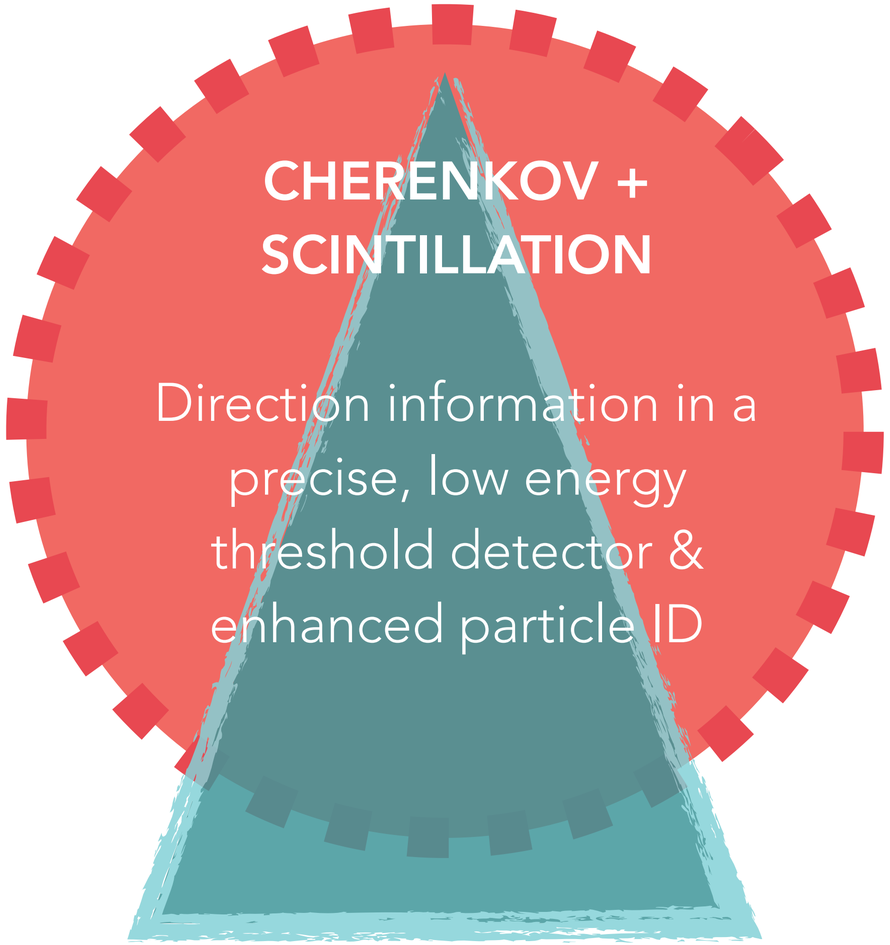
Stony Brook University, November 2019

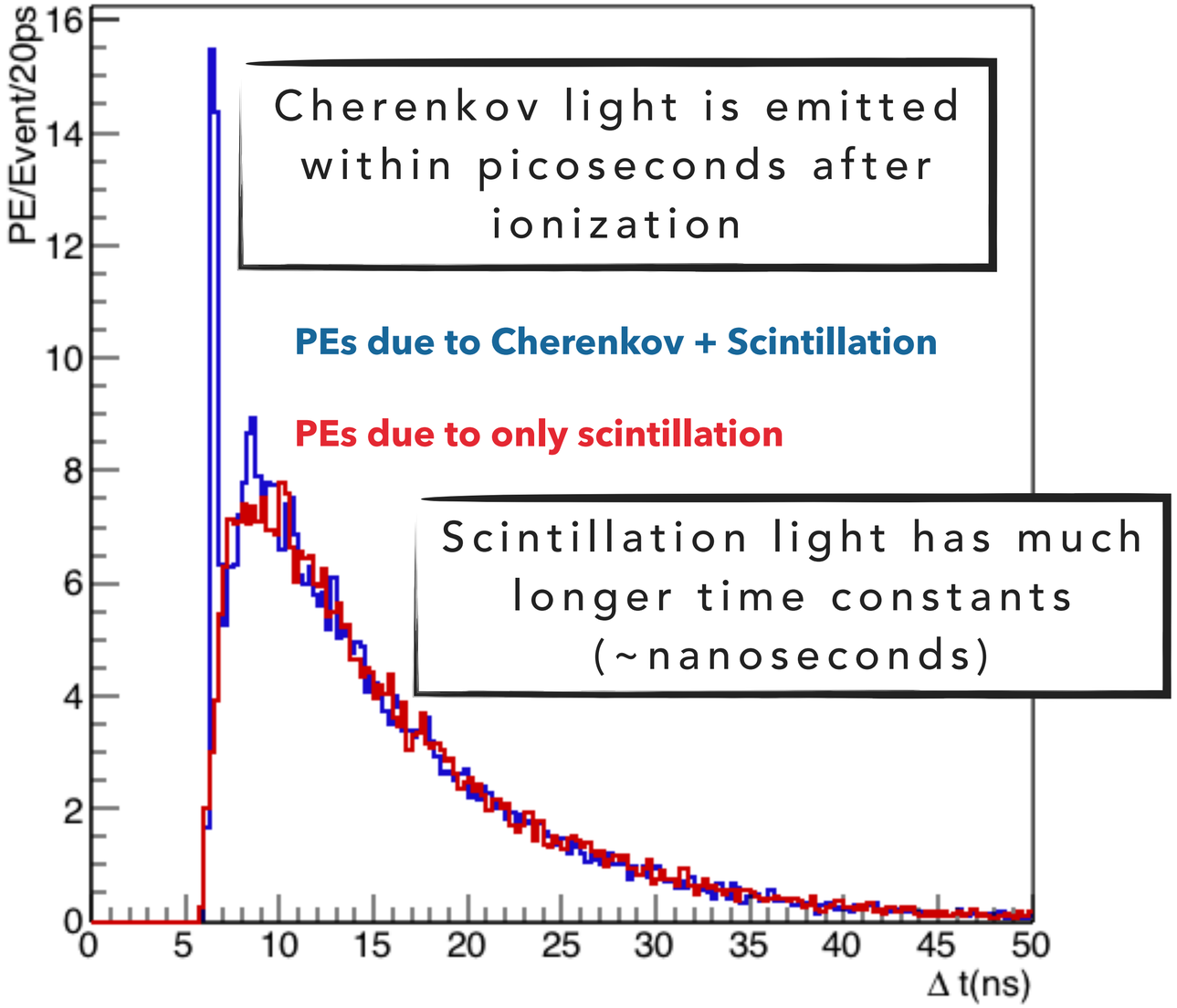
JAVIER CARAVACA

B. LAND, F. DESCAMPS, J. WALLIG, G. OREBI GANN

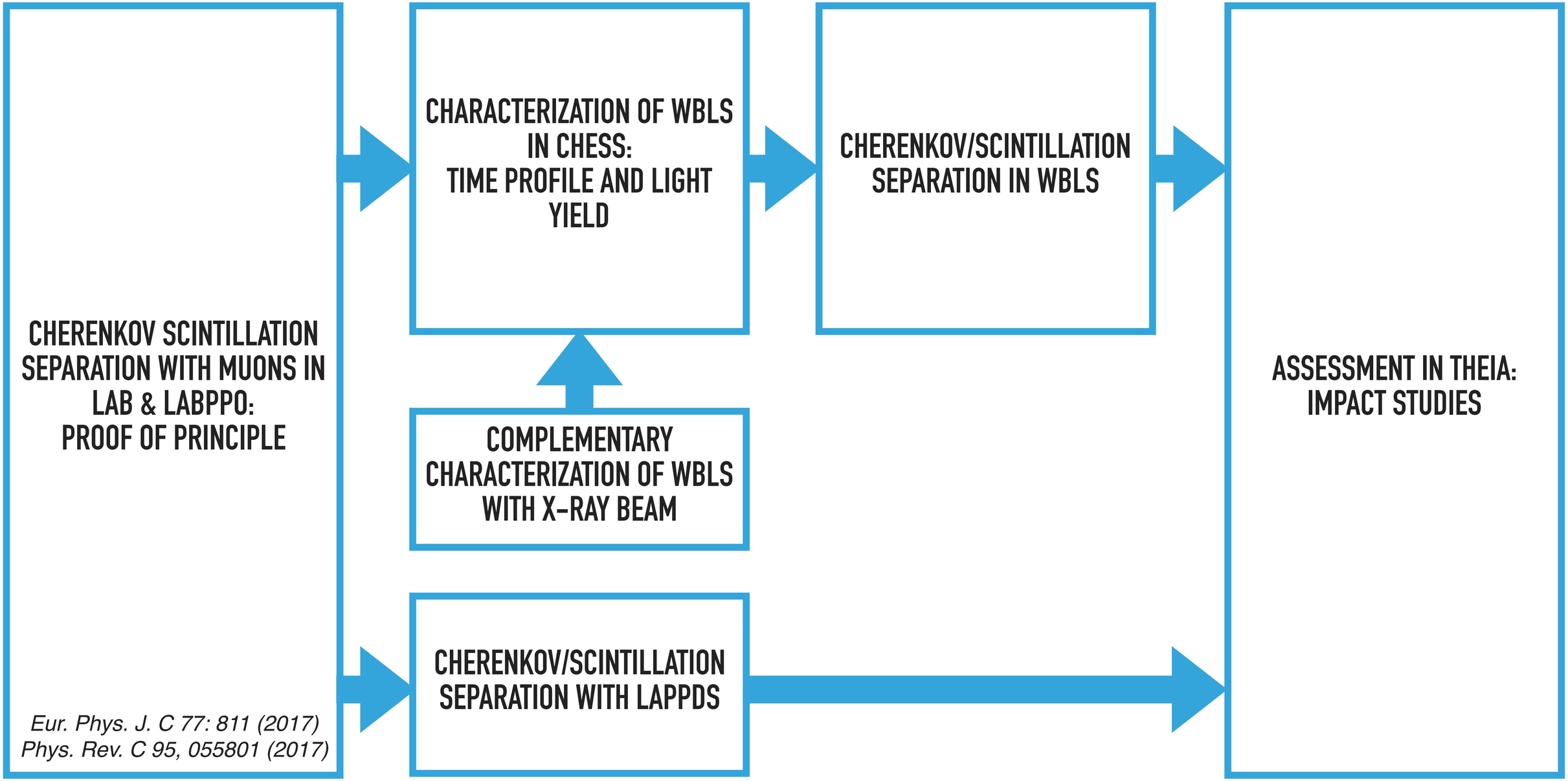
CHESS WITH WbLS: PRELIMINARY RESULTS AND STATUS

