MANCHESTER 1824

The University of Manchester

WLS Covered Foils in DUNE

-Motivation

Andrzej Szelc

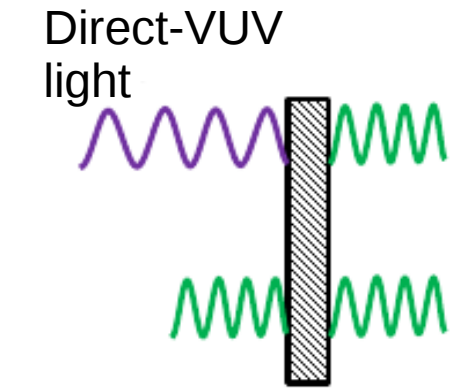
University of Manchester

Introduction

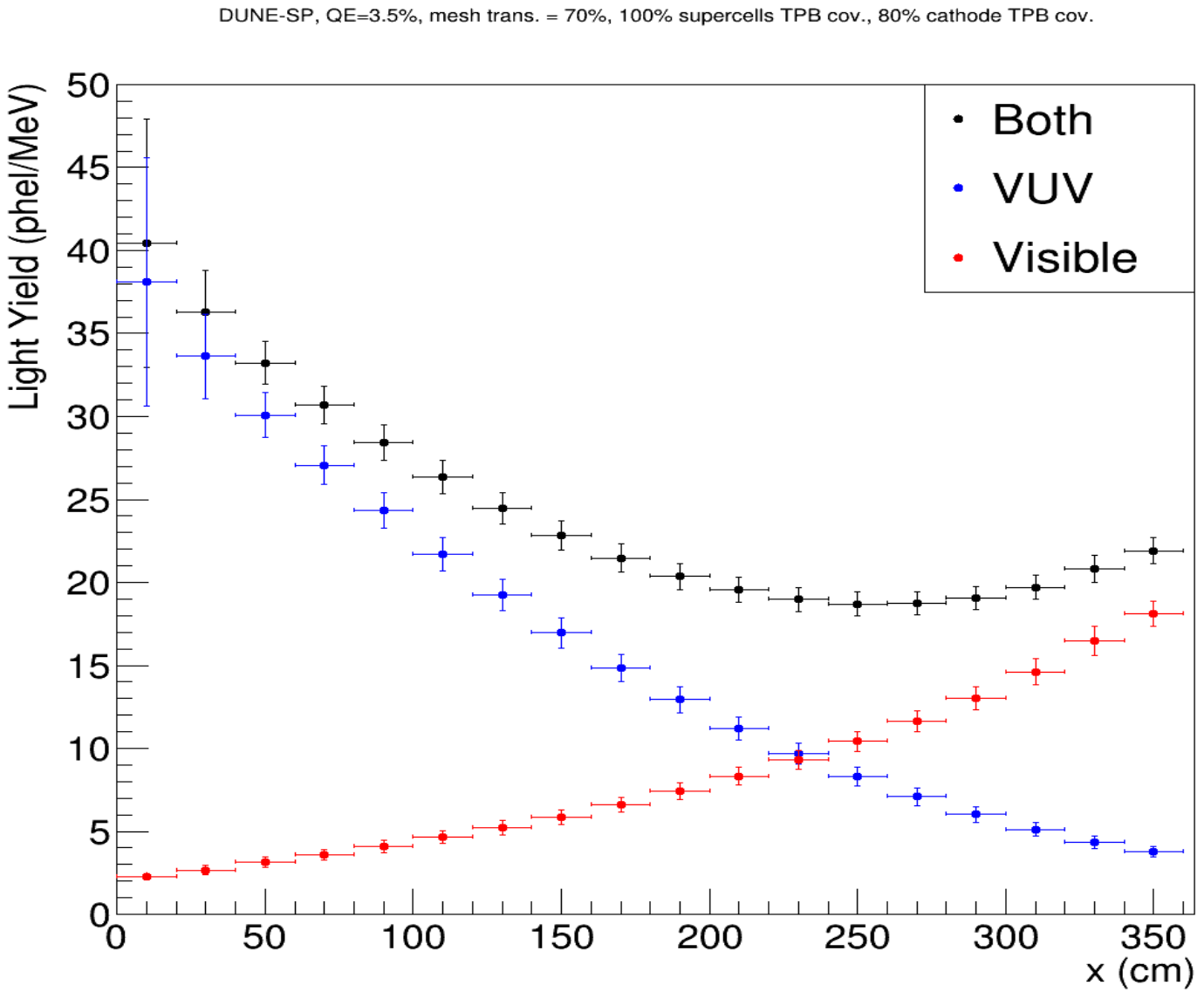
- Wavelength-shifter covered reflector foils installed on the CPA (or field-cage) can enhance the light collection efficiency in the DUNE far detectors.
- Would improve uniformity (useful for triggering), timing and potentially enable x-position resolution with light.
- Similar idea to solutions used by DM detectors. Already used by LArIAT and installed in SBND.
- Tests and measurements to find optimal solution for DUNE are ongoing.
- This talk will present the motivation and general principles, Marcin will talk about technical considerations.

Practical Things

- VUV light is absorbed by most materials – in the baseline SP design light impinging on the CPA is lost.
- Covering the CPA with reflective foils covered with a wavelength-shifter compound recovers this light.
- Most probable WLS to consider are:
  - TPB: known and used in large scale projects.
  - PEN: a new idea that would simplify engineering.
- To profit from this, the sensitive detectors need to be sensitive to visible light as well as VUV.
- The foils are di-electric, which means care needs to be taken they do not affect the CPA performance (if that's where you're installing).



Effect of foils



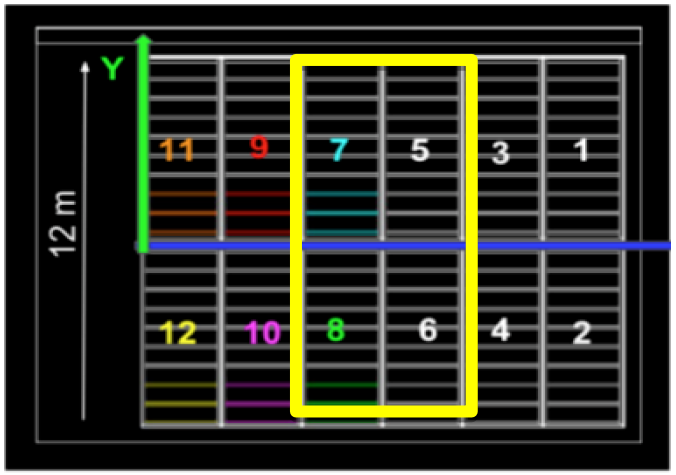
Assuming 3.5% ARAPUCA efficiency.

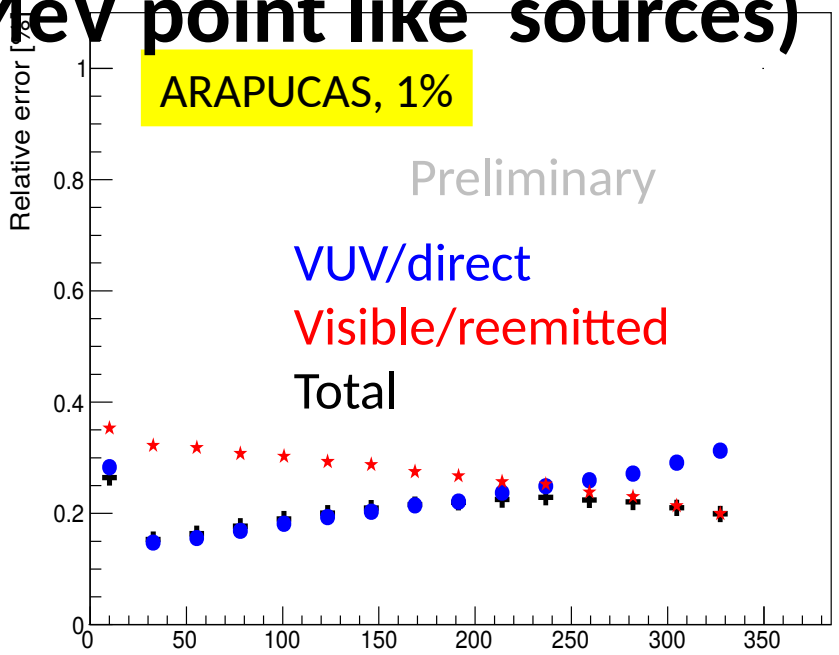
Applying measured transmittance of TPB coated glass

