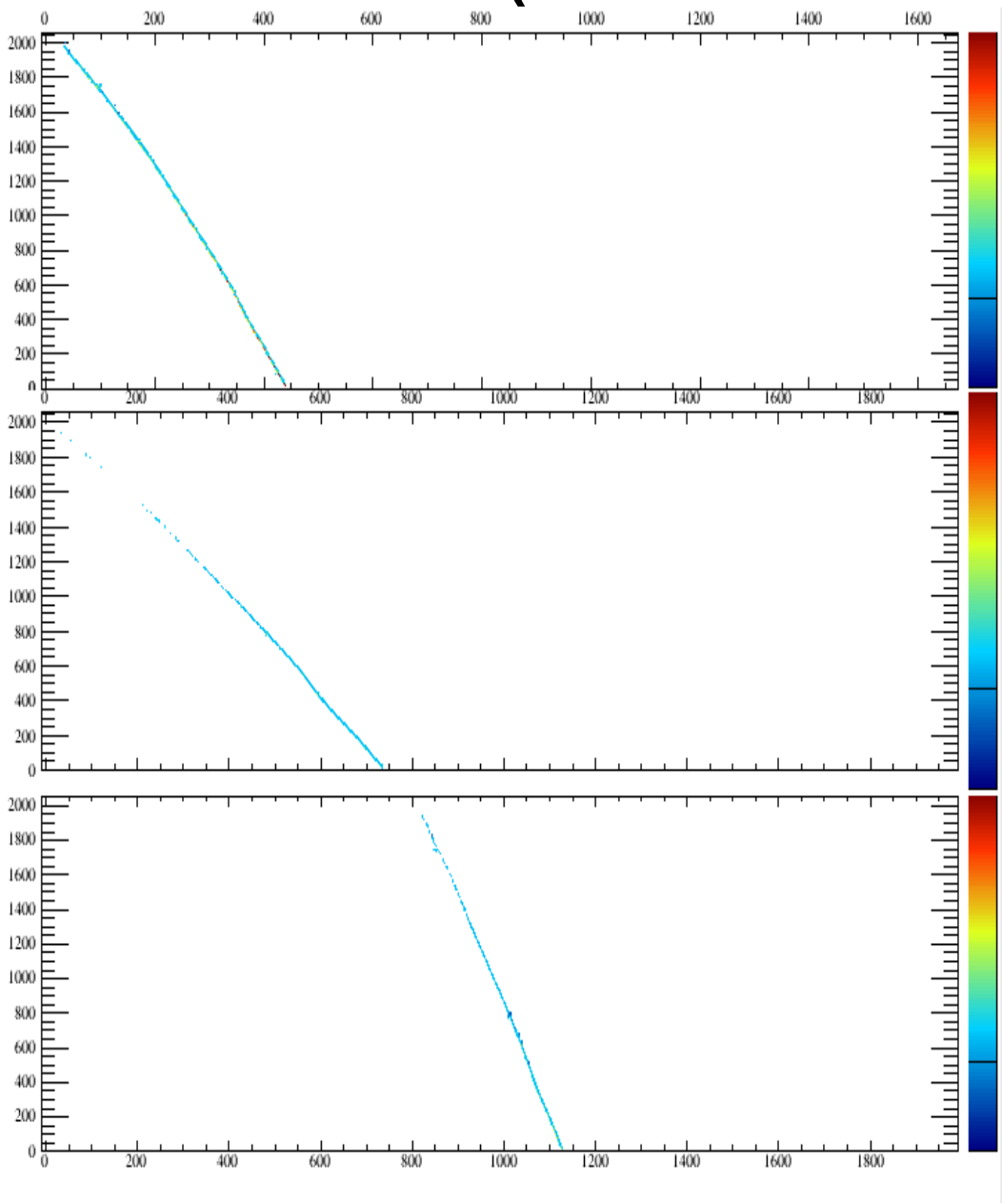


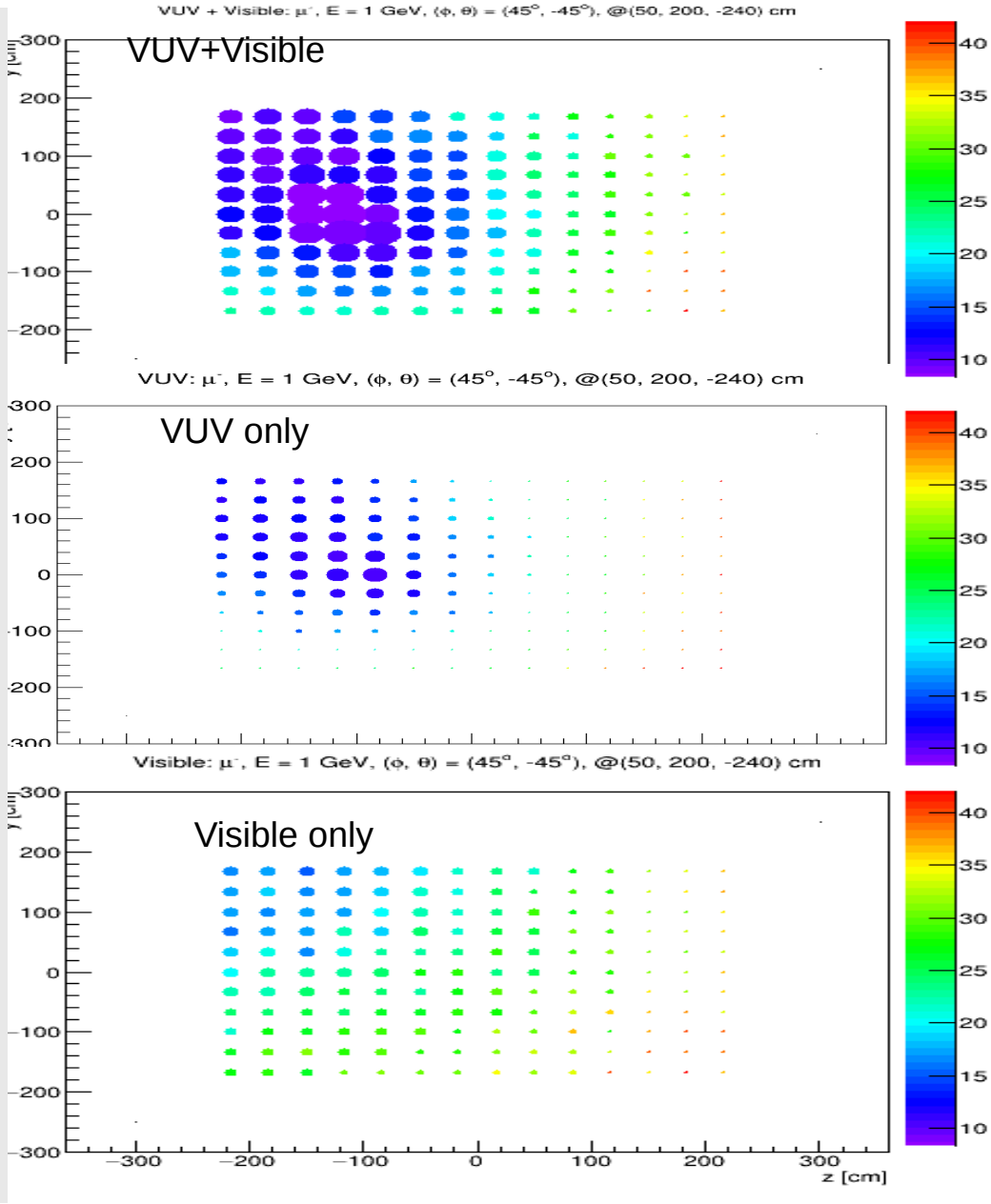
Diagonal muon