THE CHESS APPROACH: CHERENKOV/SCINTILLATION SEPARATION ATTENDING TO THE TIMING FEATURE



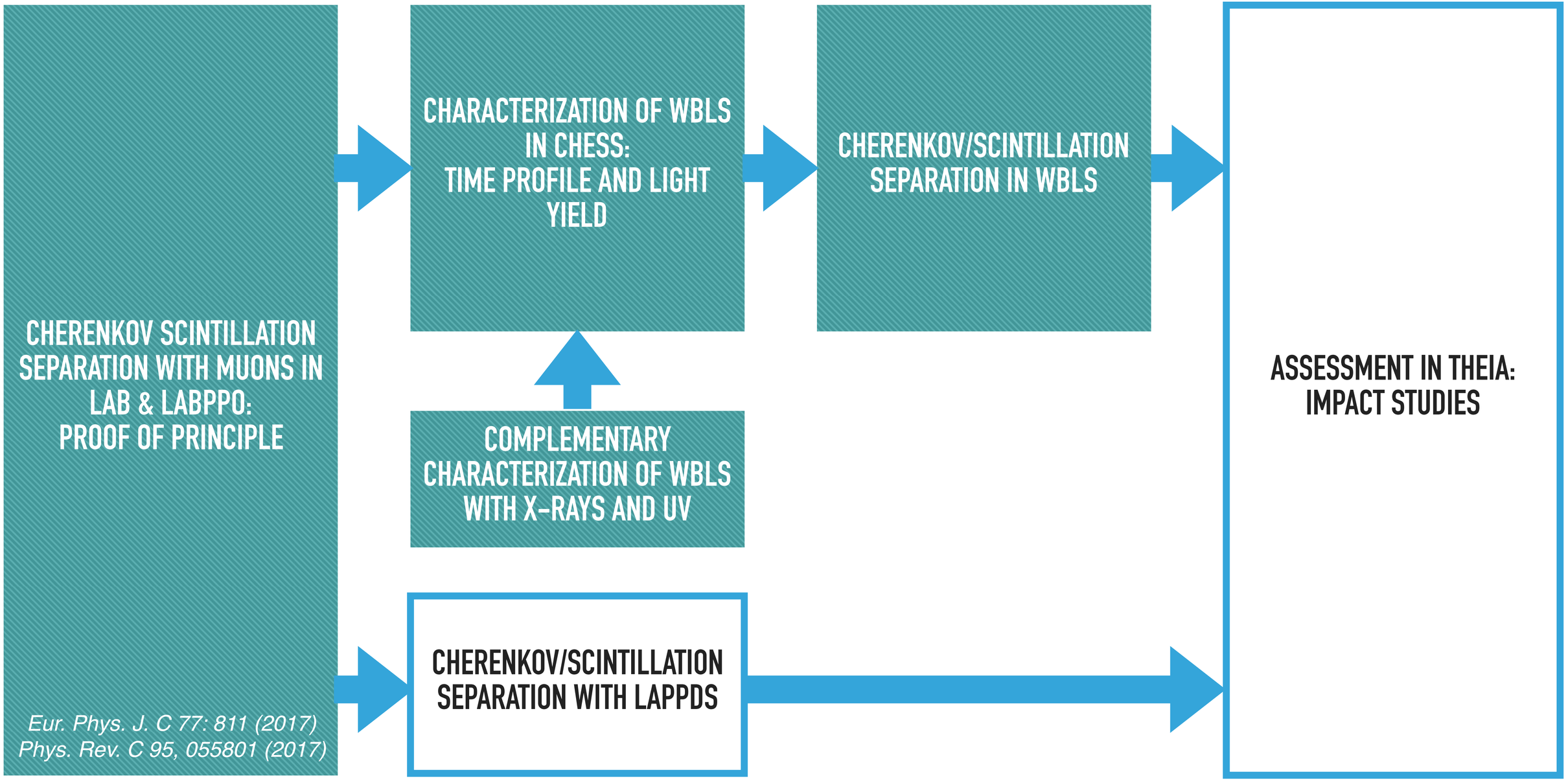


THE CHESS ROADMAP



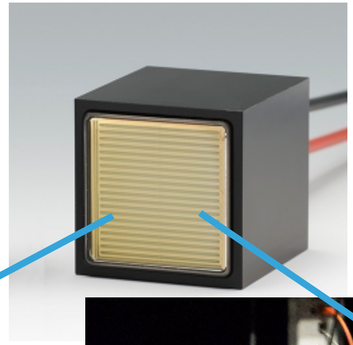
THE CHESS ROADMAP

OUTLINE OF THIS TALK

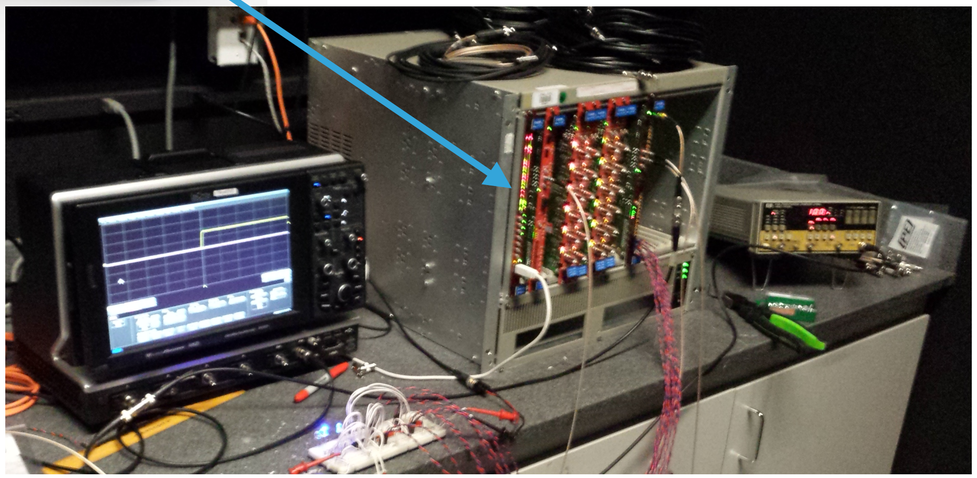


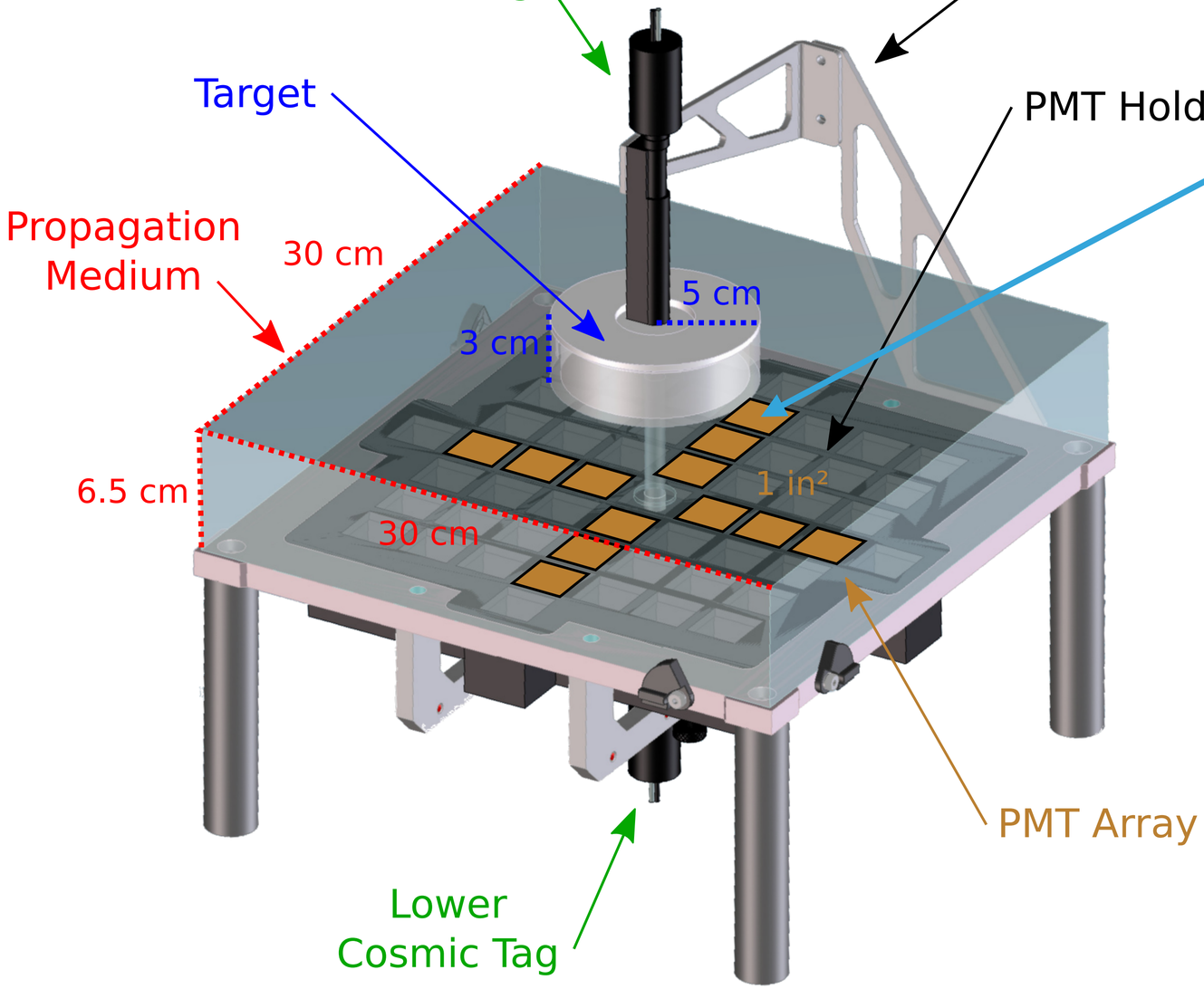
THE CHESS SETUP

12x Hamamatsu H11934 → 300ps FWHM



Instrumented with
CAEN V1742 → 5GHz





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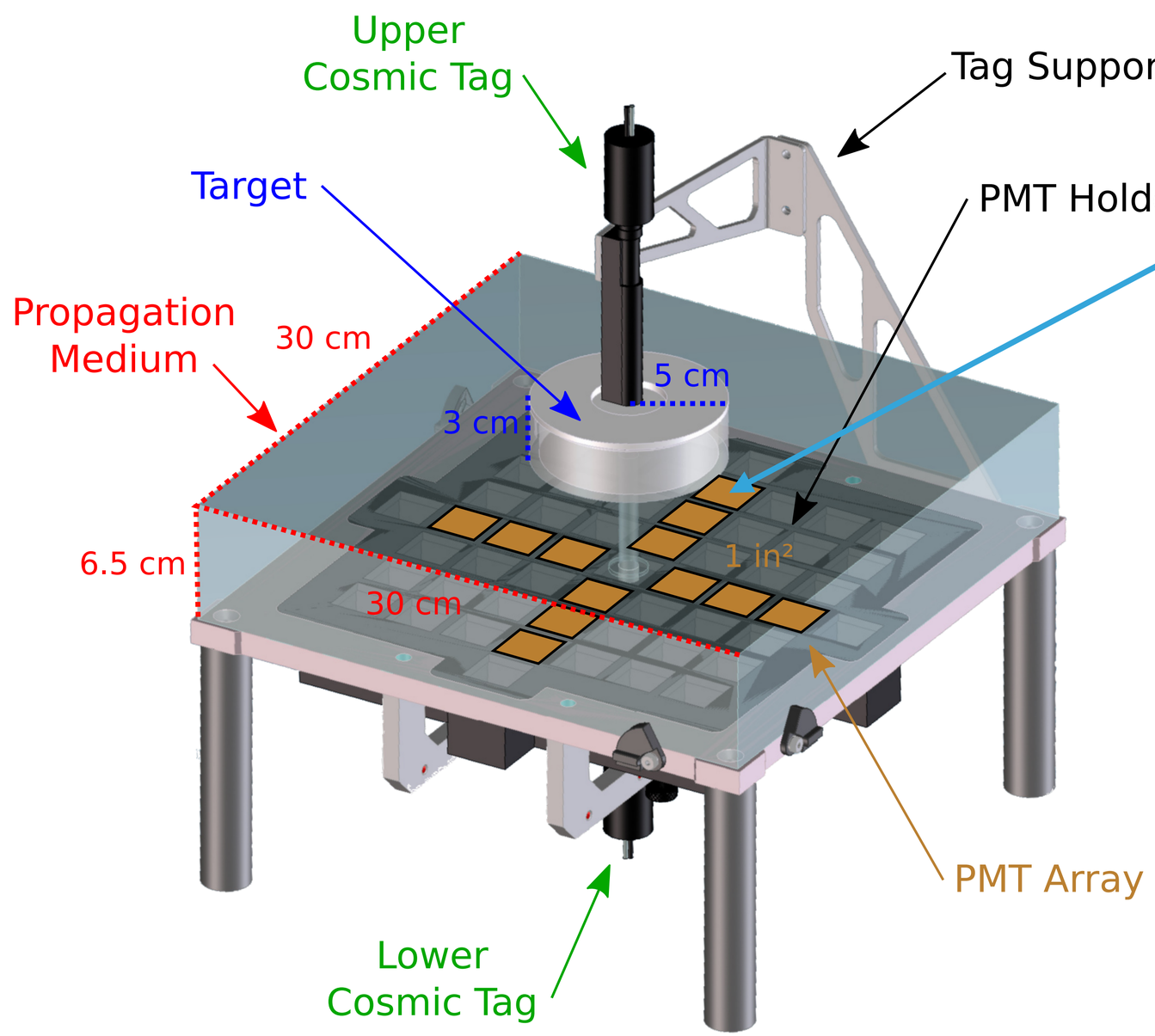

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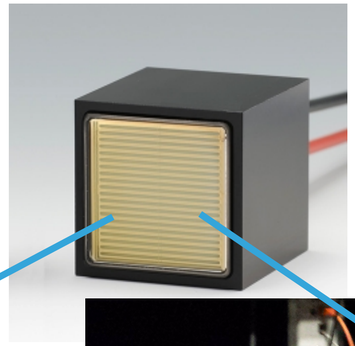

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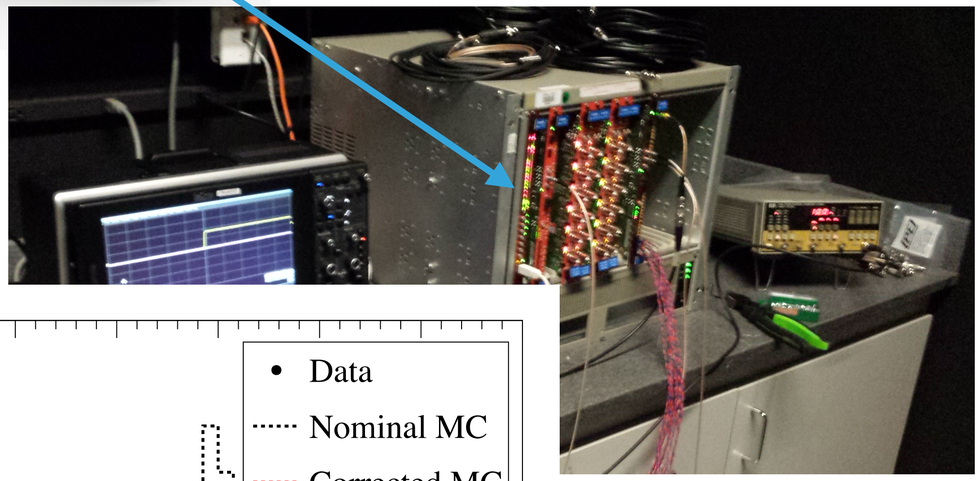
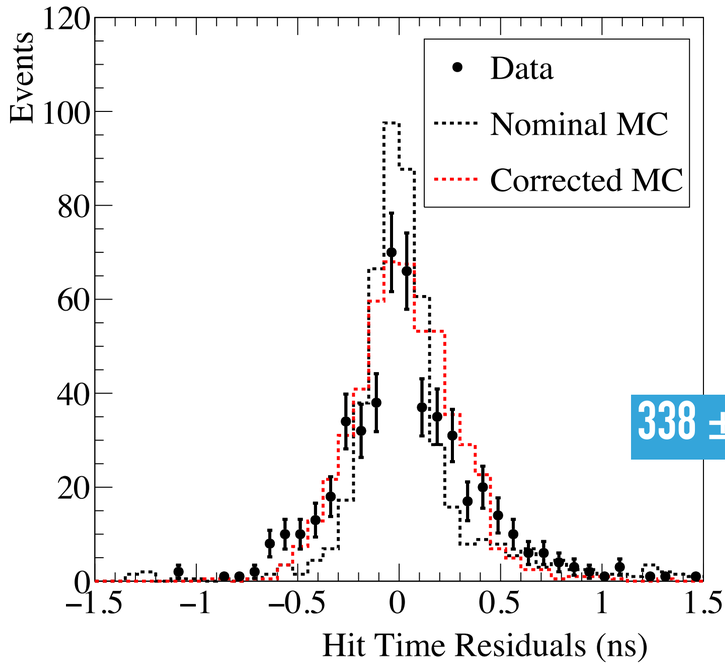
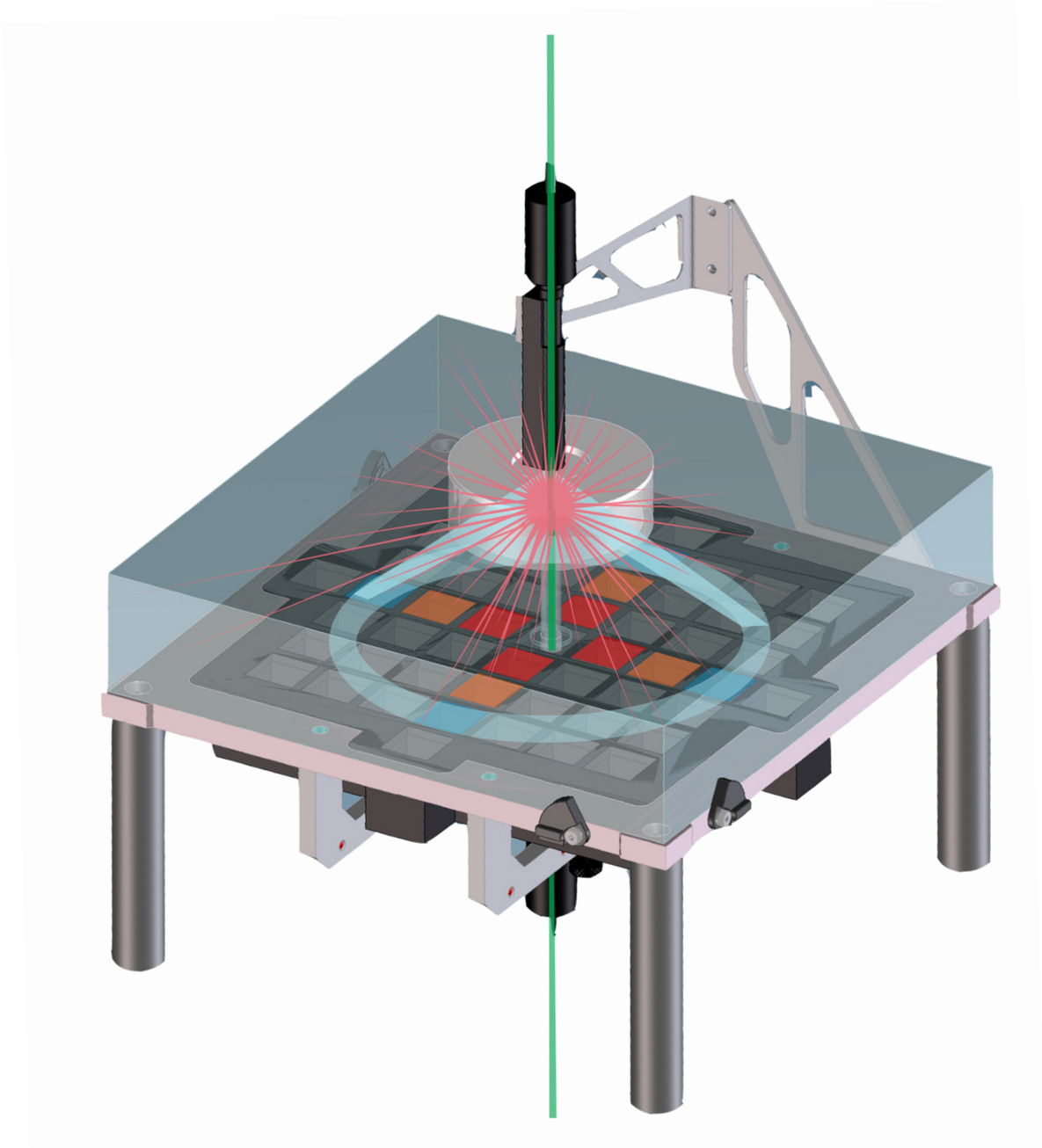
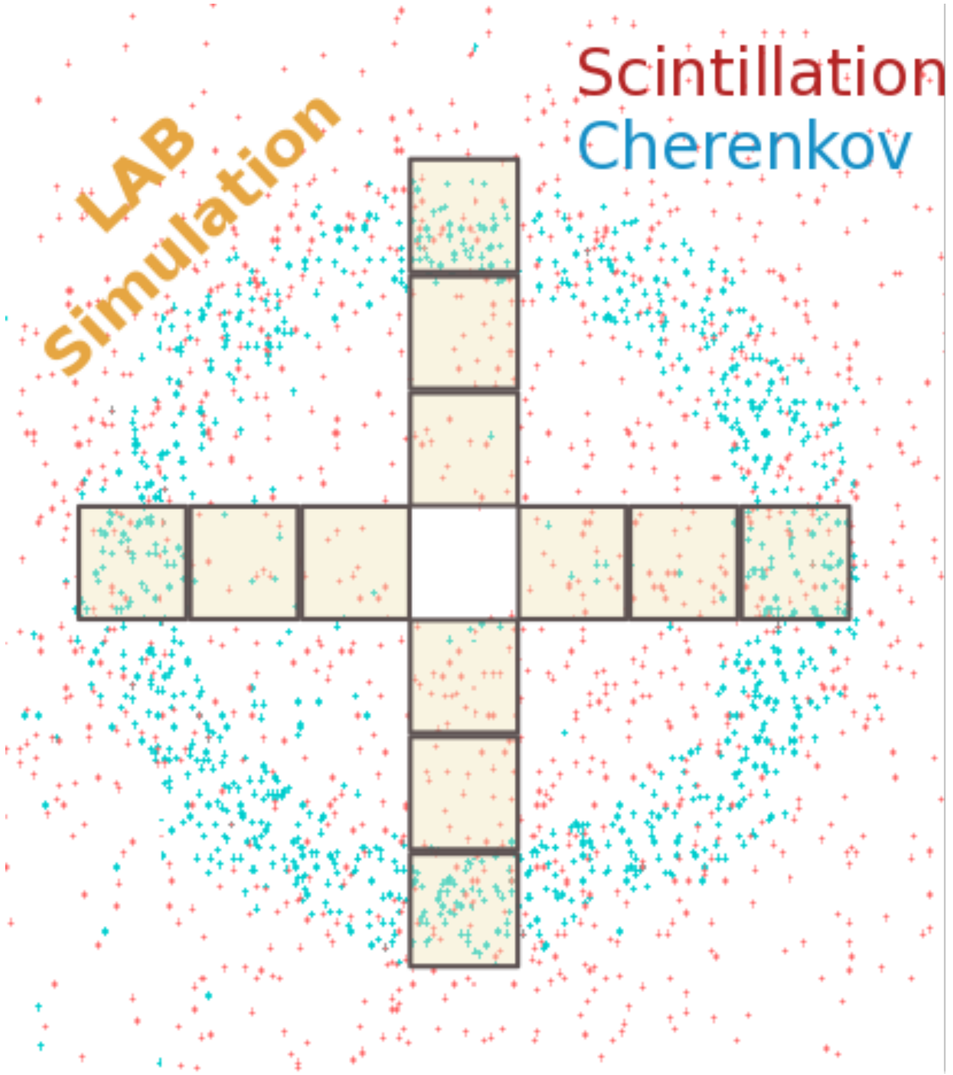