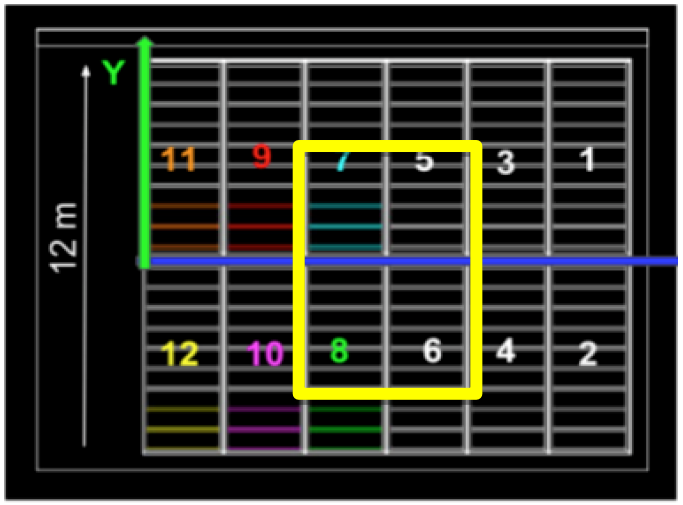
Assuming 80% cathode coverage (potentially conservative)

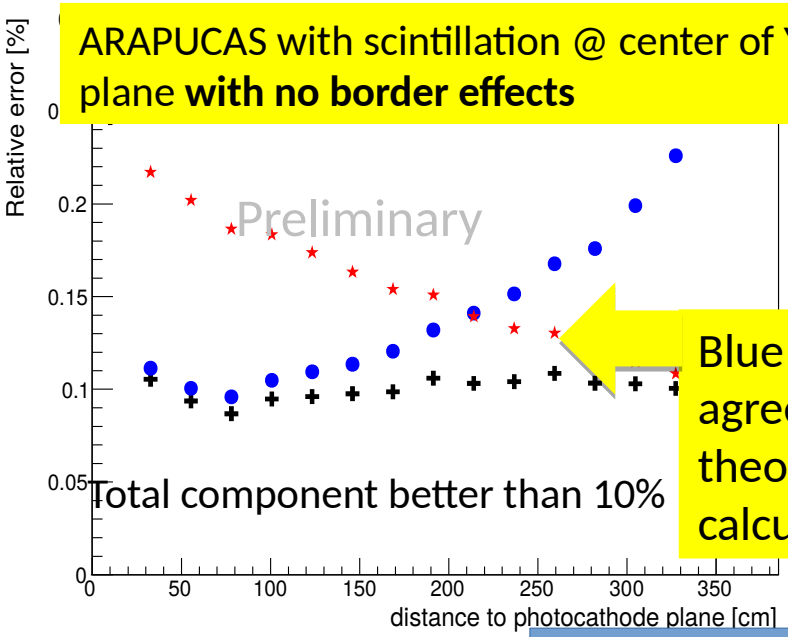
P. Green

Supernova calorimetry? (10 MeV point like sources)





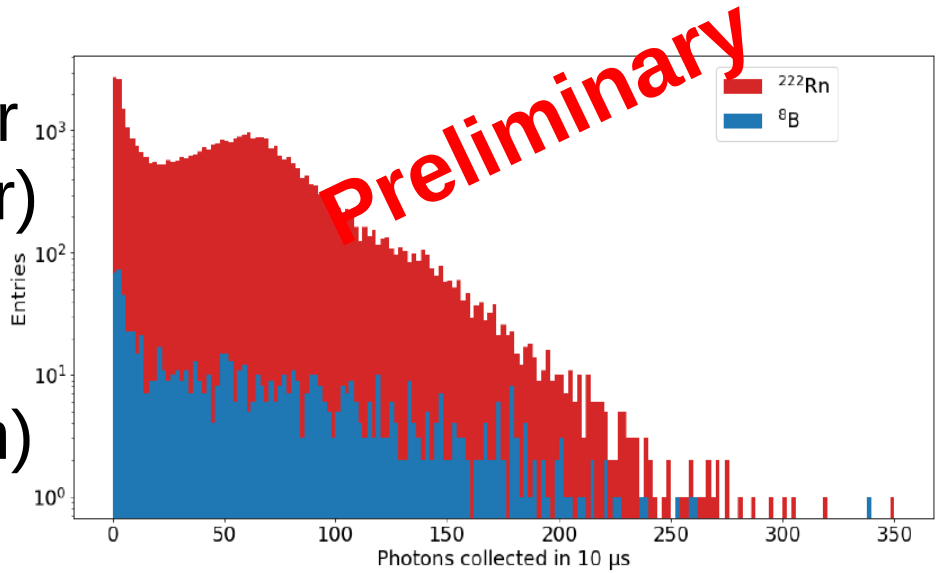


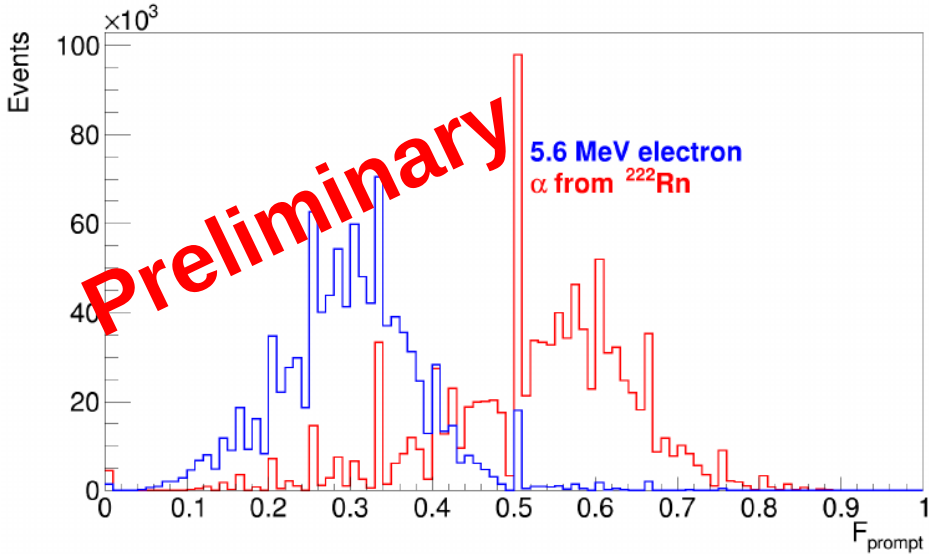


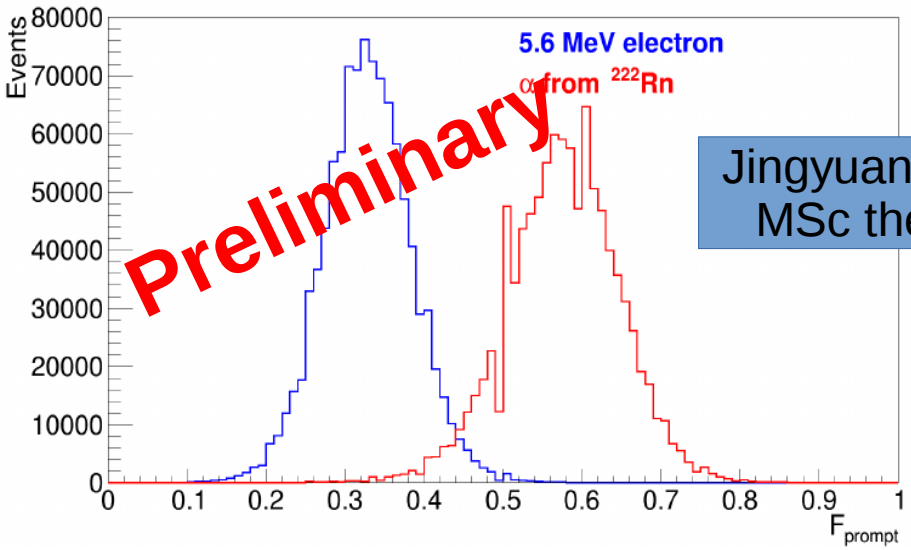
Rejecting alpha backgrounds for low energy ν_e searches

Alphas, are a big background for low energy ν searches (e.g. solar)

Can use pulse shape discrimination, but more (uniform) light helps.