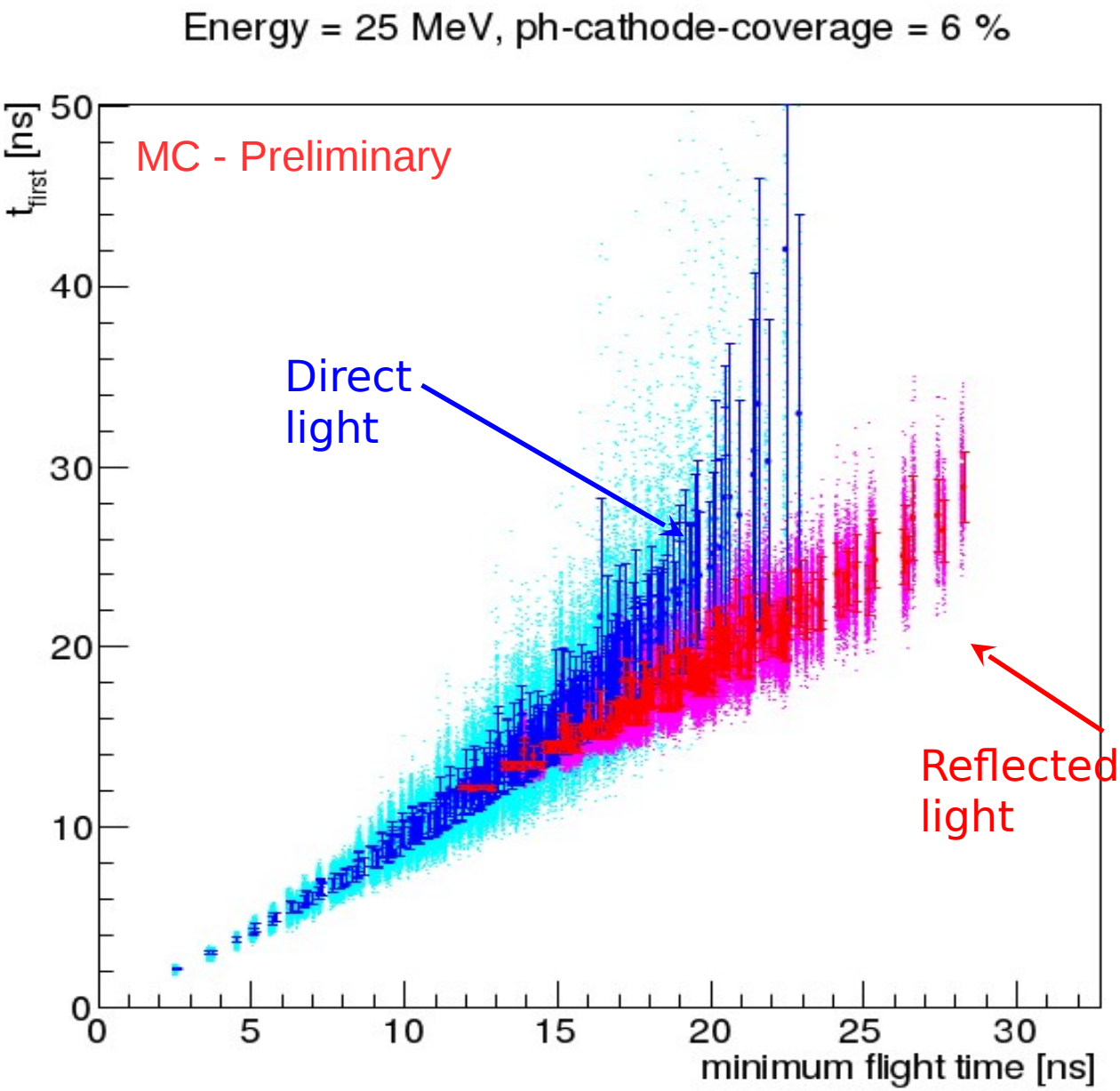


diagonal muon (cathode only)





Single PMT time resolution



Note that flight time scales differently wrt distance for reflected/visible and VUVlight.