338 ± 12 ps FWHM

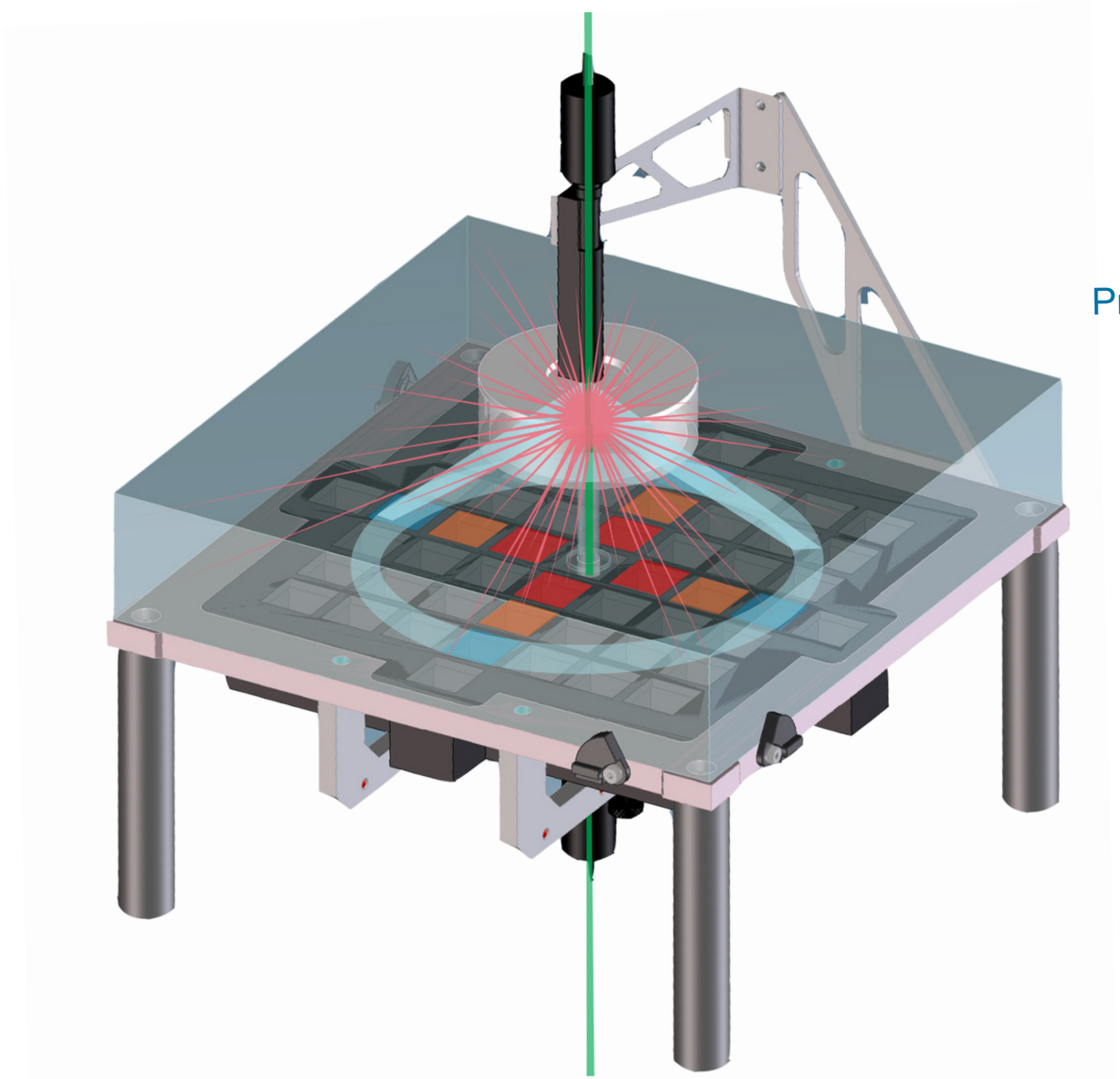
THE CHESS SETUP



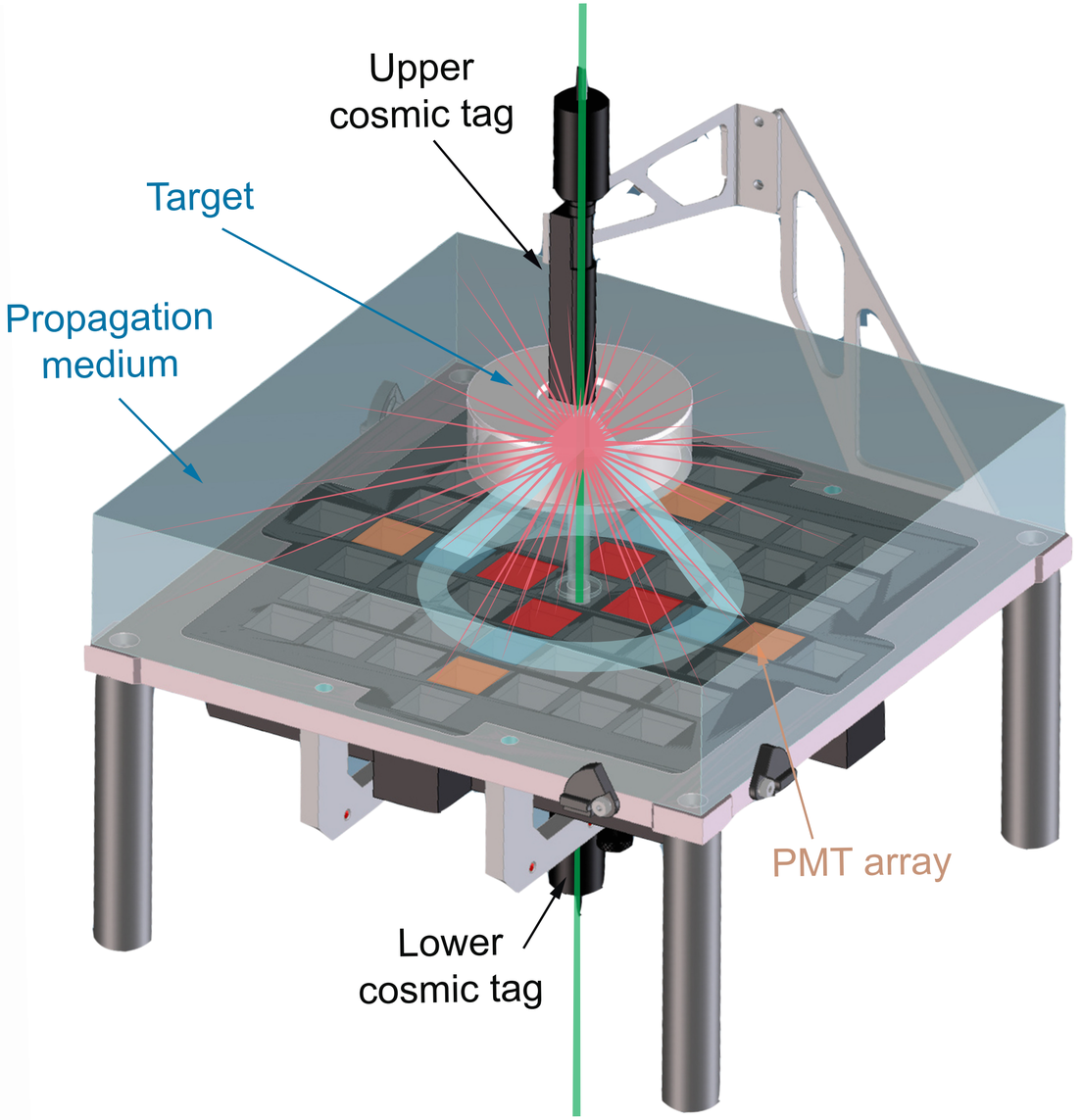


THE CHESS SETUP

LAB refractive index

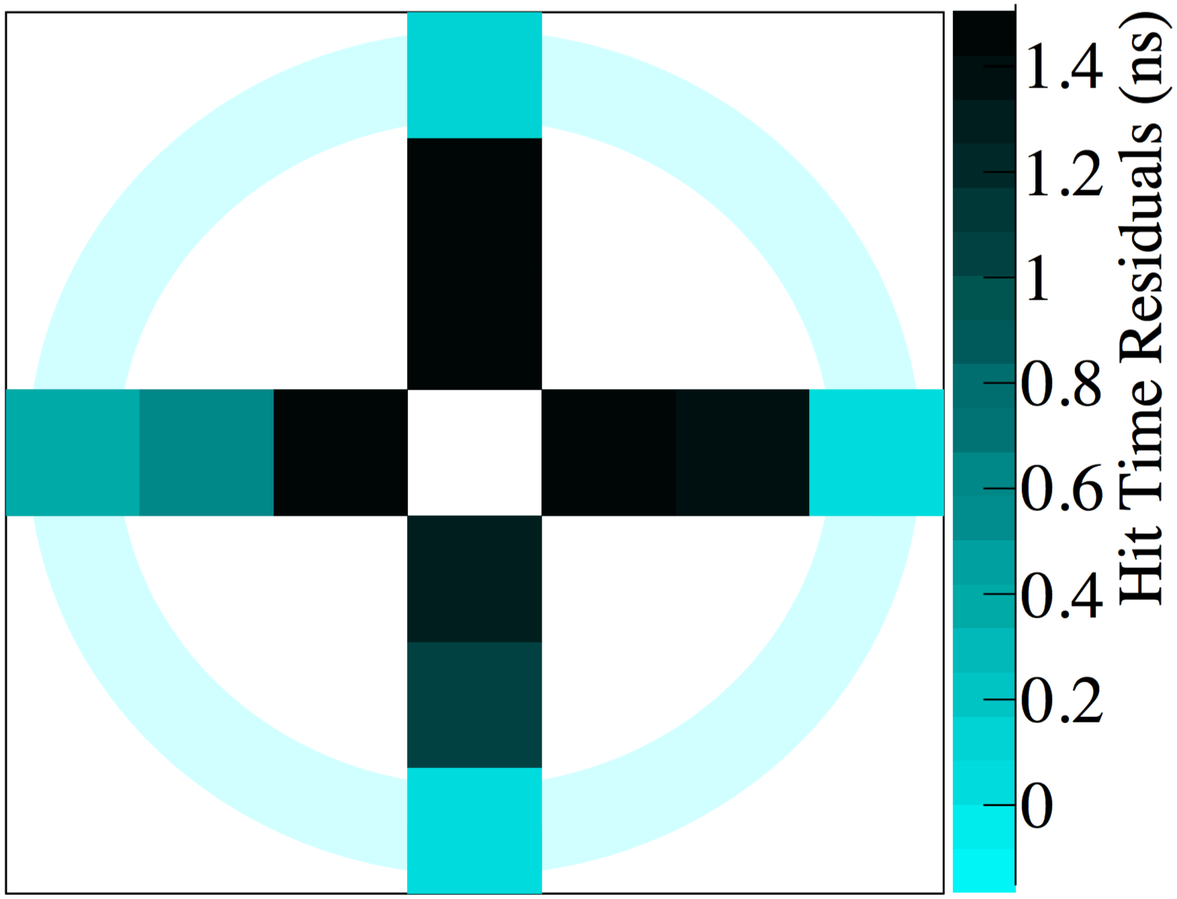


Water/WbLS refractive index

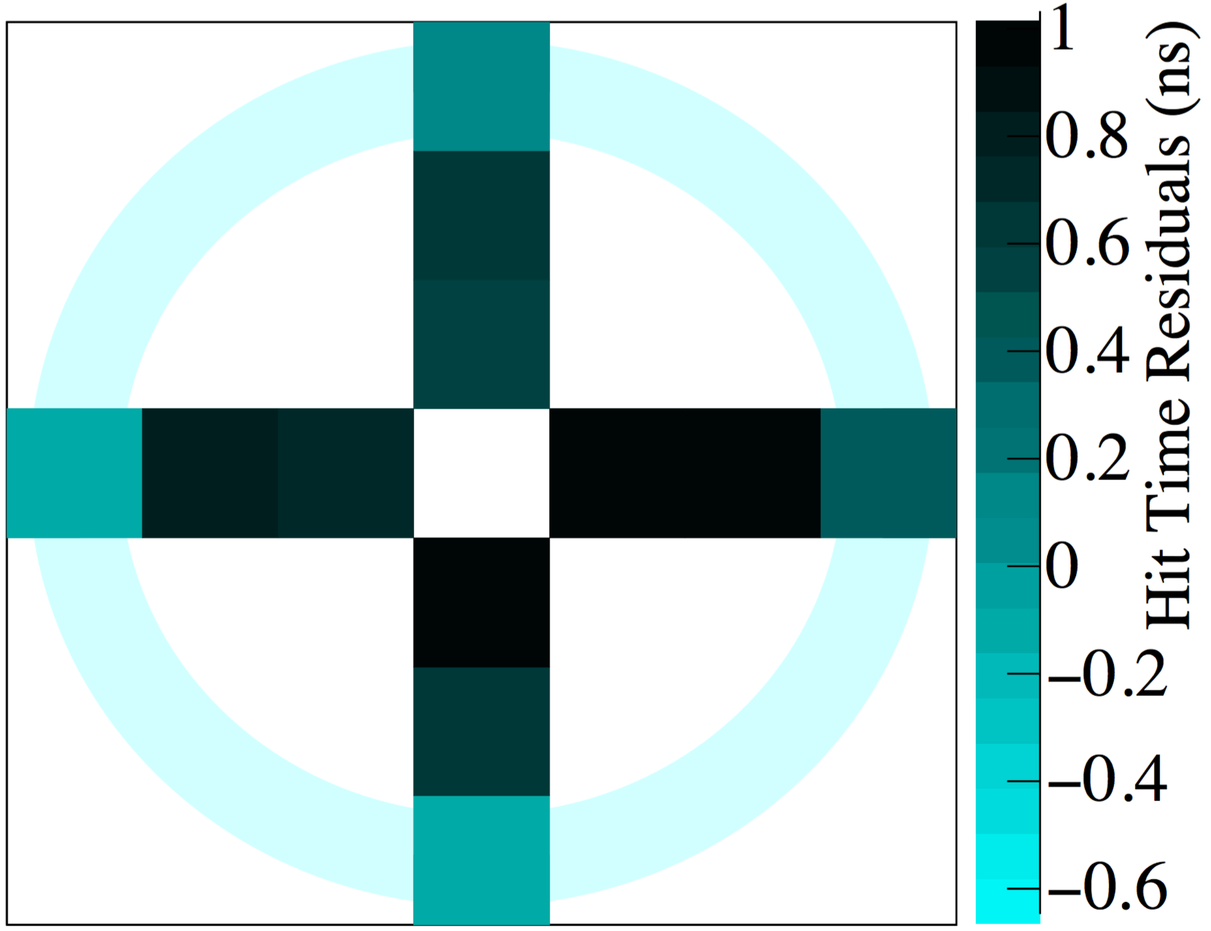


CHERENKOV AND SCINTILLATION SEPARATION IN PURE LS

Pure LAB

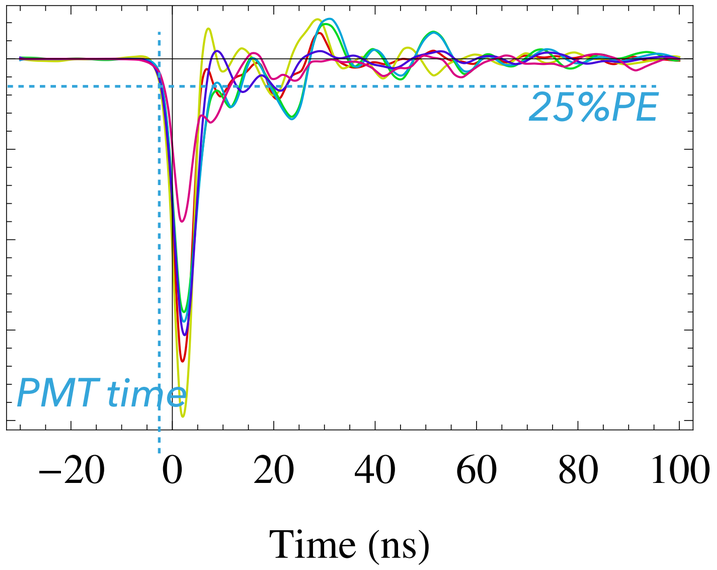


LABPPO (2g/L)



Averaged time residuals in each PMT

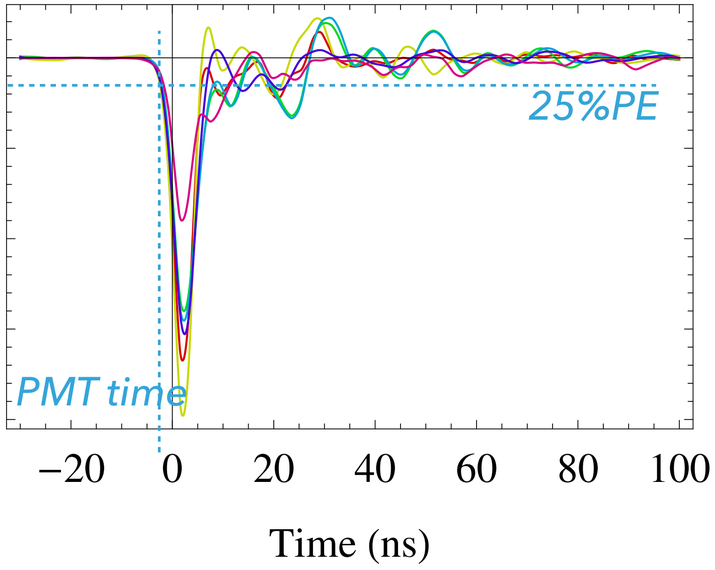
CHERENKOV AND SCINTILLATION SEPARATION IN PURE LS: TIMING



Calculate PMT time residuals as the PMT time with respect to the event time corrected by ToF:

- PMT time = waveform crossing at fixed threshold determined by 25% of a PE
- Event time = median of the first four hits
- Time of flight = minimal correction computed using MC