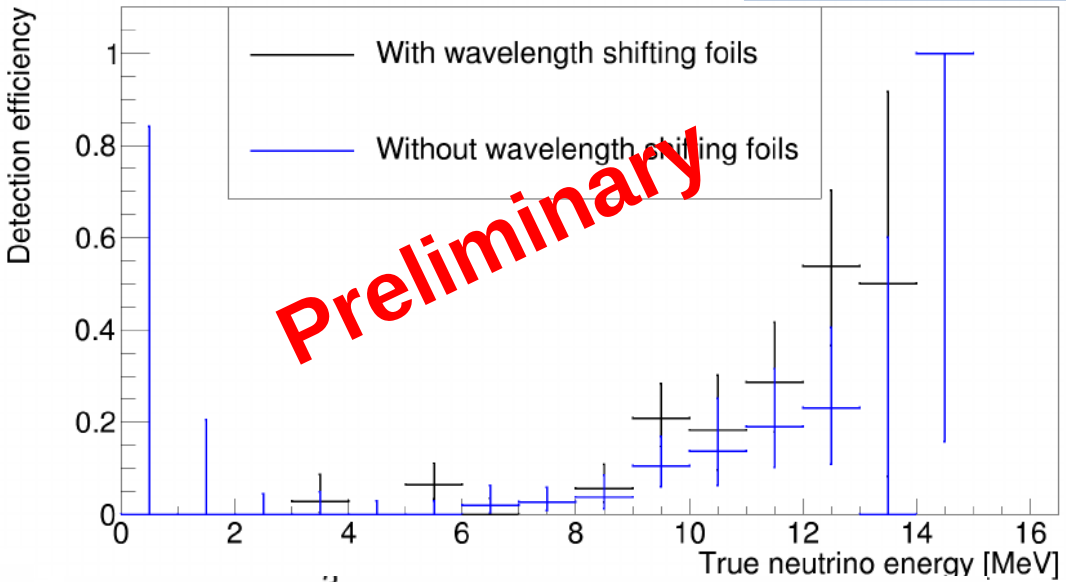


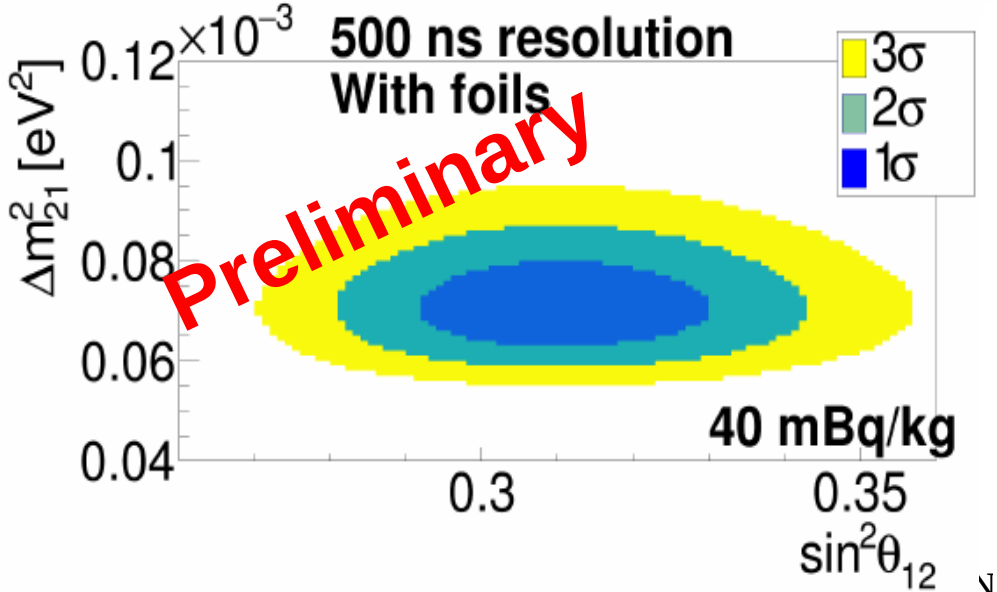
Jingyuan Shi, MSc thesis

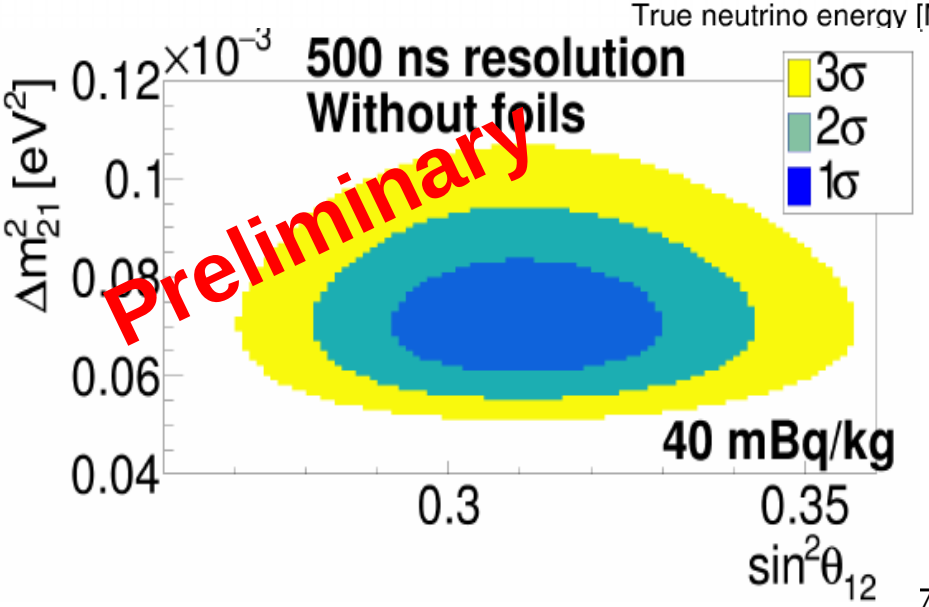
Effect on a solar neutrino search

- Study performed using DUNE radiologicals and a ToyMC to propagate light signals.
- Foils improve detection efficiency and resolution mass splitting.