CHERENKOV AND SCINTILLATION SEPARATION IN PURE LS: TIMING



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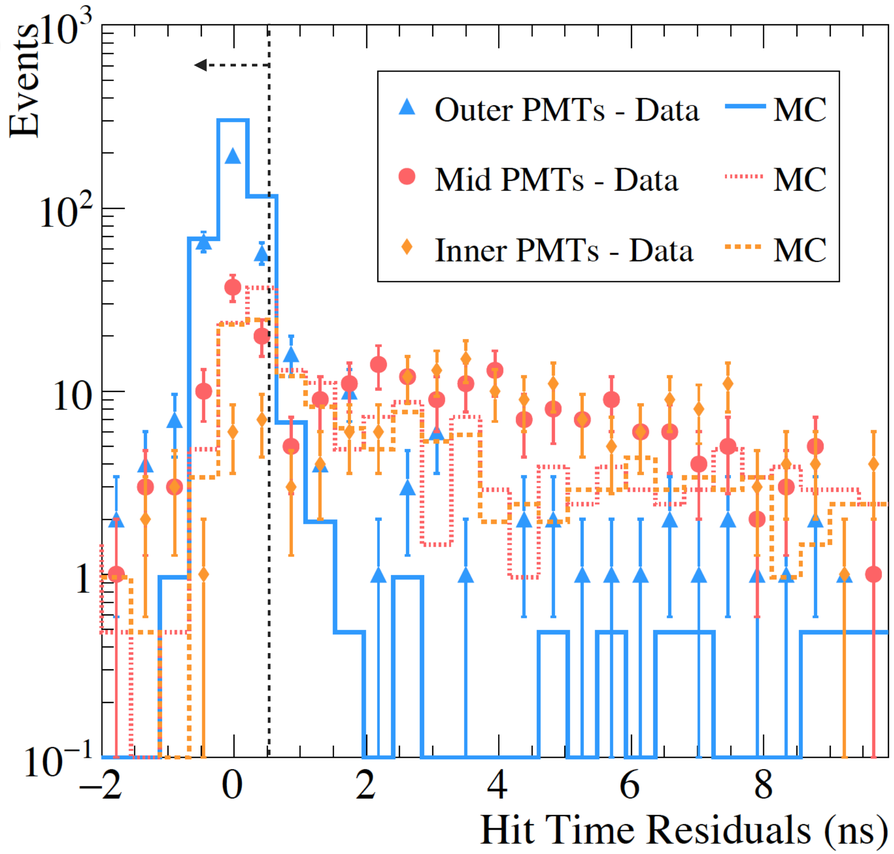
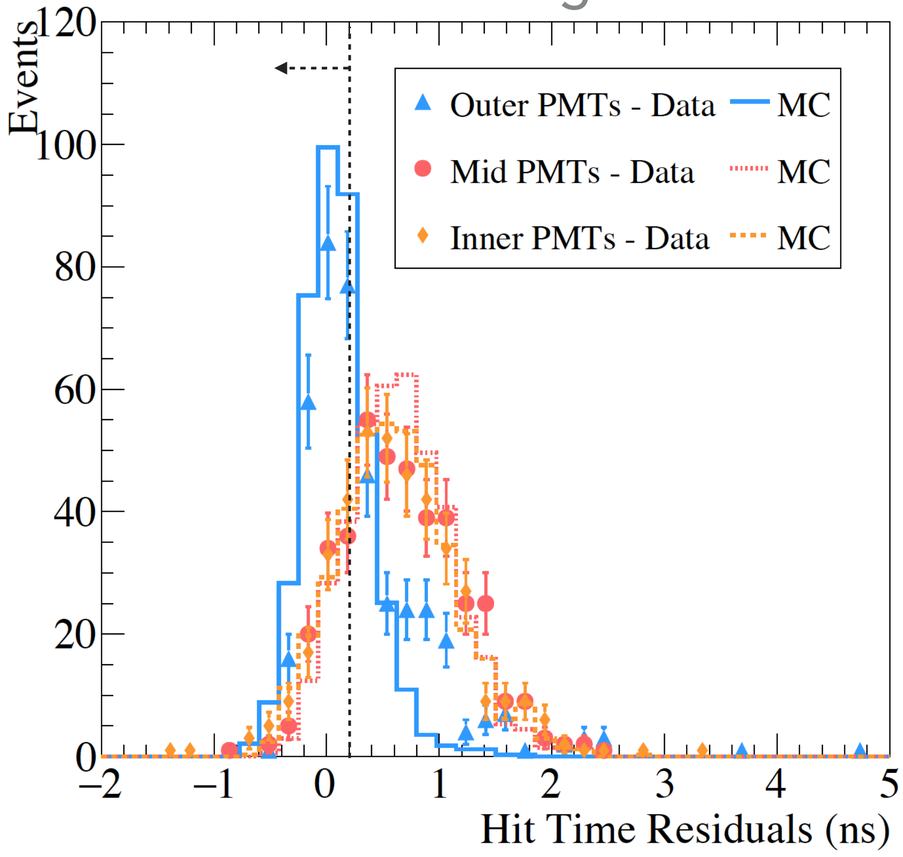


LABPPO 2g/L



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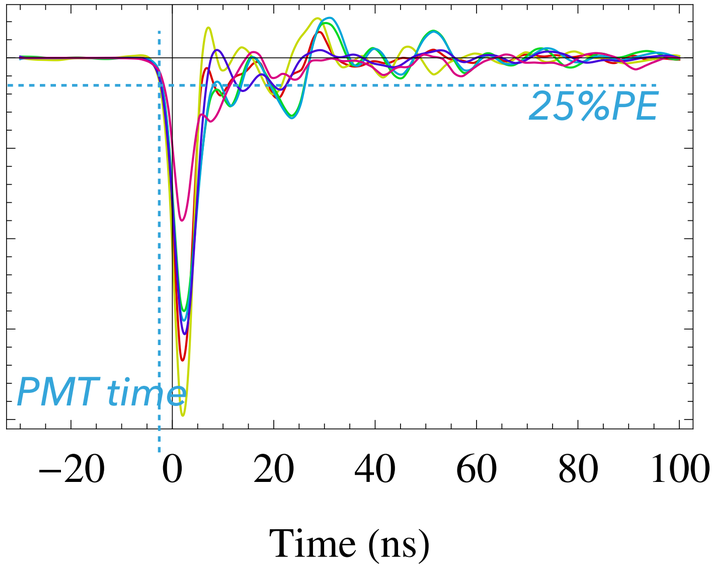

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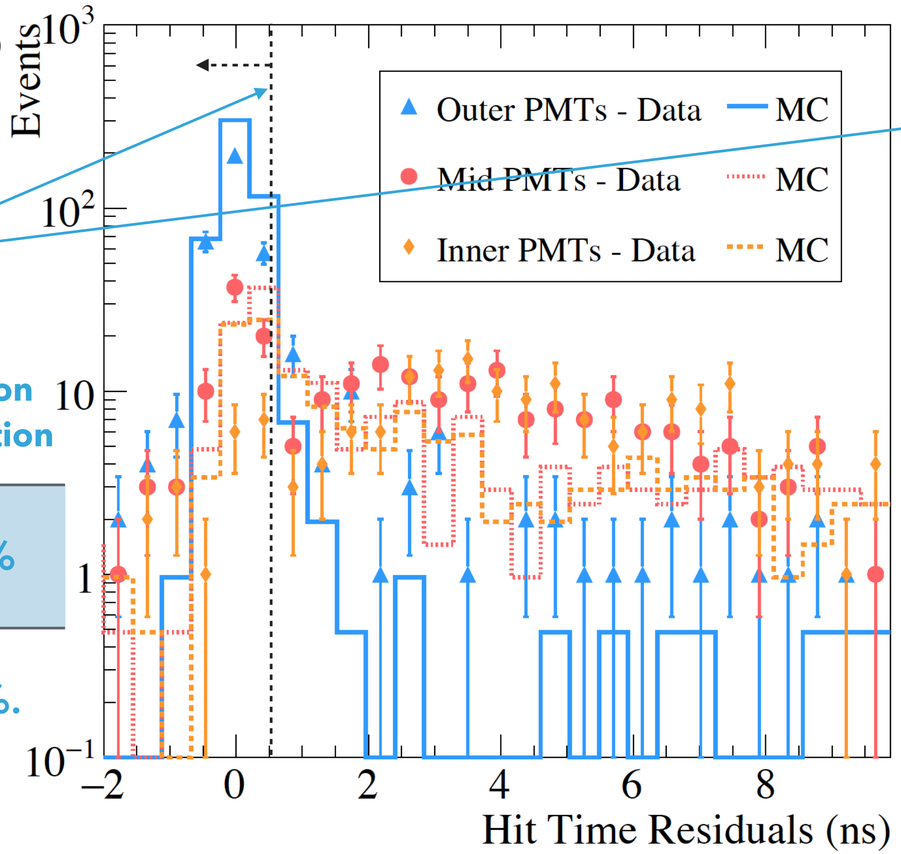
Define optimal cut

	Cherenkov detection efficiency	Scintillation contamination
LAB	83 ± 3%	11 ± 1%
LABPPO (2g/L)	70 ± 3%	36 ± 5%.

Pure LAB



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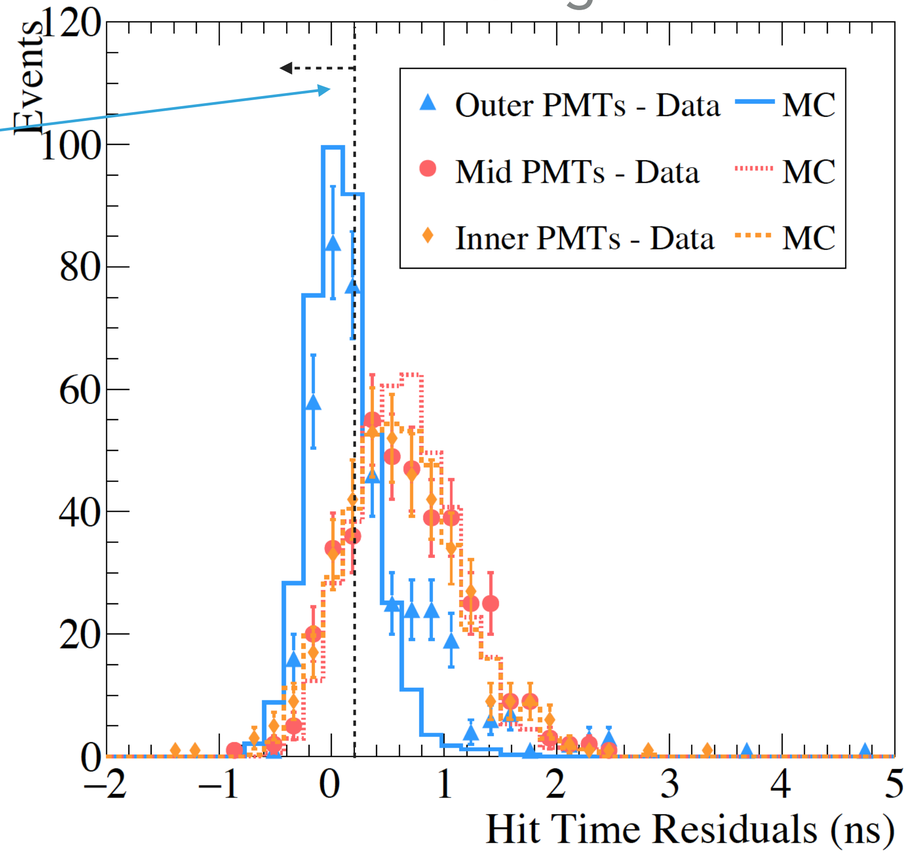
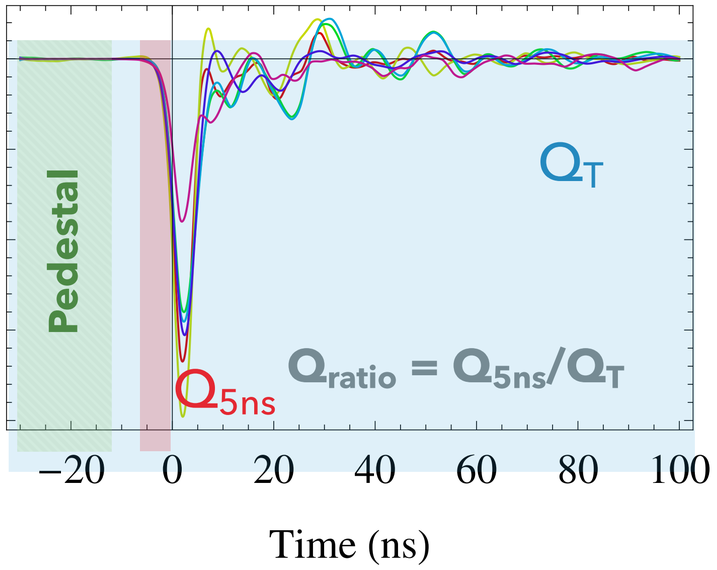


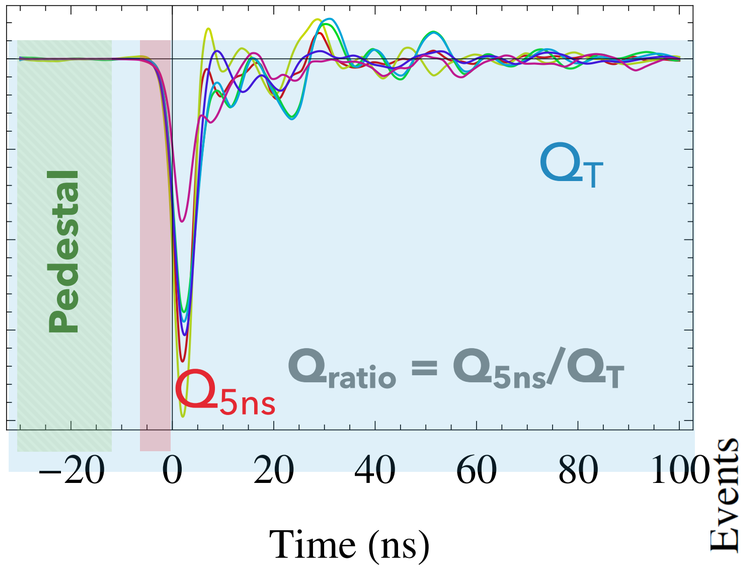
CHERENKOV AND SCINTILLATION SEPARATION IN PURE LS: PROMPT INTEGRATION WINDOW



Calculate PMT charge ration between prompt integration window and full window:

- Full event window = integrate over ~700ns correcting by pedestal
- Prompt integration window = integrate over 5ns around event time

CHERENKOV AND SCINTILLATION SEPARATION IN PURE LS: PROMPT INTEGRATION WINDOW



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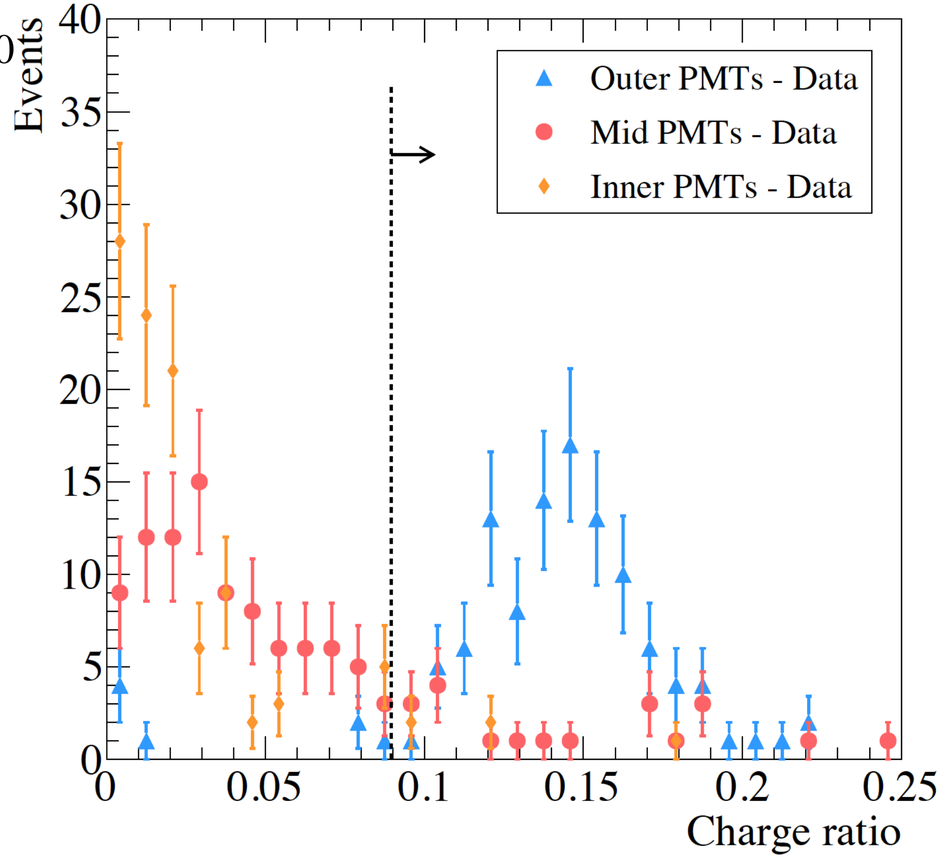
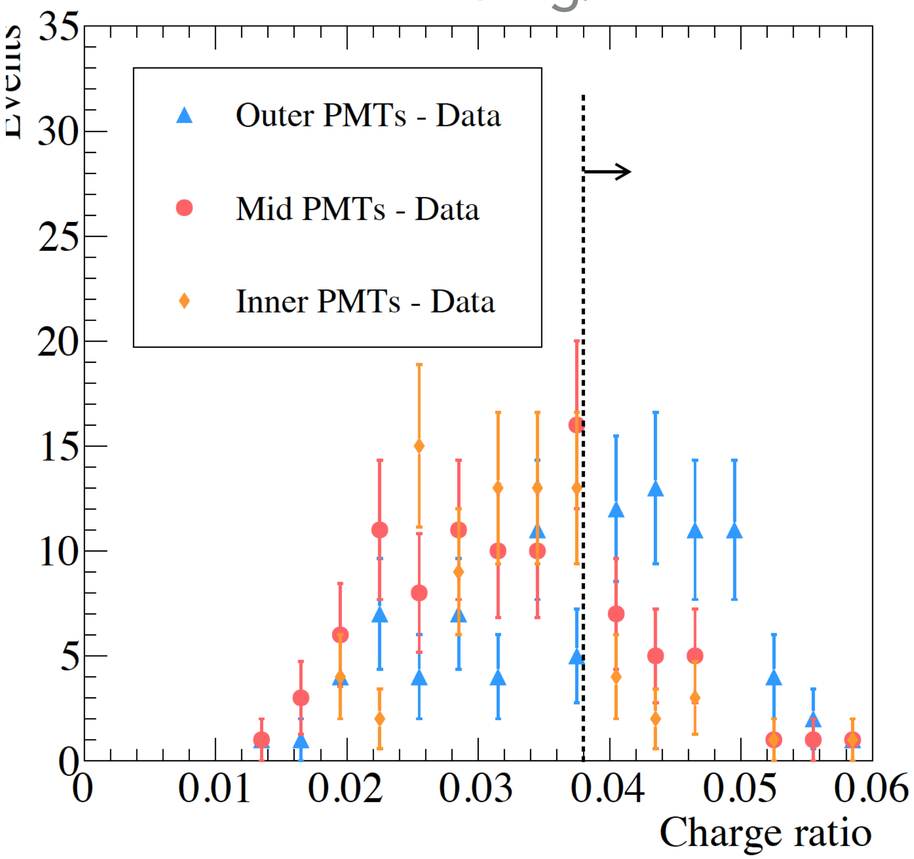