Jingyuan Shi, MSc thesis



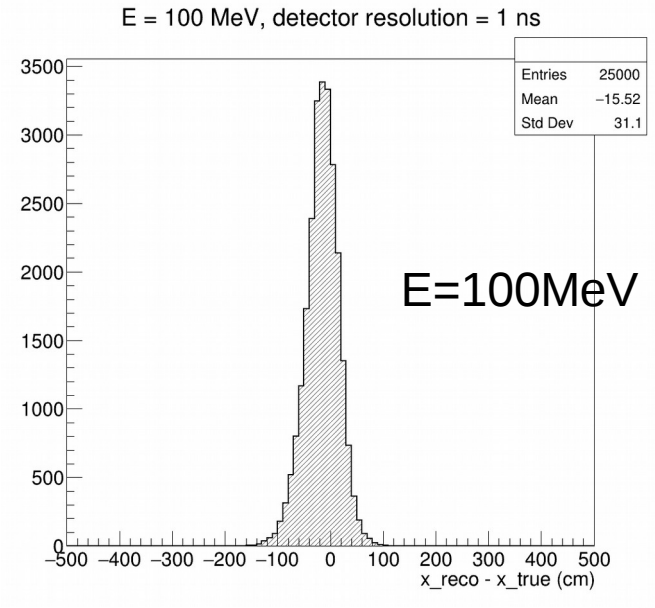


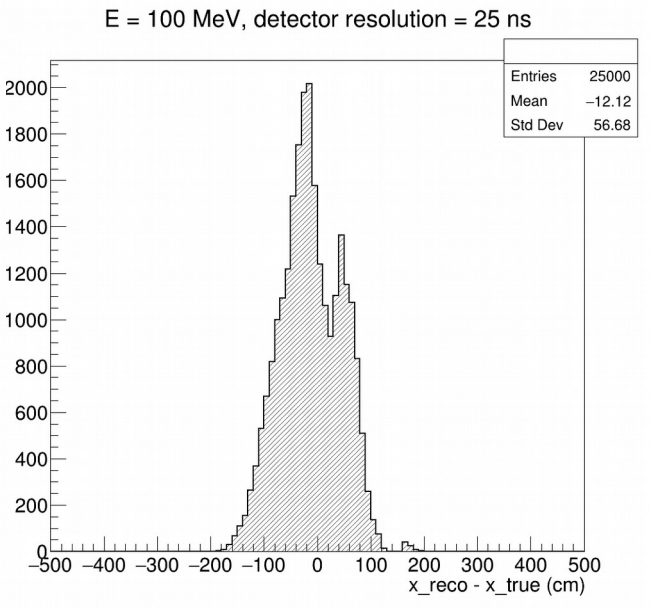


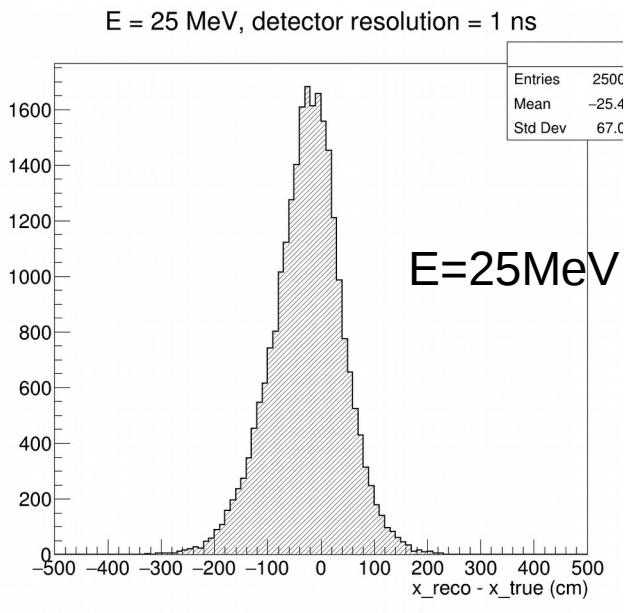
X-drift position resolution

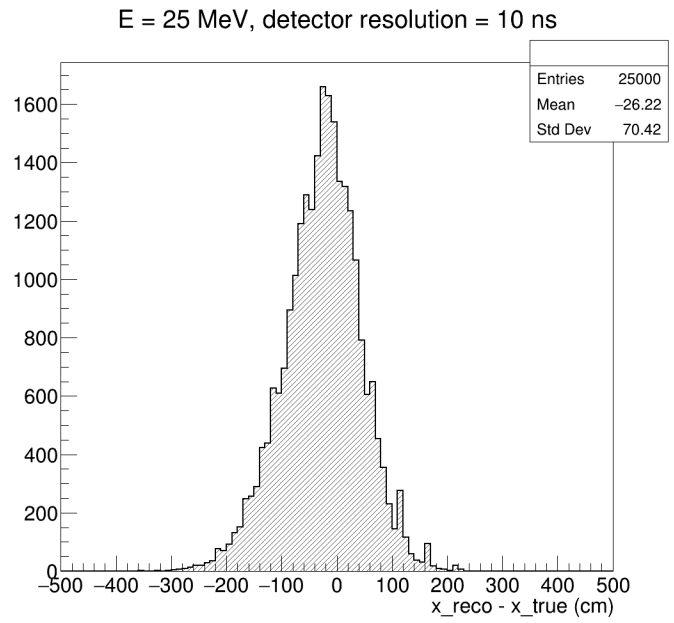
- If able to differentiate VUV from Visible (re-emitted) possible to get position in x “on the fly”.
- Additional handle to disentangle multiple events in the same frame.
- Needs good timing resolution, to achieve position resolution of o(10cm)

With ARAPUCAs can obtain this effect by leaving some detectors uncoated with WLS.









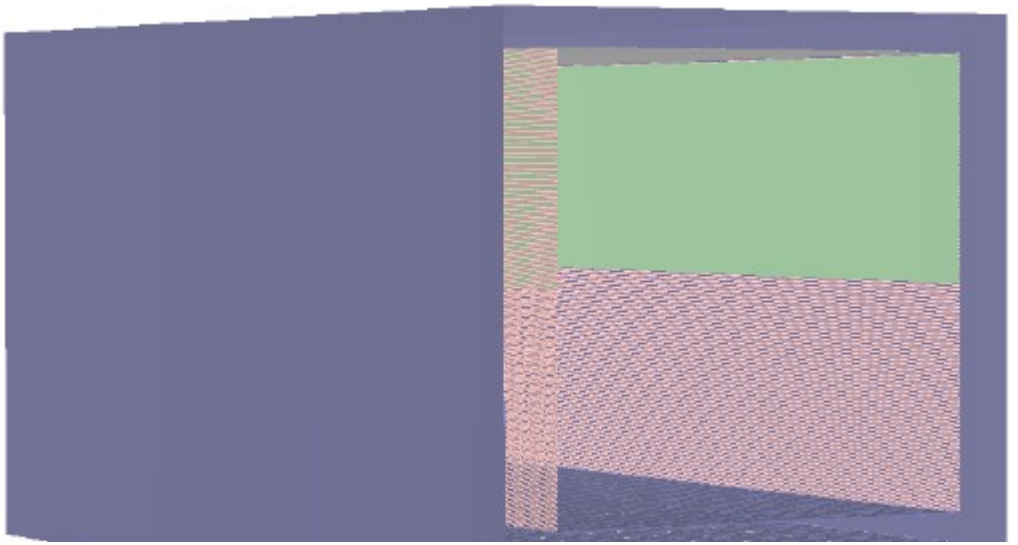
P. Green

Foils in DUNE (SP)

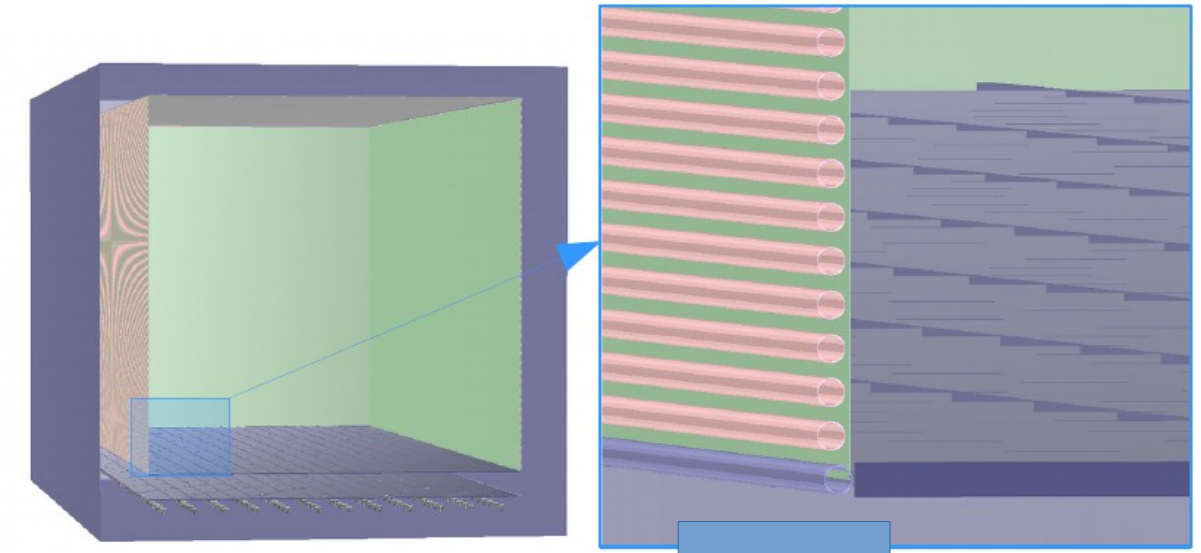
- The main items to understand:
  - Compatibility with the HV system.
  - Sensitivity of light detectors (ARAPUCA/X-ARAPUCA) to visible light.
  - Engineering and installation procedures.

Foils in DUNE DP

Double Phase consortium considering adding WLS-coated reflector foils on the field cage walls.



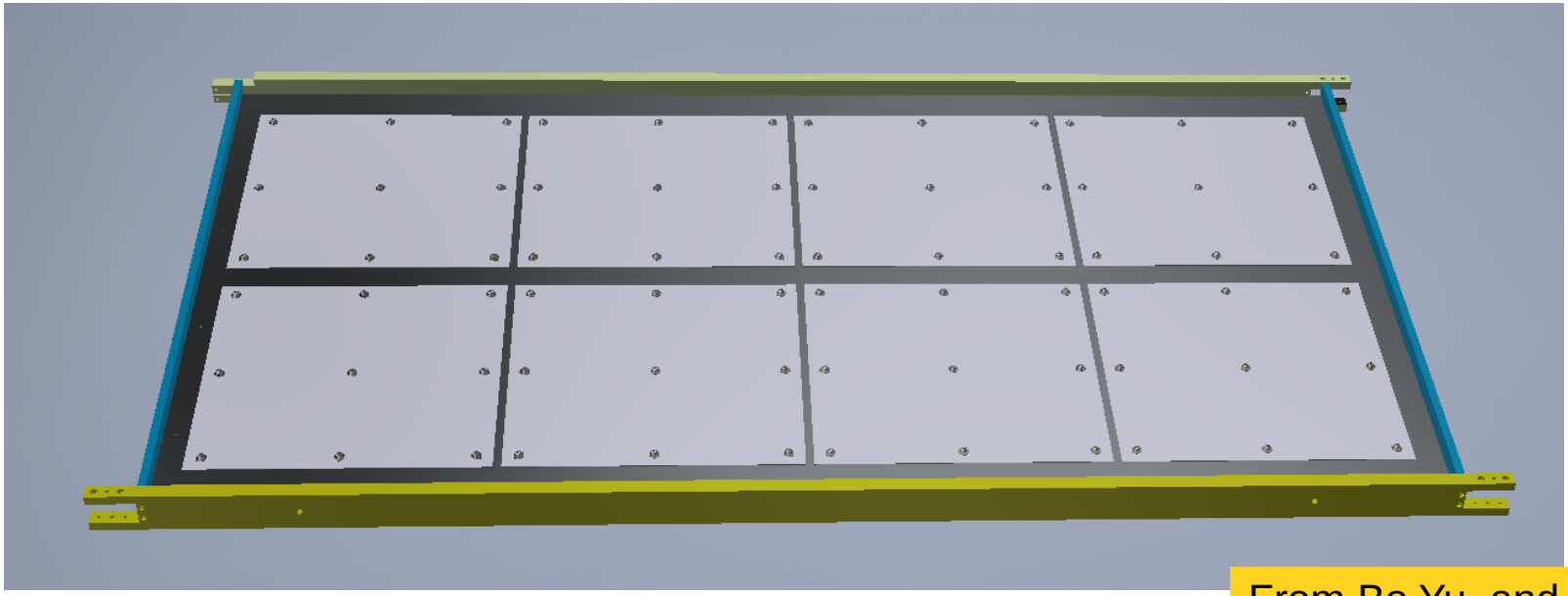
Half of detector (away from PMTs) help uniformity of light collection.



J.Soto

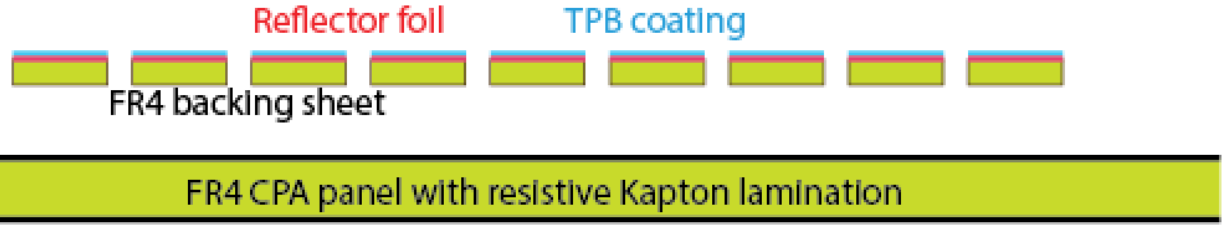
How to mount foils on the CPA (SP)

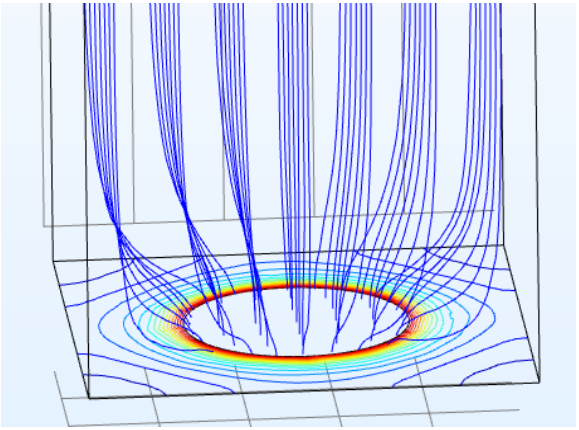
- The goal is to minimize the impact on the CPA construction. The reflector foils could be implemented post CPA production.
- The preferred solution is to maintain the current CPA design, and include a set of attachment holes on each CPA resistive panel to allow the installation of reflector foils in smaller tiles on both sides of the CPA surfaces at ITF or in the UG cleanroom.



From Bo Yu, and Francesco Pietropaolo

Reflector mounting options:





Potential distribution on a 1cm square cell with 5mm hole. The maximum voltage at the corners of the cell is 290V.

Reduces coverage, but electric field goes back to normal quickly.

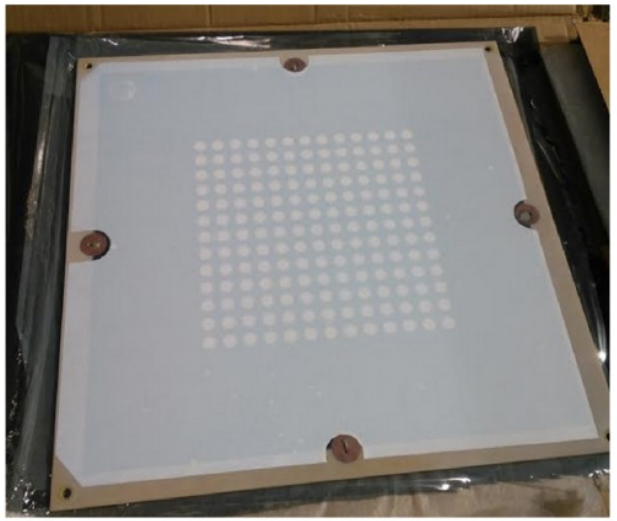
Preliminary measurements by F. Pietropaolo at CERN
Show v. high, but finite resistivity – may not need perforation.

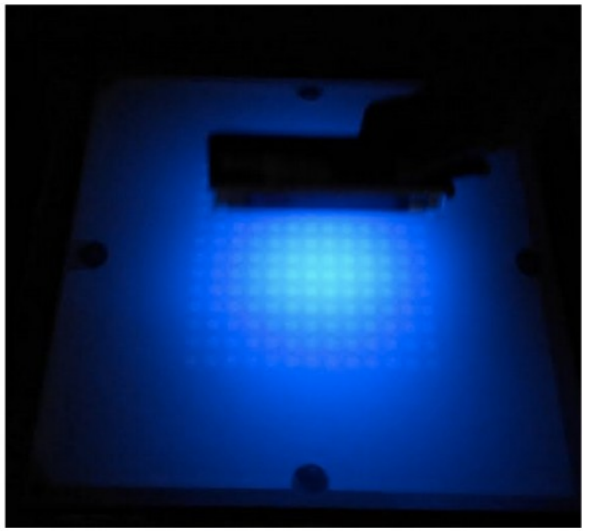
From Bo Yu, and Francesco Pietropaolo

The size and density of these perforations and whether they are needed is under study

Tests at CERN test stand (Foil – CPA, HV Compatibility)

- Runs taken in the CERN 50 l dewar (FLIC).
- Look for discharges and space-charge effects.
- Ran with TPB coated foils, PEN-coated foils and no WLS.