LABPPO 2g/L



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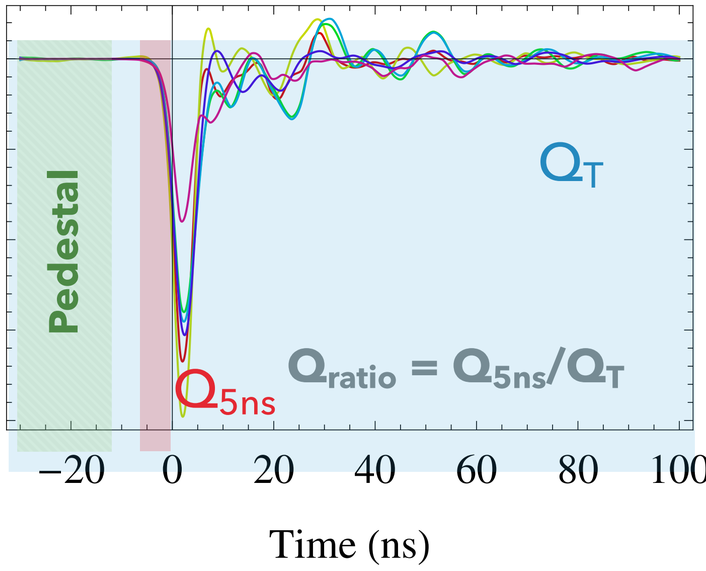

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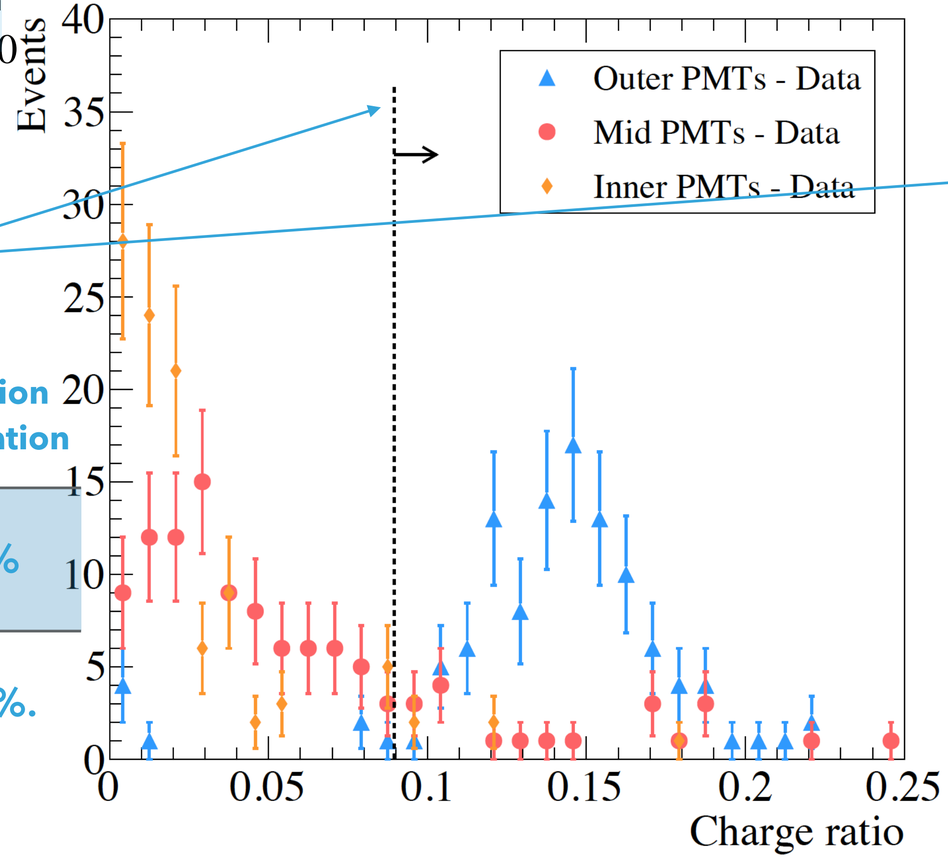
Define optimal cut

	Cherenkov detection efficiency	Scintillation contamination
LAB	96 ± 2%	6 ± 3%
LABPPO (2g/L)	63 ± 8%	38 ± 4%.

Pure LAB



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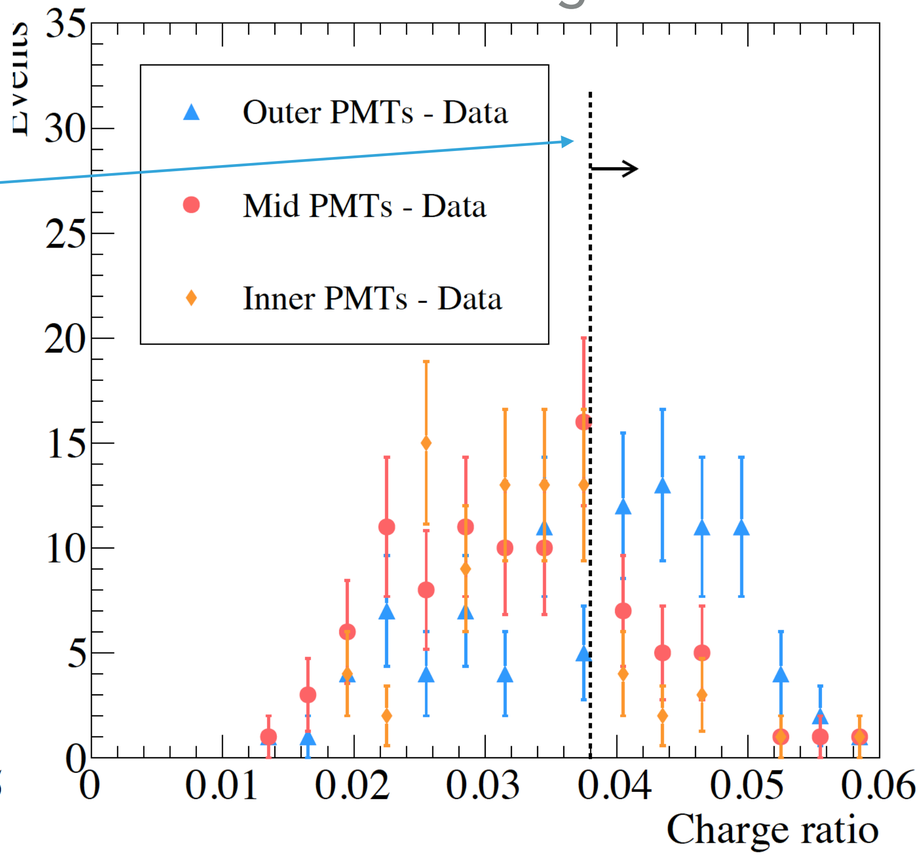
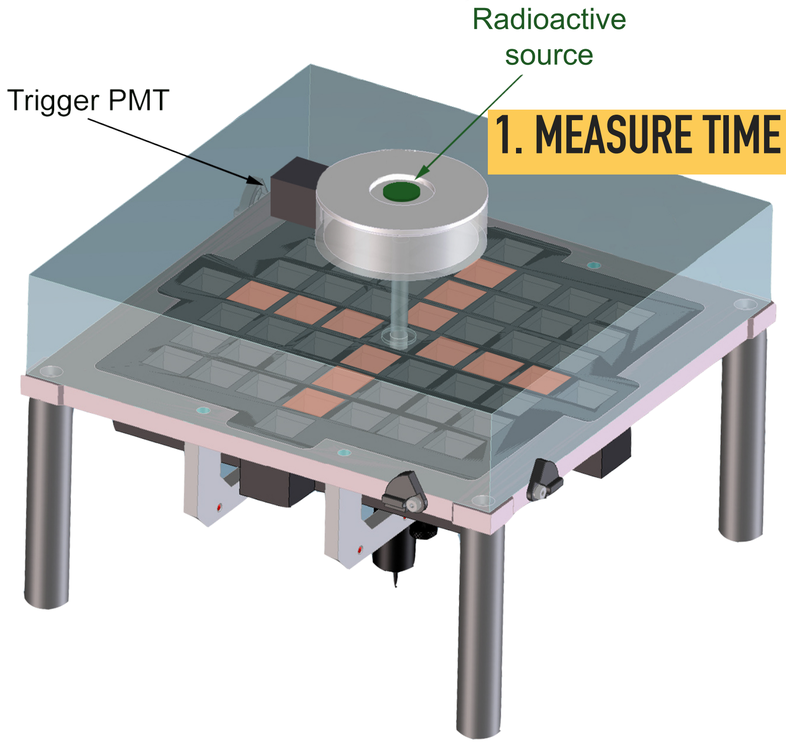


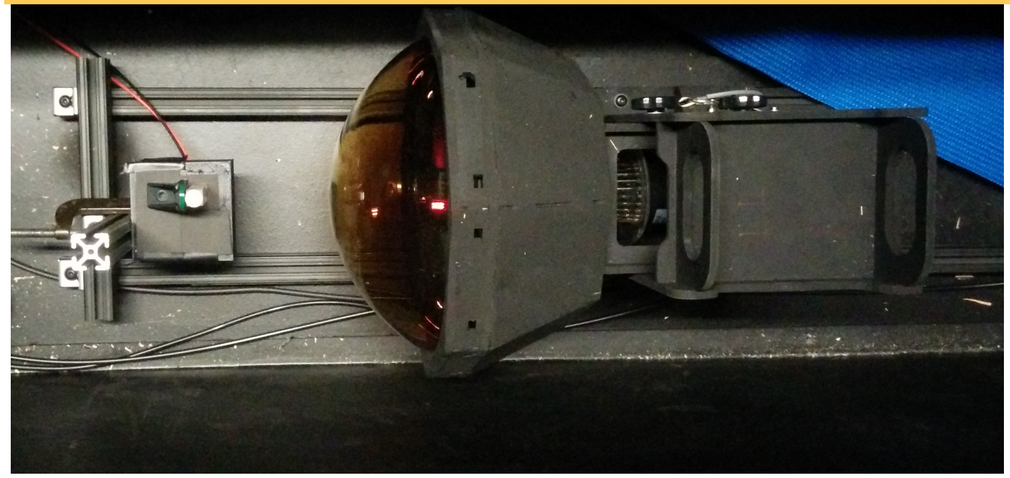
WbLS ANALYSIS

WbLS ANALYSIS STRATEGY

1. MEASURE TIME PROFILE USING BETA SOURCE

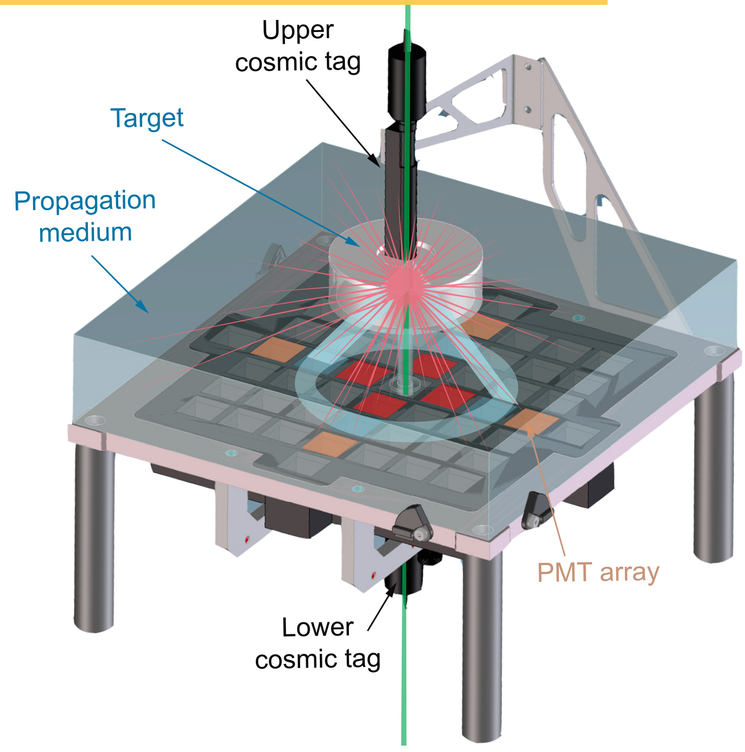


2. MEASURE ABSOLUTE LIGHT YIELD WITH SIMPLIFIED SETUP



3. X-RAY AND UV COMPLEMENTARY CHARACTERIZATION WITH DEDICATED SETUP (BOURRET'S GROUP)

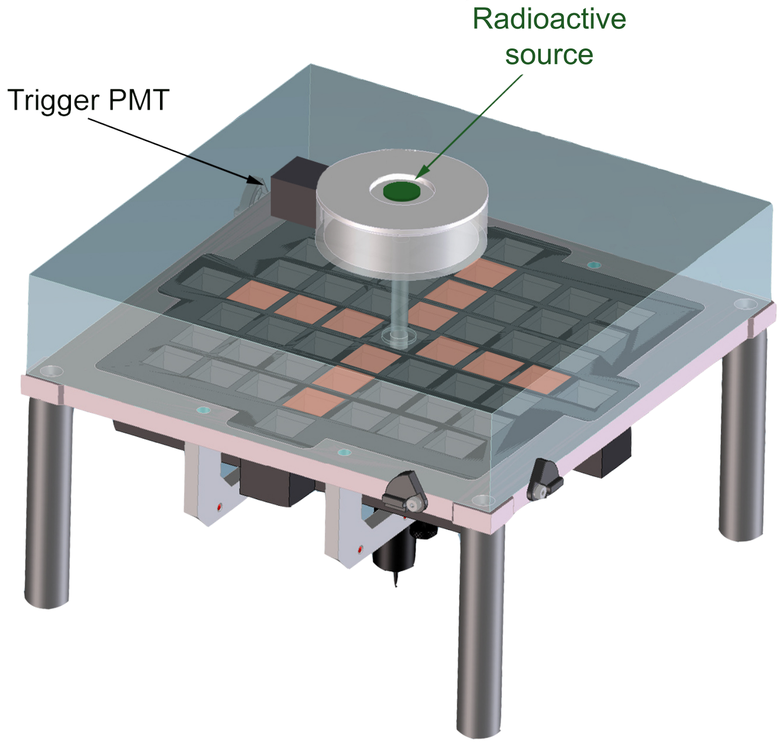
4. ASSESS C/S SEPARATION WITH MUONS



WbLS TIME PROFILE MEASUREMENT

Model → Two exponential decays plus rise time

$$p(t) = \frac{1}{N}(1 - e^{-t/\tau_r})R_1 e^{-t/\tau_1} R_2 e^{-t/\tau_2}$$



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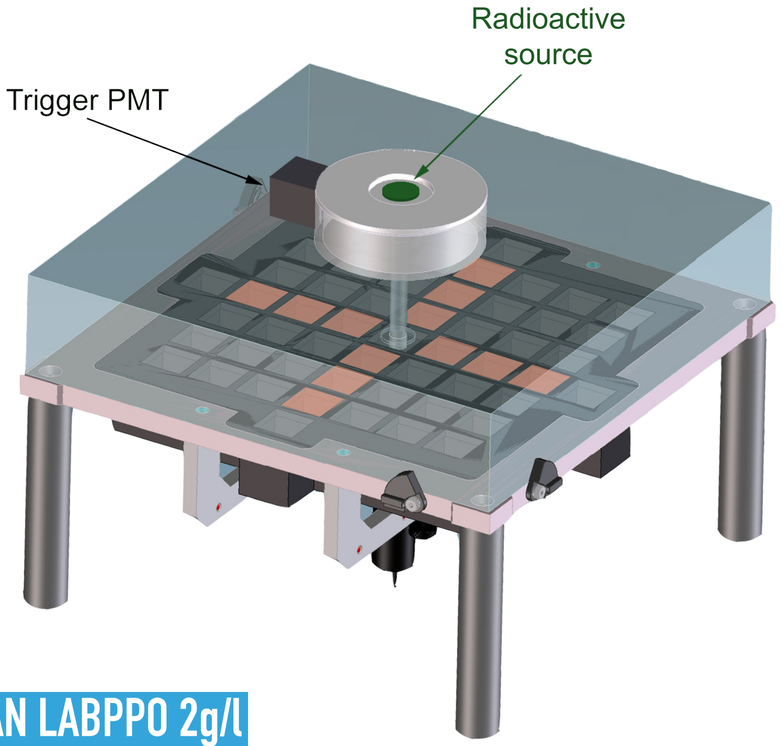
Model → Two exponential decays plus rise time