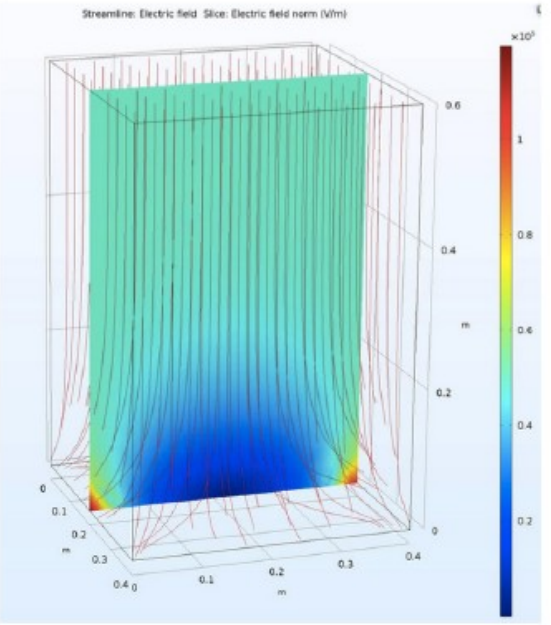




Courtesy of B. Bilki

Preliminary Results from Tests with FLIC

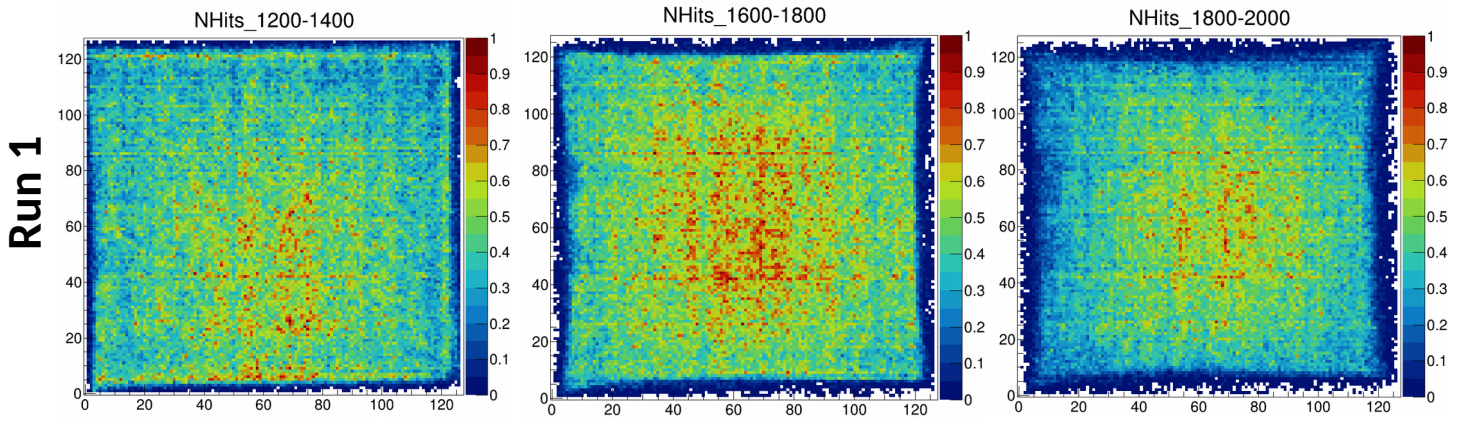
- TPC ran with foils on the cathode, without major issues.
- Tracks were observed.
- Hints of lensing effects expected from charge build up have been seen. (analysis in progress).



B. Yu

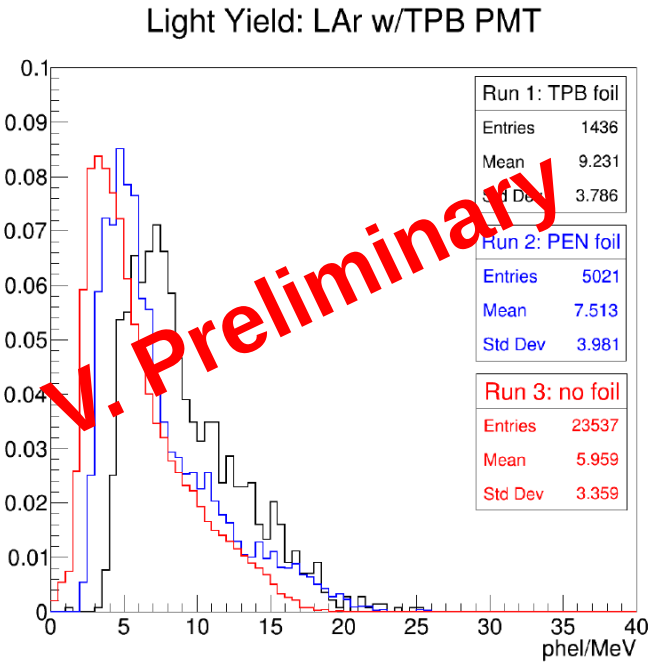
anode

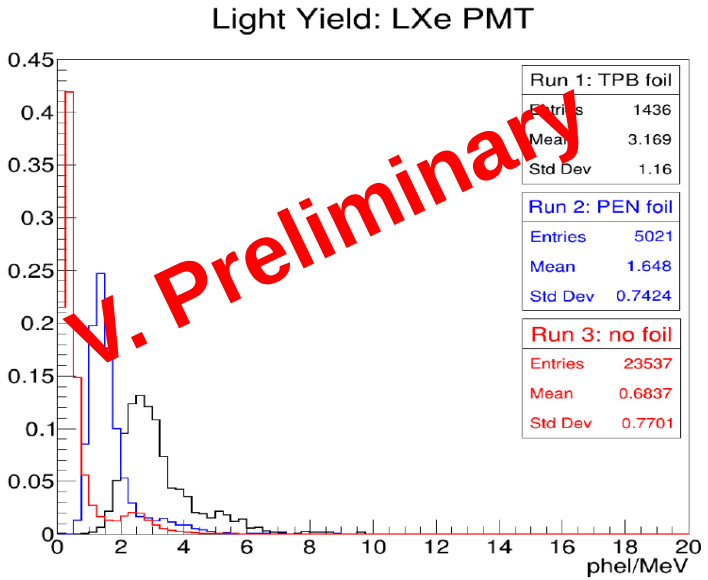
cathode



Courtesy of B. Bilki

Preliminary results from CERN tests





- Comparing LY of TPB-coated, PEN-coated and no foil setups.
- **V. Preliminary** analysis shows about a 50% efficiency loss of PEN wrt. To TPB.
- Not all effects are taken into account correctly yet (e.g. Cherenkov light reflected on walls, etc.)

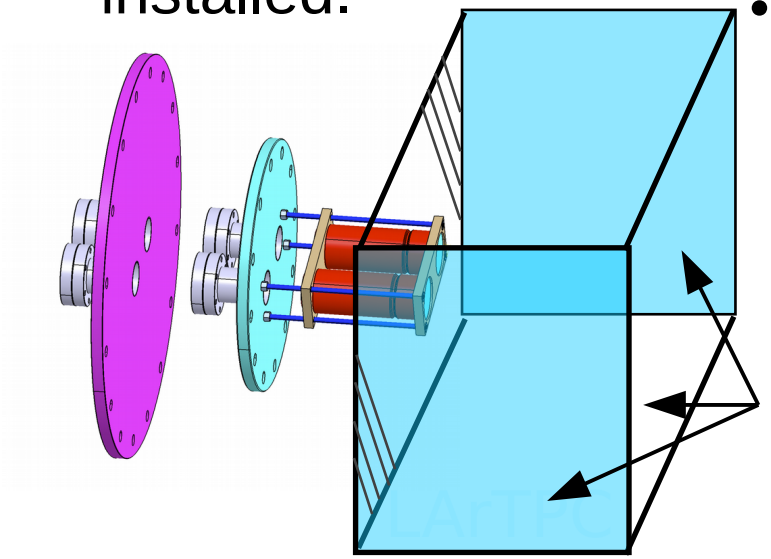
Conclusions

- Wavelength-Shifter covered reflector foils can improve the DUNE Light Collection System performance, especially far away from PMTs.
- Improvement in low energy physics reconstruction, and opening possibility to use for X-position reconstruction on the fly.
- R&D needed to ensure it works in DUNE is underway.
- The production technology is understood, and has been employed in relatively large scale projects before, but scaling up to DUNE is not trivial (see next talk by Marcin)

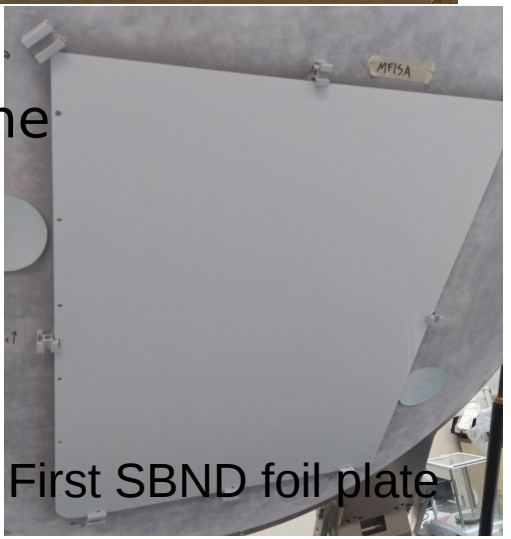
Backup

Foils in SBND/LArIAT

- LArIAT, a test beam experiment has completed three full runs with WLS-covered foils installed.