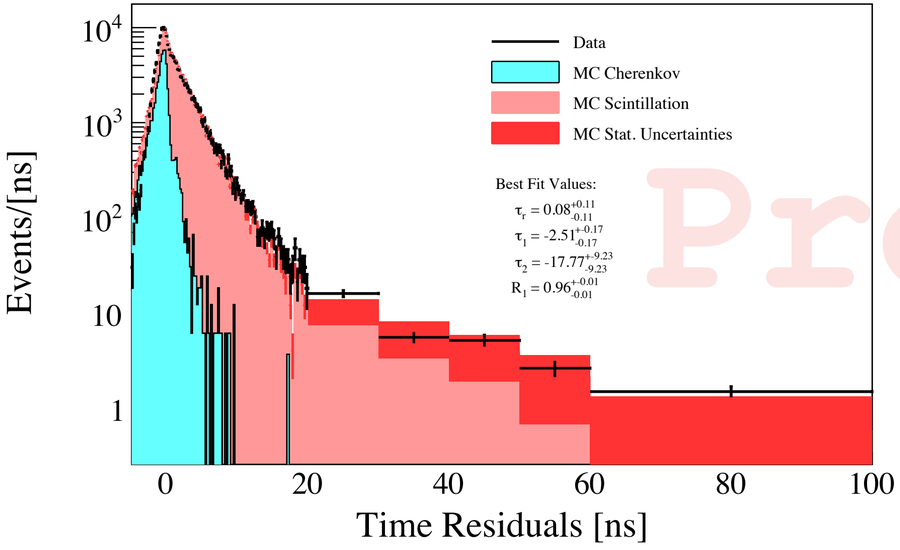
$$p(t) = \frac{1}{N}(1 - e^{-t/\tau_r}) R_1 e^{-t/\tau_1} R_2 e^{-t/\tau_2}$$

WbLS	1%	5%	10%
τ_r [ns]	0.08 ± 0.11	0.02 ± 0.13	0.11 ± 0.15
τ_1 [ns]	2.51 ± 0.17	2.46 ± 0.14	3.03 ± 0.17
τ_2 [ns]	17.77 ± 9.23	21.37 ± 3.11	33.09 ± 5.09
R_1	0.96 ± 0.01	0.93 ± 0.01	0.96 ± 0.01

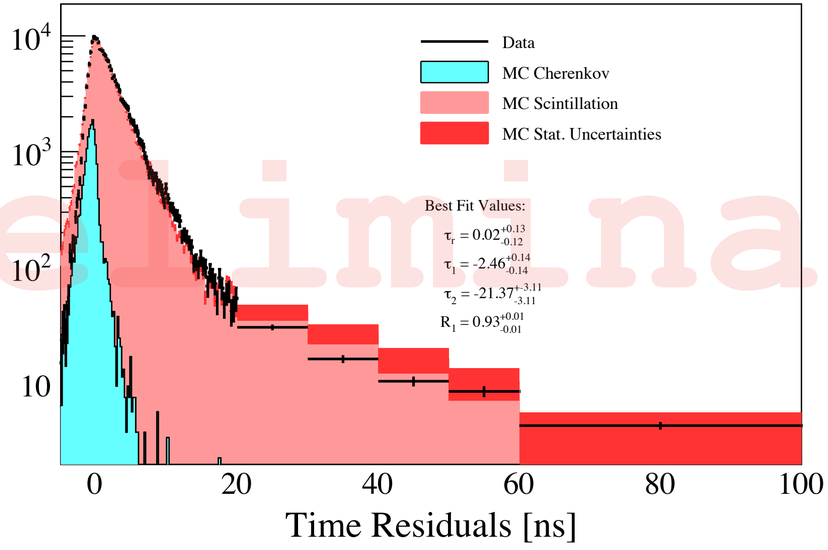


FASTER THAN LABPPO 2g/l

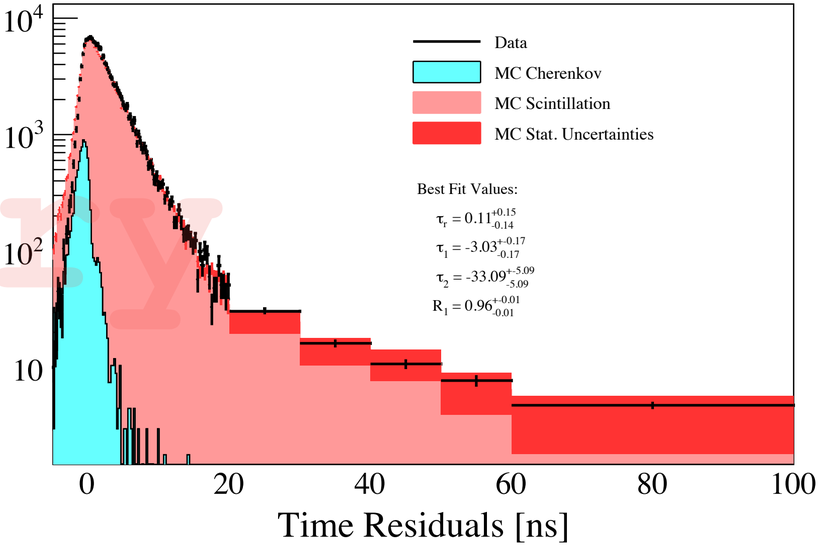
WbLS 1%



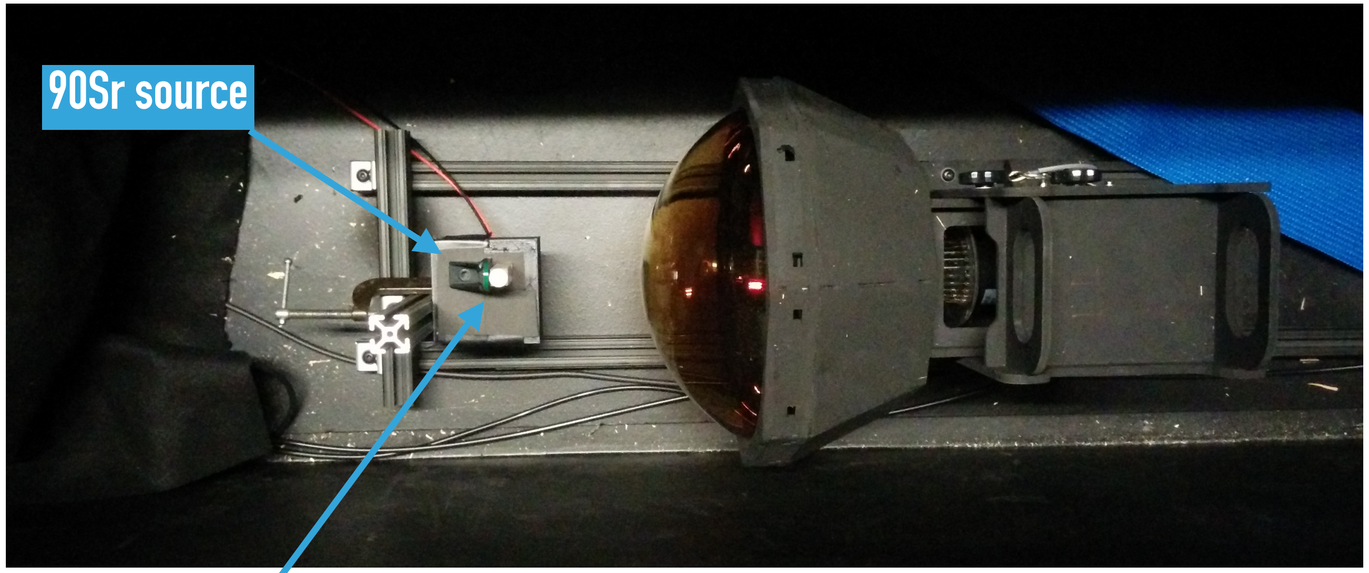
WbLS 5%



WbLS 10%



ABSOLUTE LIGHT YIELD MEASUREMENTS FOR WbLS



HIGH PERFORMANCE QUARTZ CUVETTES

- Used simplified setup to reduce systematic uncertainties due to optics or geometry
- Built detailed MC model using 3D PMT model and material optical properties
- Only free parameter is the WbLS light yield (photons/MeV)

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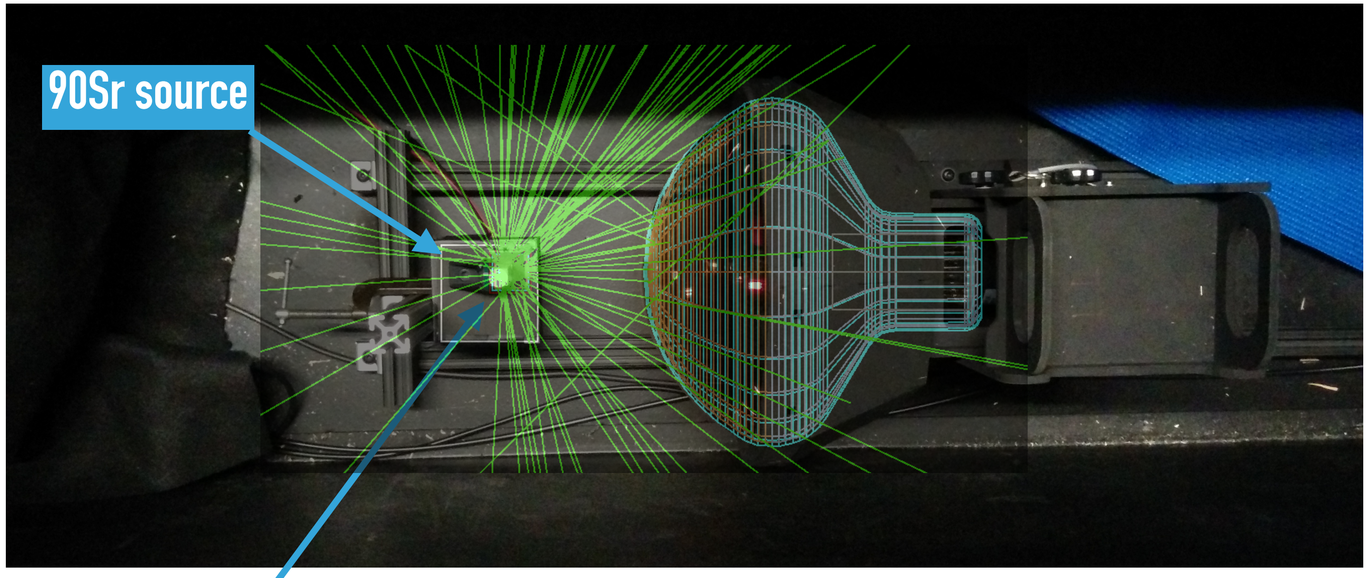

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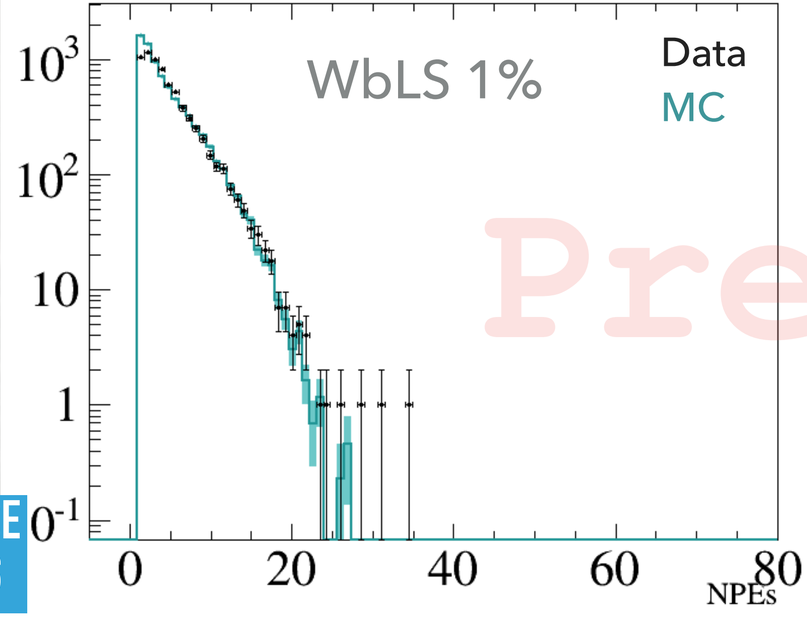
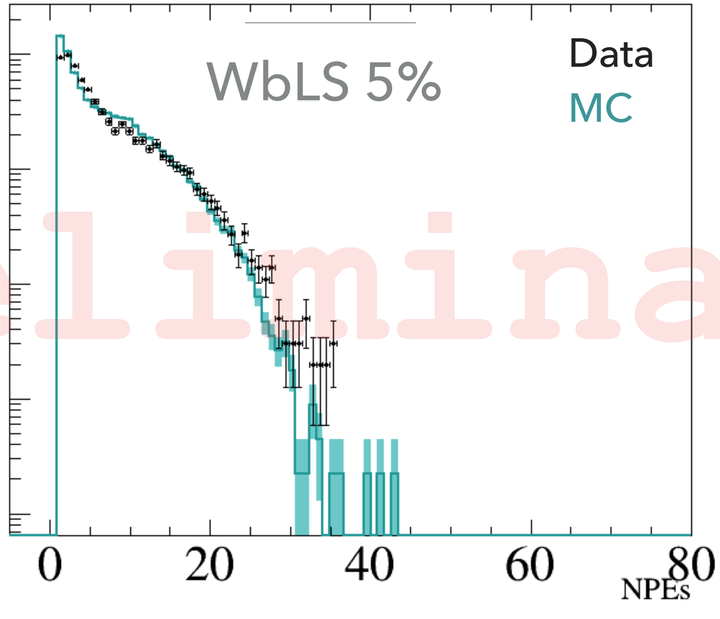
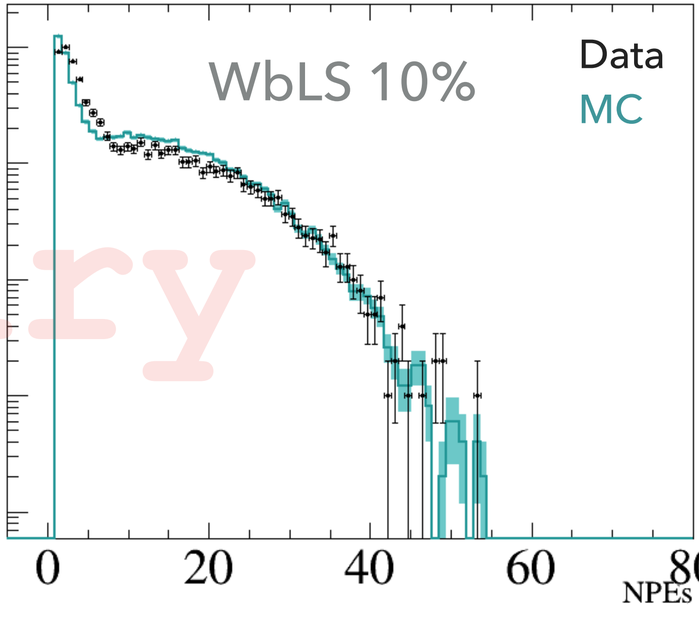


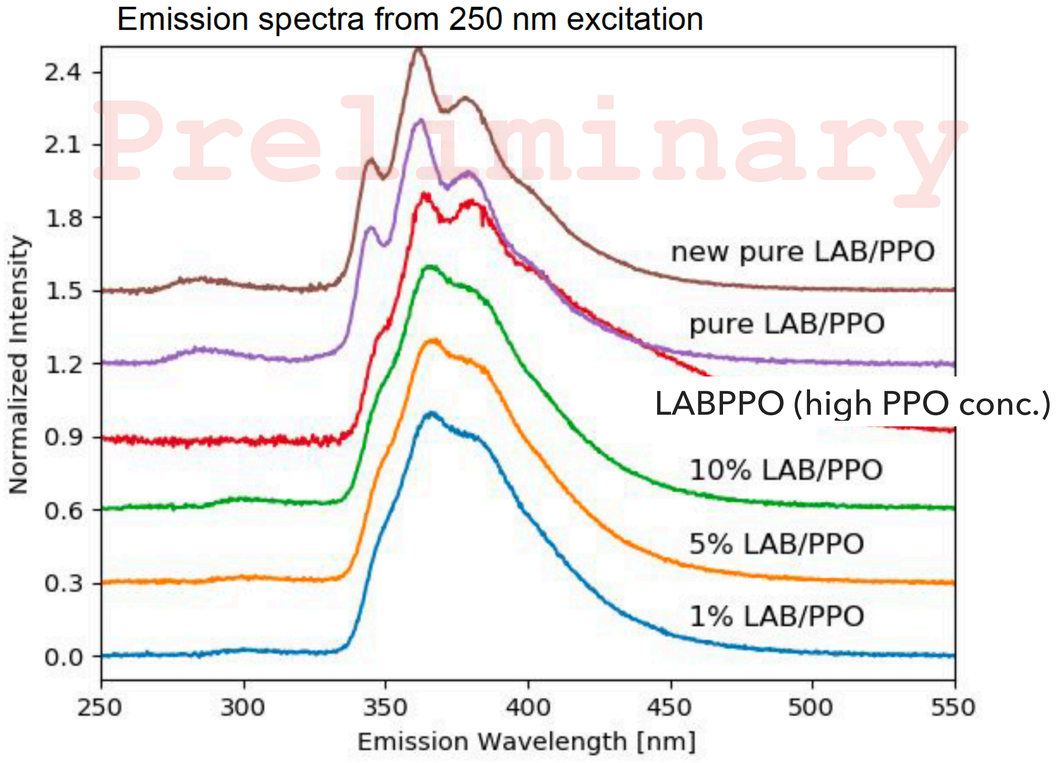


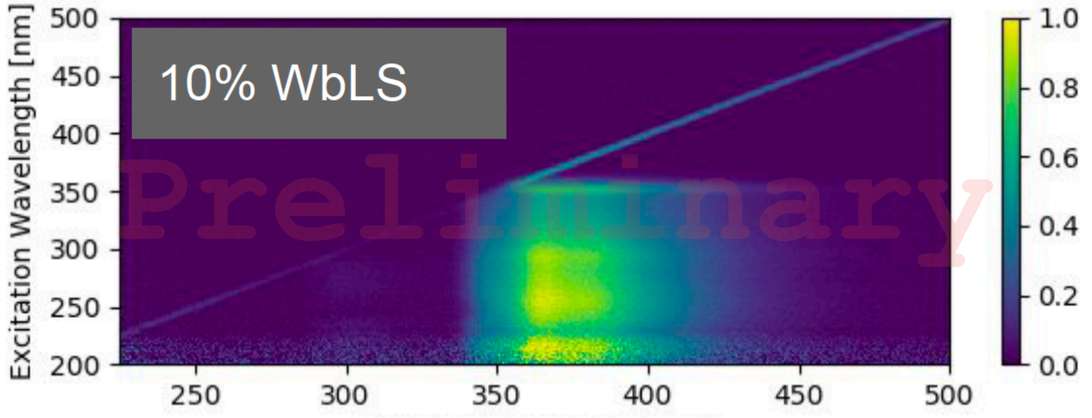


WBLS CHARACTERIZATION WITH UV (BOURRET'S GROUP)