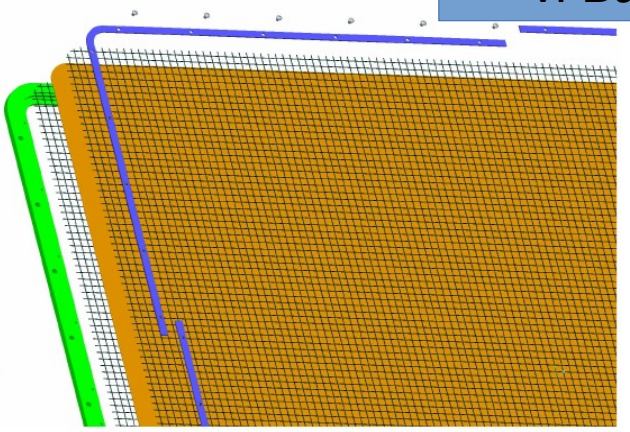


- SBND will implement WLS-covered reflector foils on the cathode to improve light collection.
- Sandwiched between two layers of metallic mesh.
- Production is halfway complete.



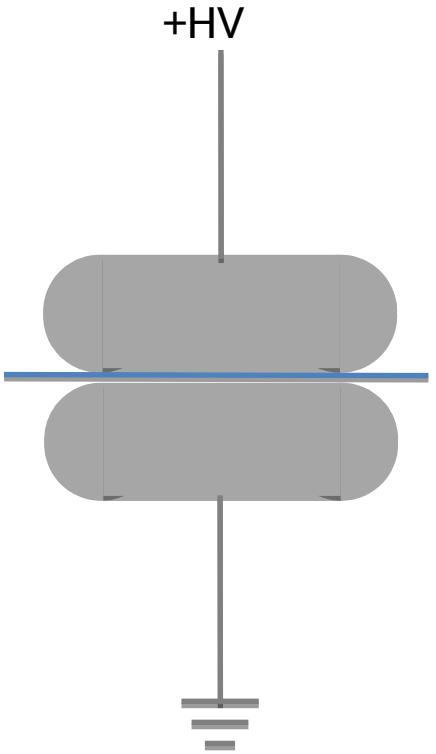
First SBND foil plate

V. Basque



How do we know the foils are dielectric?

- foils on cathode will need to tolerate some charge build-up or voltage variation
  - eg 0.5 cm perforations lead to 300 V variation on foil surface (from simulations)
- Checked HV breakdown strength across film/foil samples submerged in LN
  - samples sandwiched between 6 cm diameter electrodes
  - stepped up voltage until breakdown occurred



Material	Voltage Breakdown
ViKuity TPB coated	>40.0 kV
PEN film	22.5 kV
DM2000 non coated	46.3 kV

Clark Griffith, Sussex

Effects on timing constants

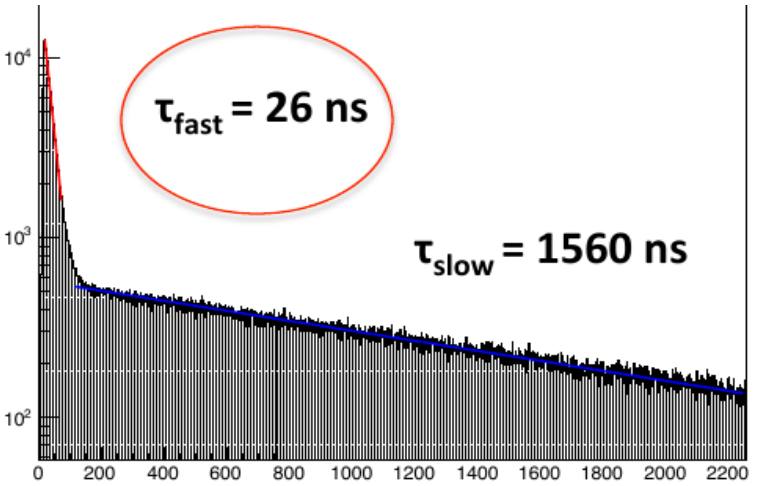
Scintillation:

0.3 x τ_{fast}(6 ns) + 0.7 x τ_{slow}(1590 ns)

+

Propagation:

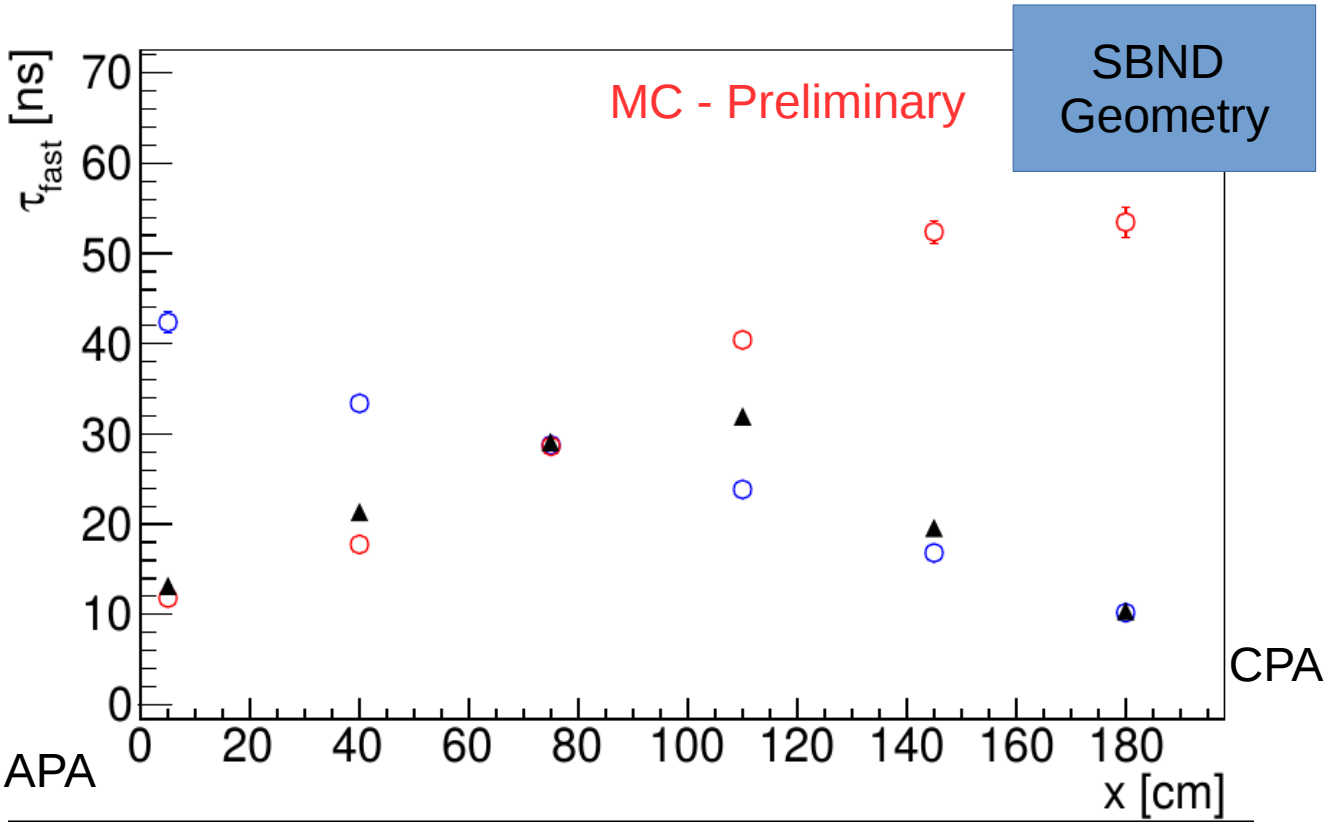
Direct transportation + Rayleight Scattering



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.



Can we do SN calorimetry?