D. Onken, F. Moretti, E. Bourret

- Excite small LS samples with UV
- Measure emission spectra and absorption/reemission
- WbLS emission spectra equivalent to each others but slightly different from LABPPO's



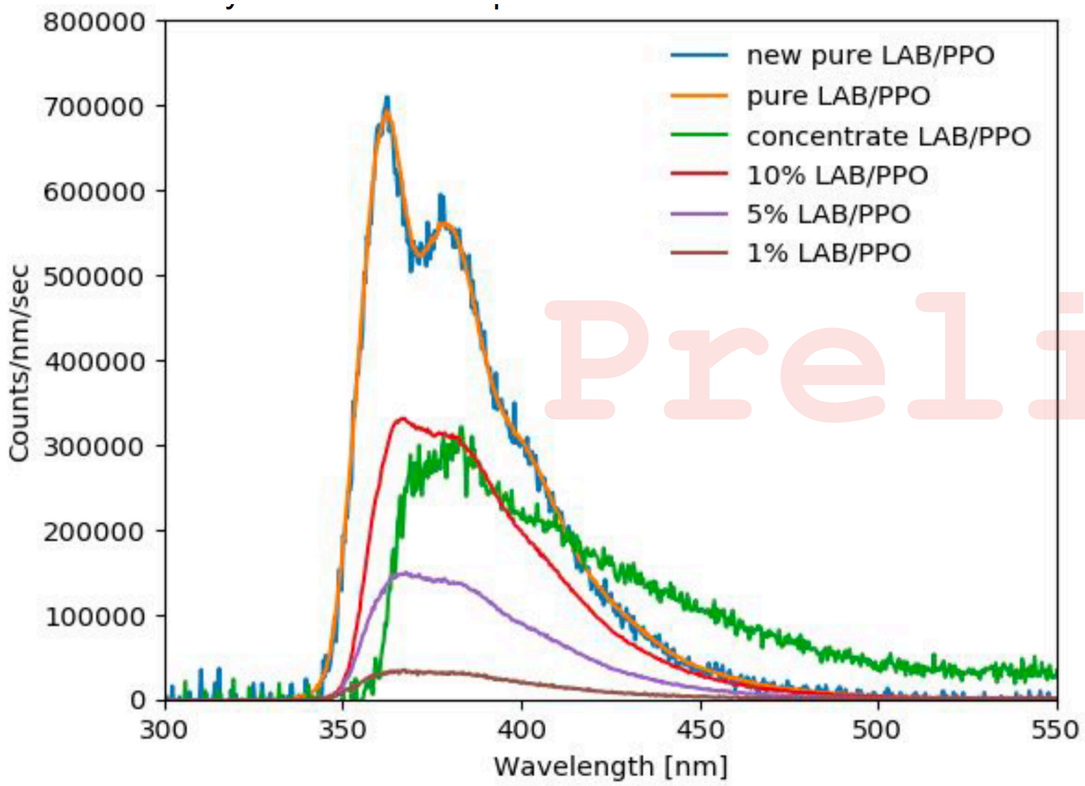


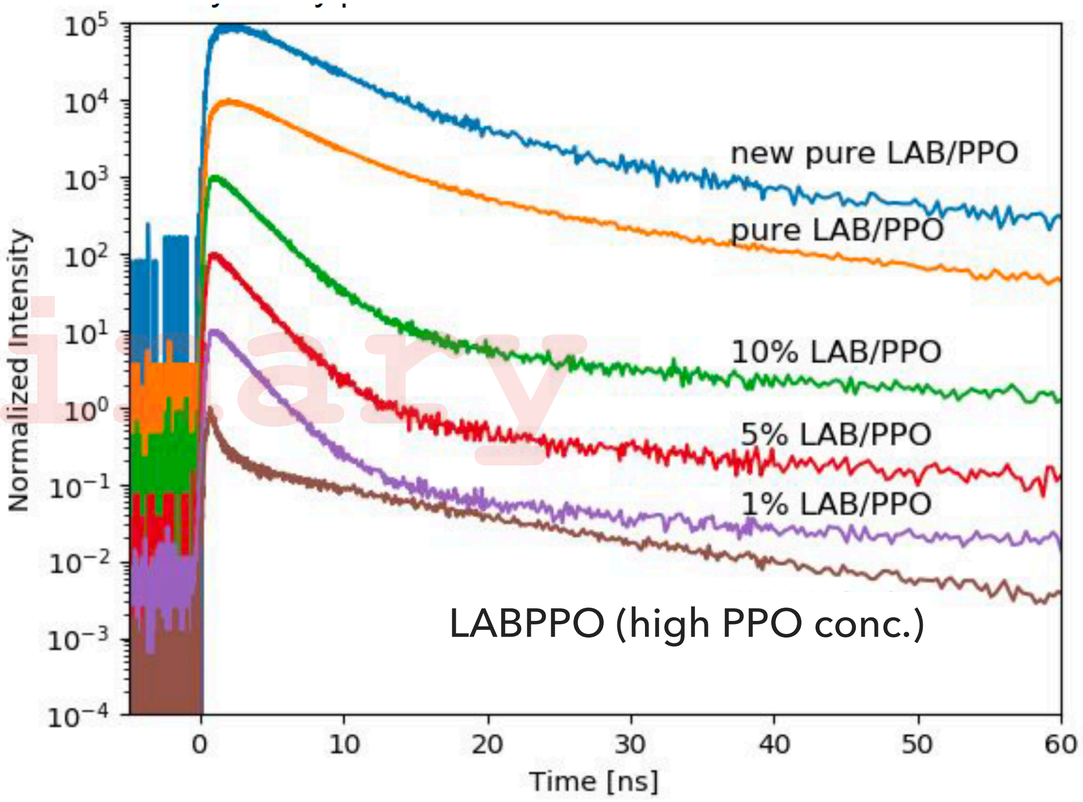
Intensity of emission when excited with a given wavelength

WBLS CHARACTERIZATION WITH PULSED X-RAY BEAM (BOURRET'S GROUP)

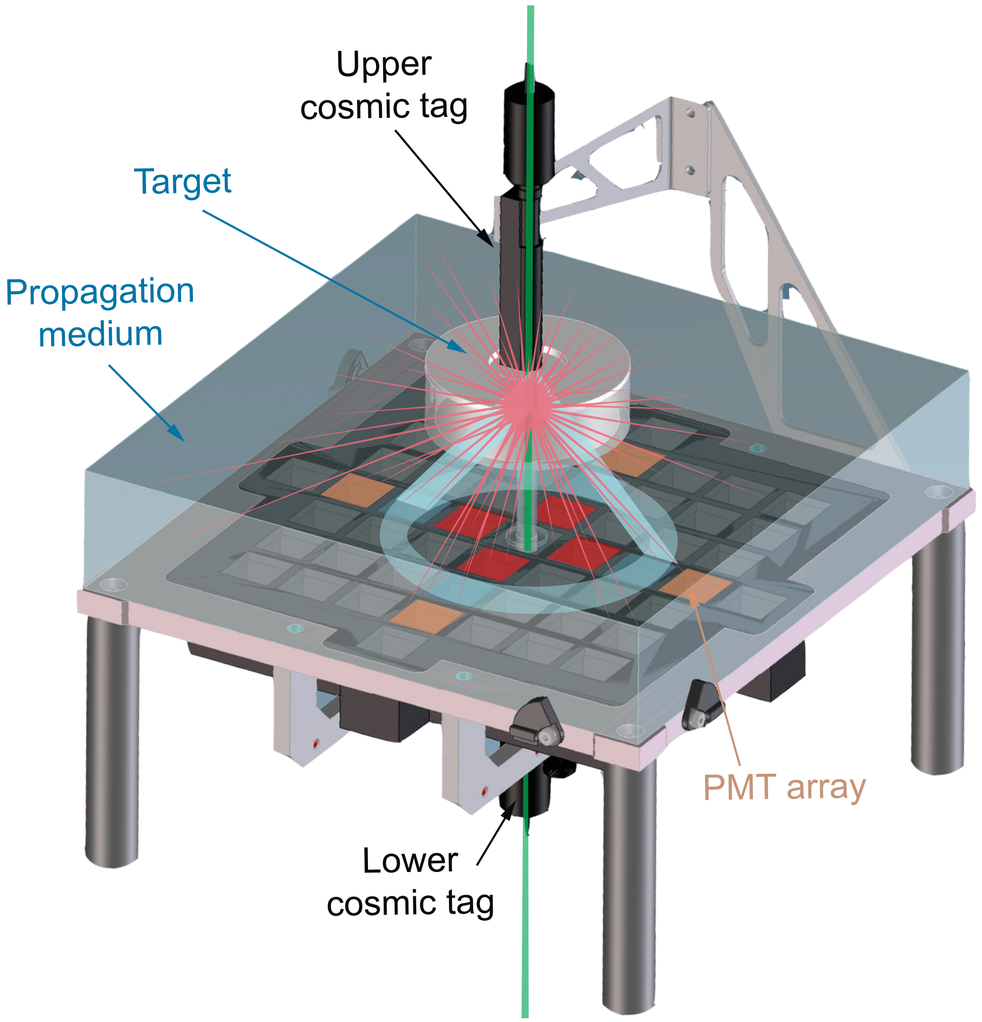
D. Onken, F. Moretti, E. Bourret

- Using a pulsed laser-induced X-Ray beam → 40 keV picosecond-level pulse
- Measured emission spectra and time profile
- Currently working on MC simulation to provide complementary absolute light yield





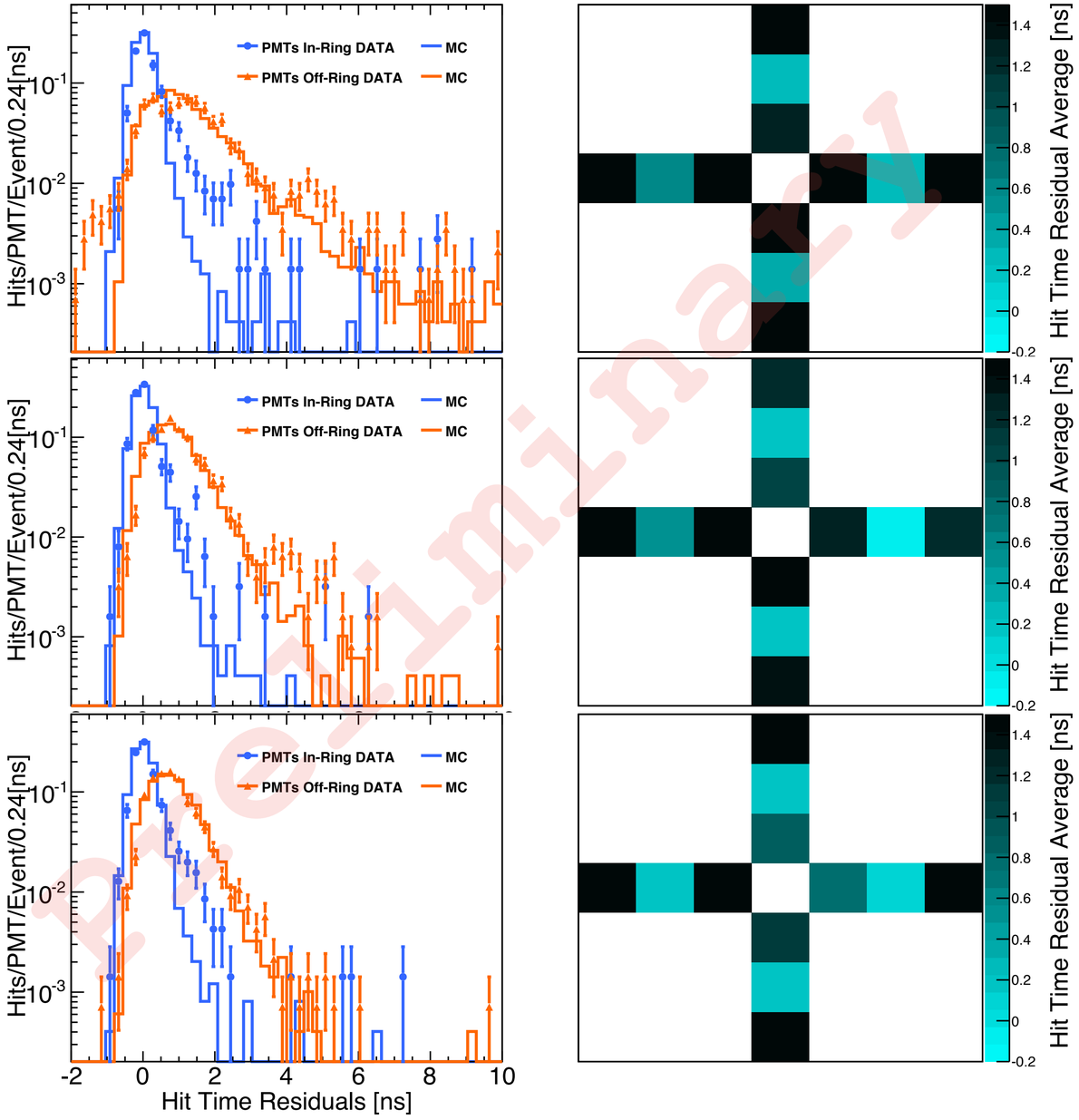
CHERENKOV AND SCINTILLATION SEPARATION IN WbLS: TIME SEPARATION



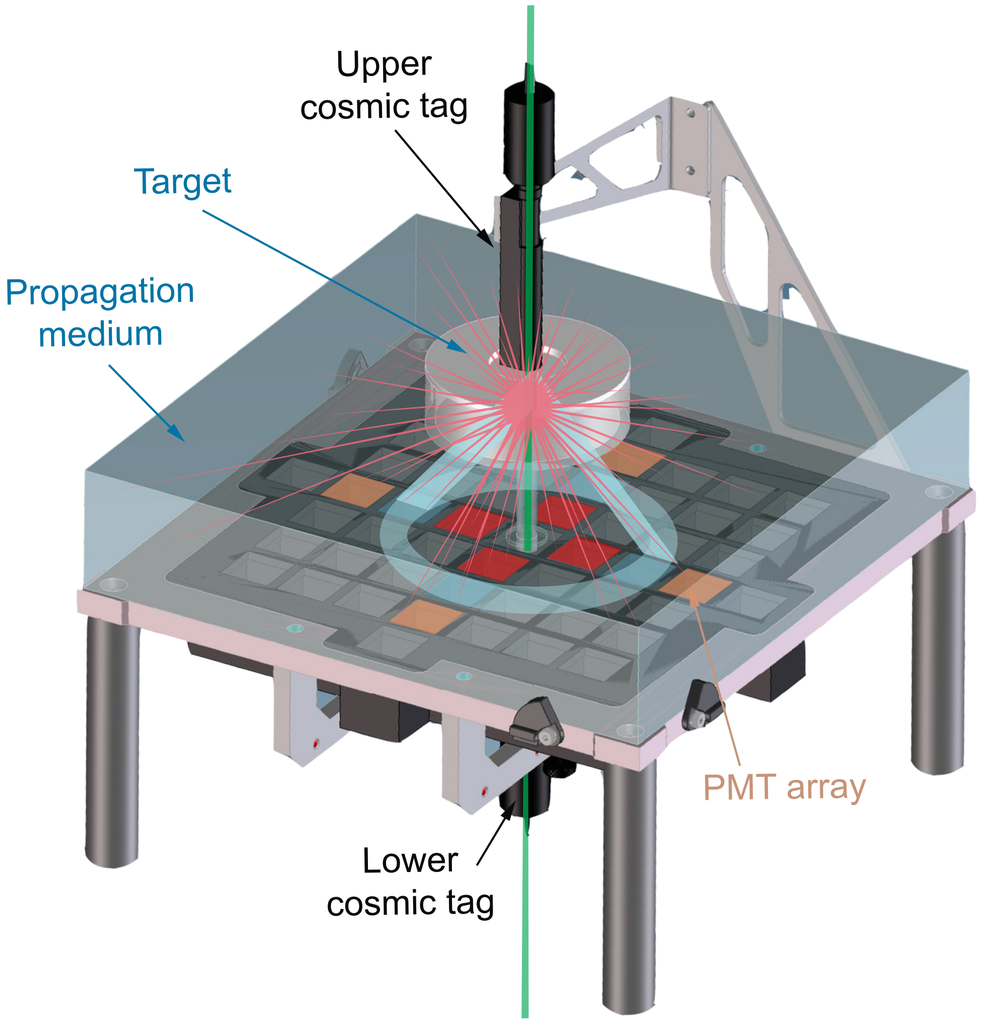
WbLS 1%

WbLS 5%

WbLS 10%



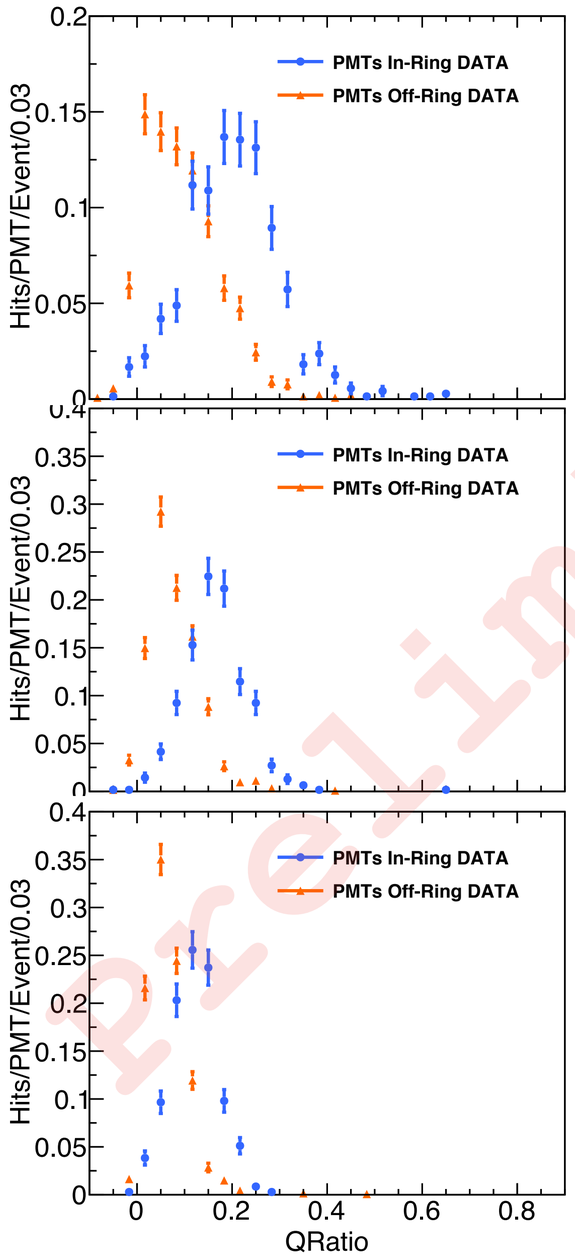
CHERENKOV AND SCINTILLATION SEPARATION IN WbLS: 'CHARGE RATIO' SEPARATION

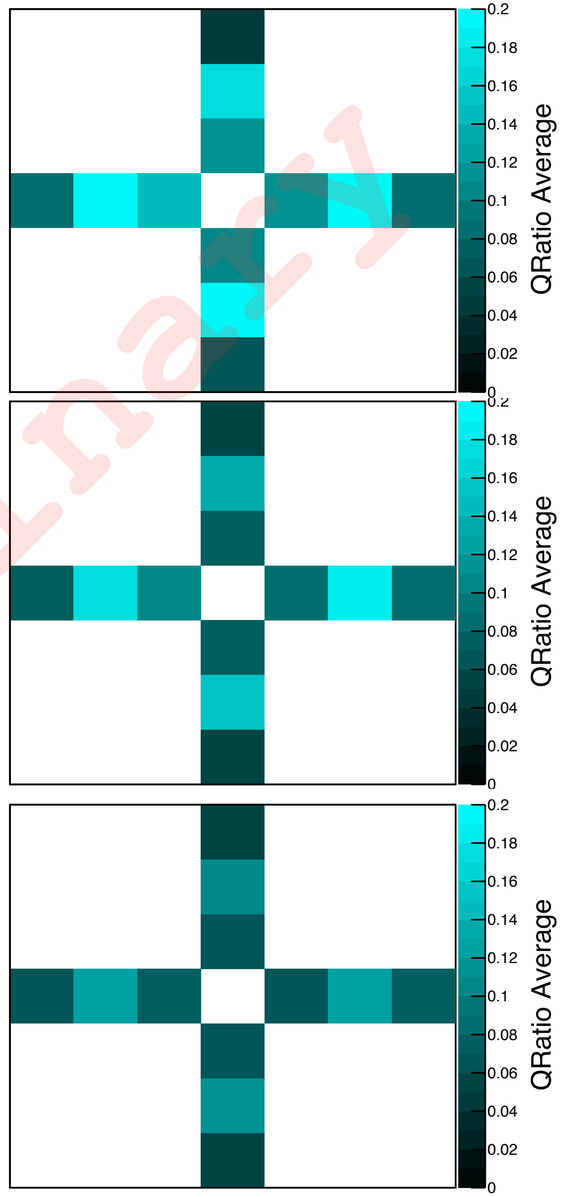


WbLS 1%

WbLS 5%

WbLS 10%





SUMMARY

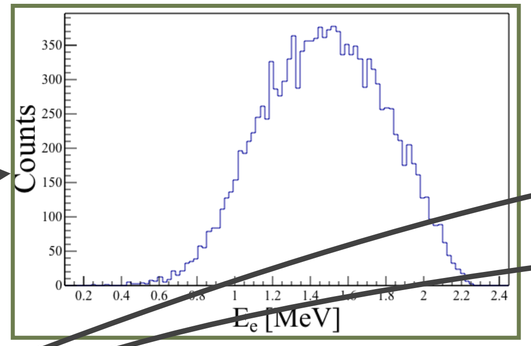
- CHESS' publications:
  - Experiment's description → Phys. Rev. C 95, 055801 (2017)
  - LAB and LABPPO results → Eur. Phys. J. C 77: 811 (2017)
- CHESS has measured the WbLS time profiles for different concentrations
- We are currently characterizing the absolute WbLS light yield with a dedicated setup
- A parallel effort from Bourret's group will provide interesting complementary results with UV and X-Rays
- Once we build the final model we will evaluate C/S separation on THEIA

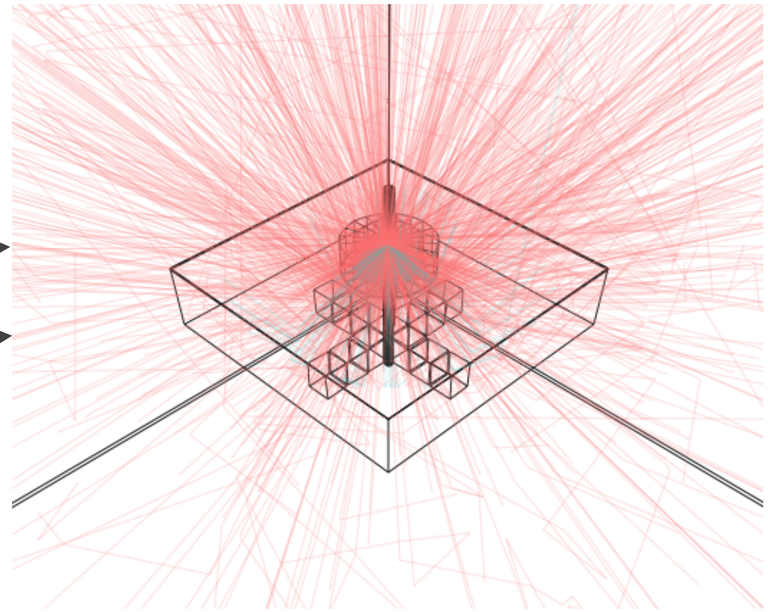
BACKUP

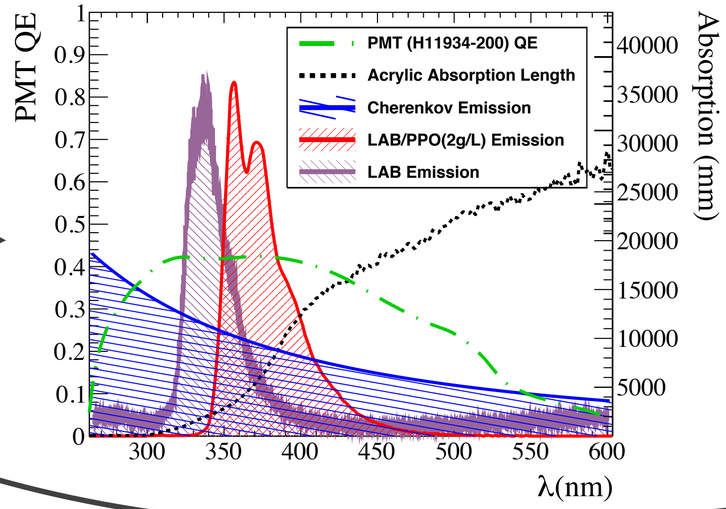
RAT-PAC: GEANT4-BASED SIMULATION (SIMPLE)

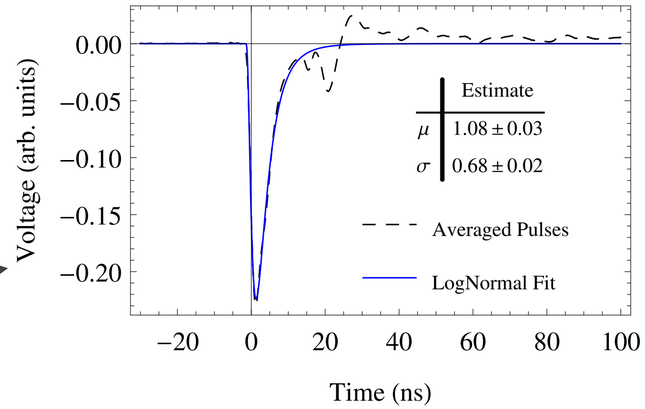
HTTP://RAT.READTHEDOCS.ORG/EN/LATEST/

- Beta decay generator
- Detailed geometry
- Modified GLG4Scint
- Optical properties
- DAQ simulation







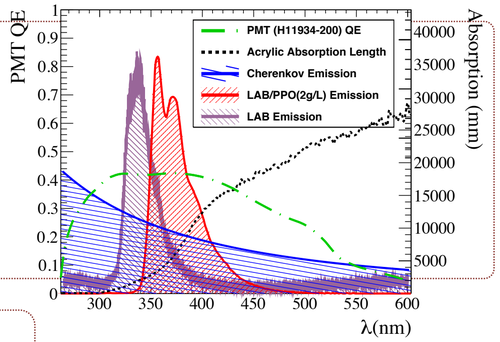


RAT-PAC: GEANT4-BASED SIMULATION (COMPLETE)

HTTP://RAT.READTHEDOCS.ORG/EN/LATEST/

Optics from specifications and custom measurements:

- Refractive indices
- Absorptions
- PMT QEs

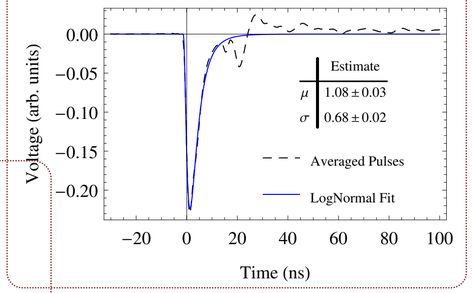


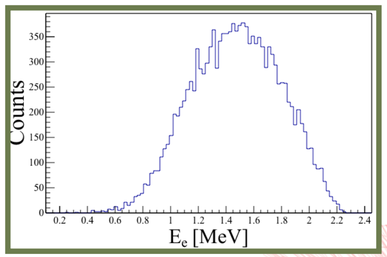
3D PMT optical model in RAT-PAC:

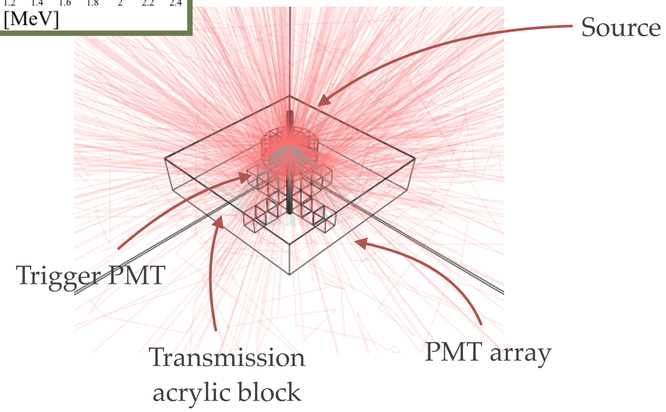
- Inner PMT tracking
- Complete geometry:
  - Glass
  - Dynode
  - Mirror (only R7081)
  - Case (only H11934)

DAQ:

- Waveform
- Gain
- TTS







Using modified version of GLG4Scint as scintillation model (SNO+RAT):

- Birks constant = 0.0798 mm/MeV [1]
- LAB-PPO emission spectrum [2]
- Absorption [2]
- Reemission → Using LABPPO values
  - Probability
  - Emission spectrum
  - Time profile = emission time profile
- Multi-component

[1] B. von Krosigk, et al., Eur. Phys. J. C 73, 2390 (2013).
[2] SNO+ measurements.

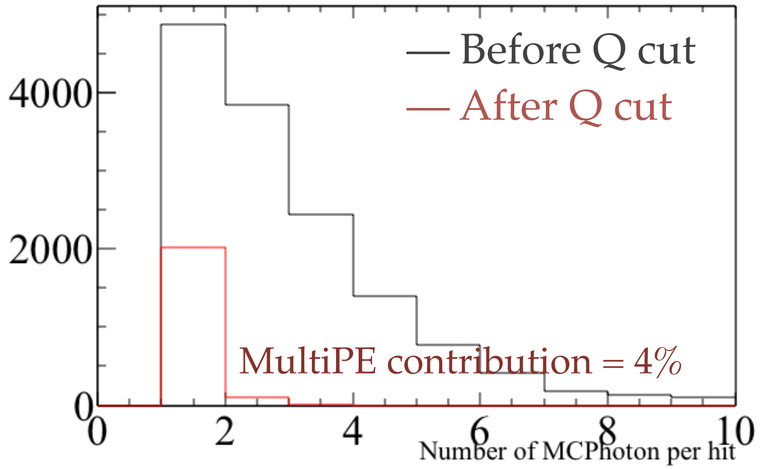
TIME PROFILE SCAN

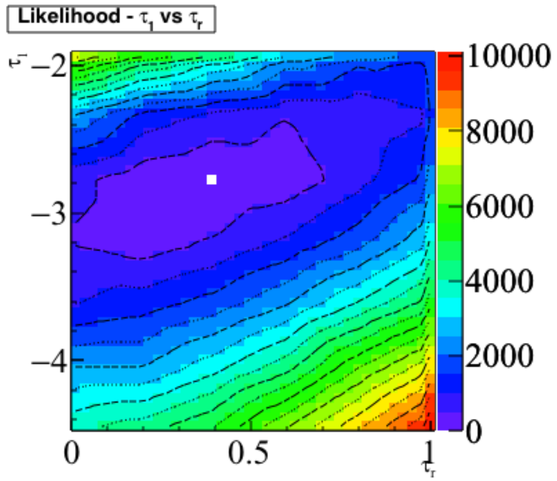
Fitted time profile model → 2 exps. + rise time:

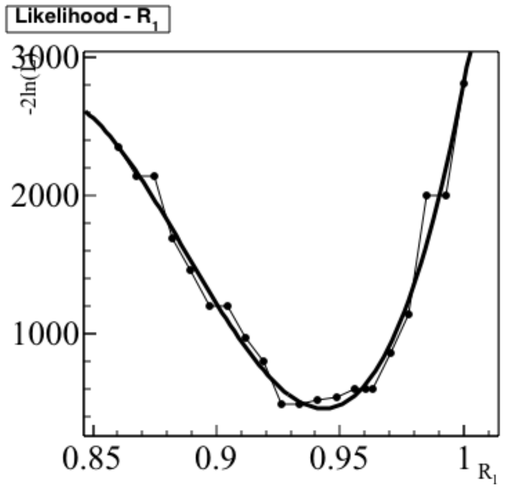
$$f(t) = (1 - e^{-t/\tau_r})(A_1 e^{t/\tau_1} + A_2 e^{t/\tau_2})$$

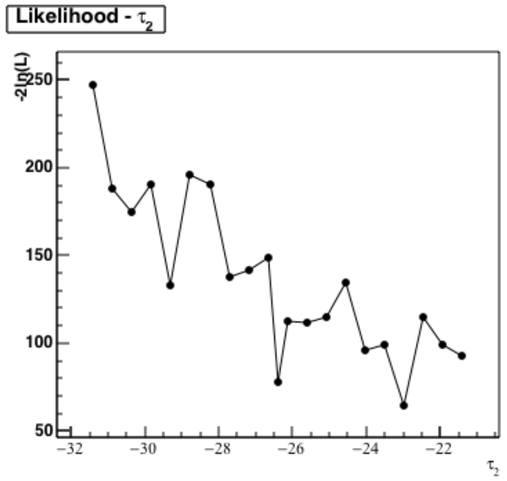
- Fit time profile model using MC → Includes trigger and multiPE effects
- Measure WbLS 10% time profile → Minimize reemission
- Use SPE hits → Include hit charge cut based on gain calibration: 0.5 PEs < NPE < 1.0
- 'Shape-only' analysis → Normalize by area and scan 4 time profile parameters: τ's and A_1

MC PE multiplicity









CHERENKOV AND SCINTILLATION SEPARATION IN WbLS: SUMMARY

WbLS	1%		5%		10%	
	Time	QRatio	Time	QRatio	Time	QRatio
Optimal cut	0.8ns	0.1	0.2ns	0.1	0.2ns	0.05
ε	88%	86%	83%	85%	80%	96%
C	27%	30%	19%	26%	25%	45%