(slides in indico)

Alex Himmel, Fermilab

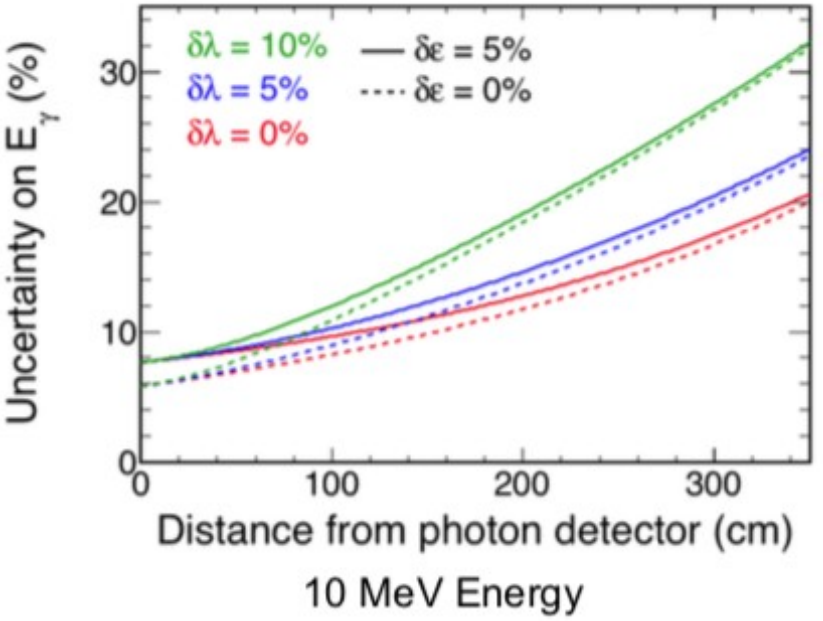
PD Consortium Sim+Physics Meeting

March 23rd, 2018

(best current ARAPUCA expectations)

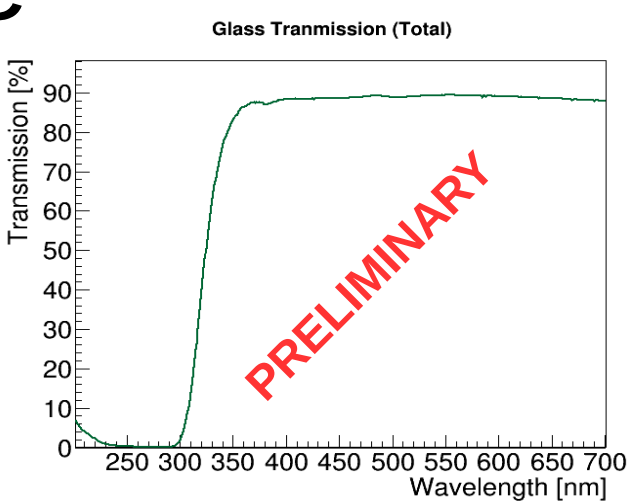
$$\frac{\delta E_\gamma}{E_\gamma} = \frac{1}{\sqrt{N_\gamma}} \oplus \frac{\delta x}{\lambda} \oplus \frac{x}{\lambda}\left(\frac{\delta\lambda}{\lambda}\right) \oplus \frac{\delta\varepsilon}{\varepsilon}$$

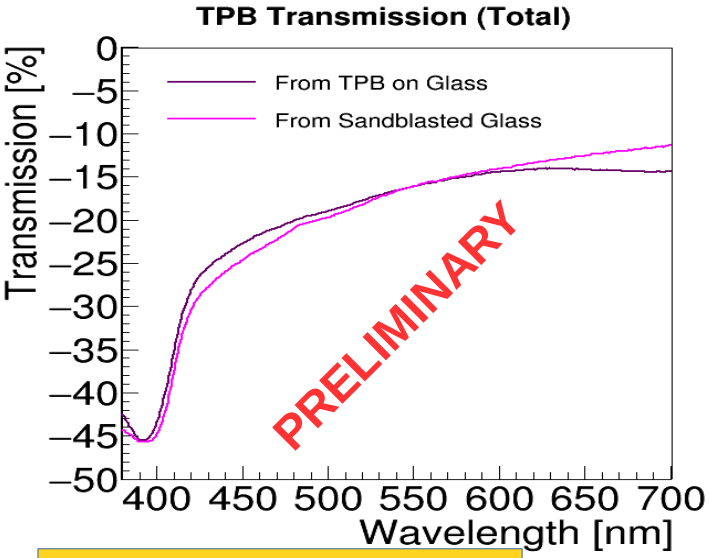
- Photon counting statistics
- Uncertainty on position, relative to attenuation length.
- Uncertainty on attenuation correction.
- Uncertainty on efficiency and yield.



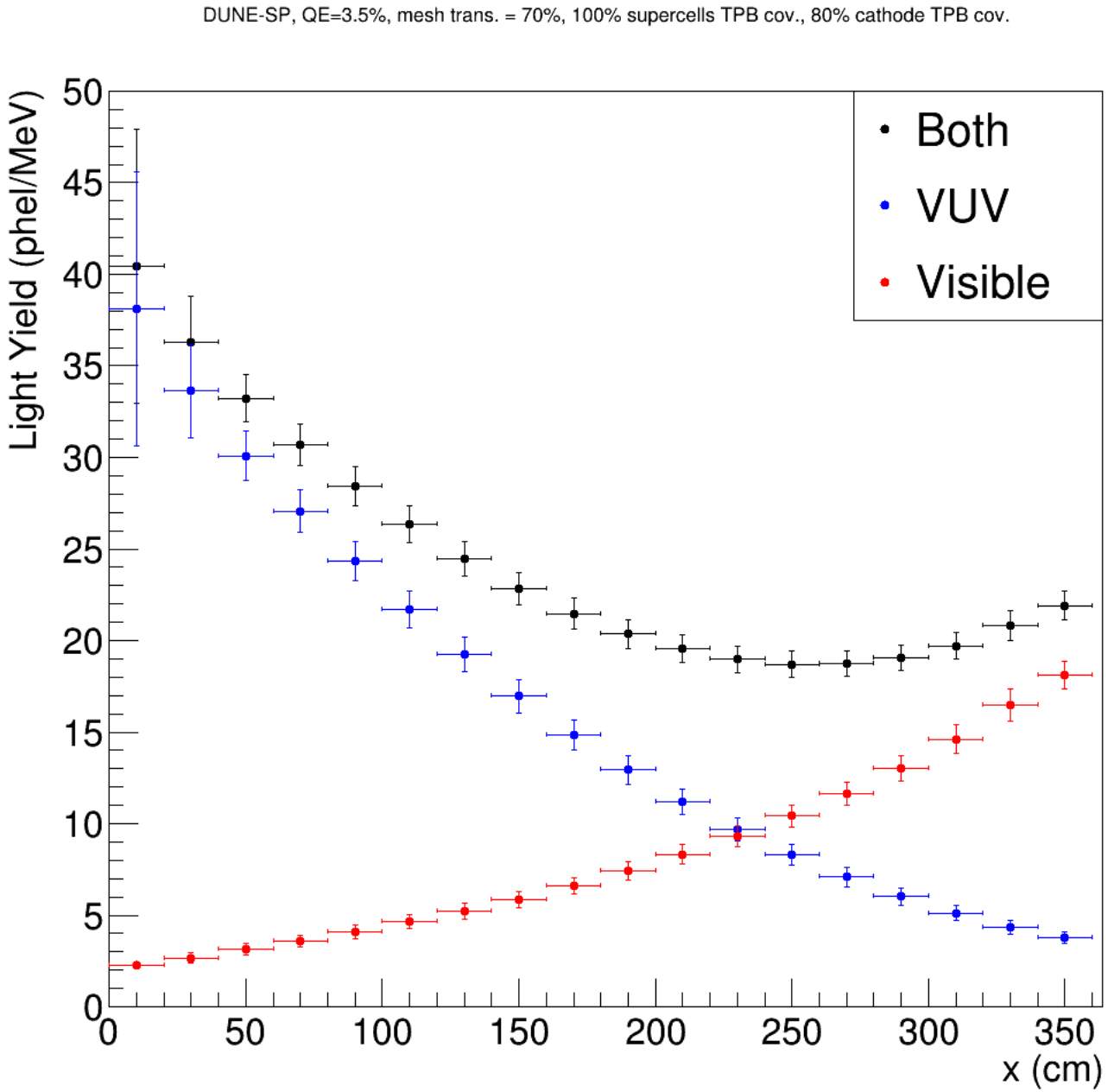
Measurements of Transmittance/Reflectance to Visible

- Performing a suite of measurements to benchmark the transmittance and reflectivity of various detector elements glass, filters, foils, acrylic (and the effect of TPB and PEN coverage).
- Will try to expand to pTp.
- Currently measuring at visible Wavelengths.
- May expand to VUV later this month with UNICAMP setup.





S. Cotton, C. Harrison, Manchester


DUNE-SP, QE=3.5%, mesh trans. = 70%, 100% supercells TPB cov., 80% cathode TPB cov.
Light Yield (phel/MeV)
x (cm)
Both
VUV
Visible
0
5
10
15
20
25
30
35
40
45
50
0
50
100
150
200
250
300
350