Brief summary on Redout MC studies

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S-PMT meeting

Padova, Oct. 27th 2015

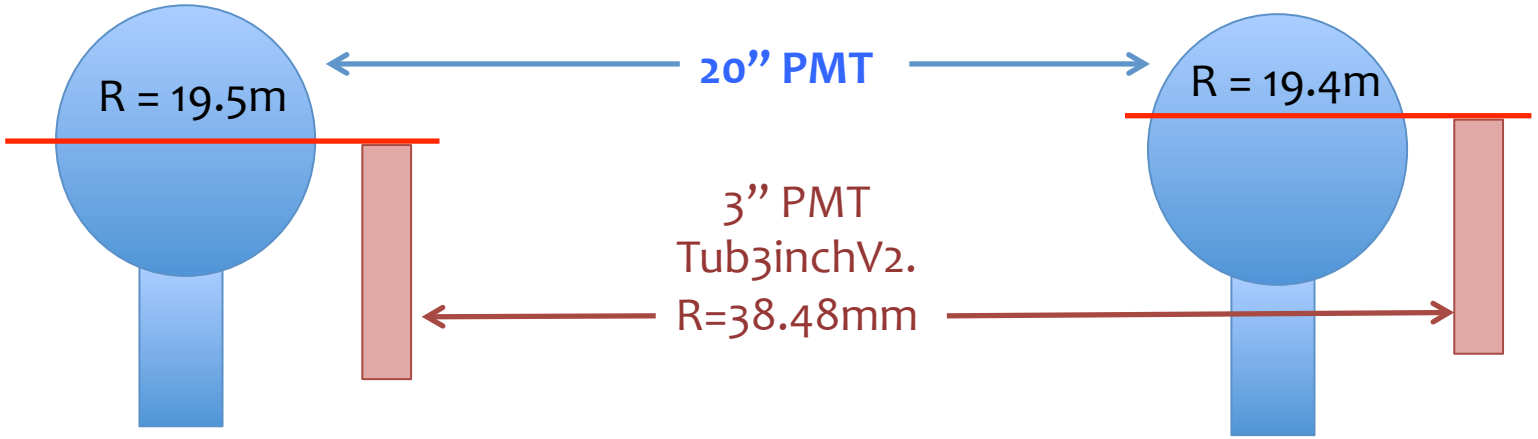
Dictionary

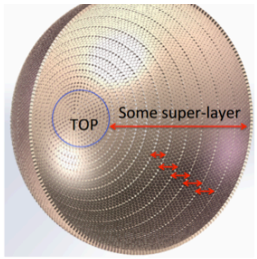
- **L-PMTs** = 20” PMTs
- **S-PMTs** = 3” PMTs
- **S-N_{PE}** = number of photo electron (= perfect charge integration) for 3” PMTs
- **S-N_{PMT}** = number of hit 3” PMTs
- **L-N_{PE}** = number of photo electron (= perfect charge integration) for 20” PMTs
- **L-N_{PMT}** = number of hit 20” PMTs

Two 3” PMT geomtries implemented in Sniper

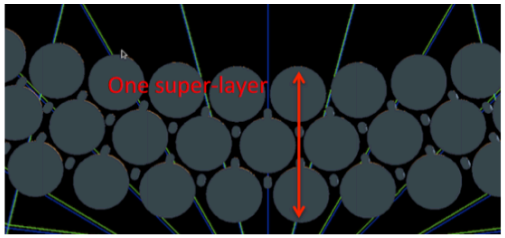
Normal configuration

+10cm offset configuration





Arrangement of 20”PMTs



Add 3”PMTs in the gaps

- 20” PMTs: 17746
- 3” PMT: 35794

Designed by
J.J. Hao, mechanics group
X.Y. Li, offline group

See JUNO-doc-922-v1 for details

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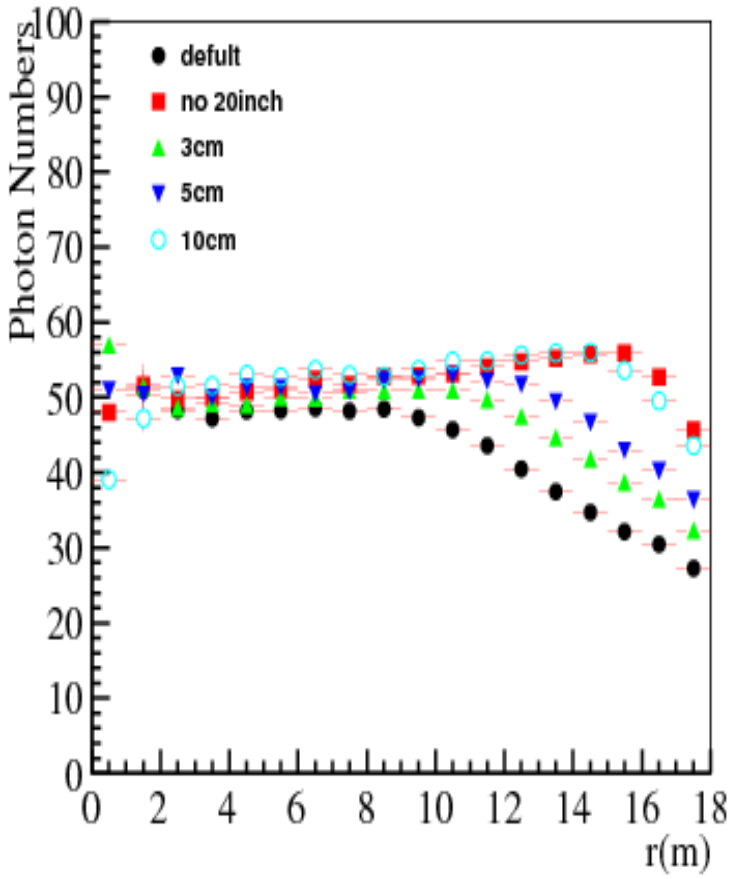
Miao He, JUNO-15 phone meeting

Optimization of S-PMTs' position

Tub3inchV2 in different position (adding 20 inch)



Compared with the default position , percentage of increased photons :

	3 inch PMT	20 inch PMT
3cm	~15%	~ -0.07%
5cm	~25%	~ -0.2%
10cm	~42%	~ -0.6%

Moved forward about 10cm, light shadowed by 20 inch PMT is almost negligible.

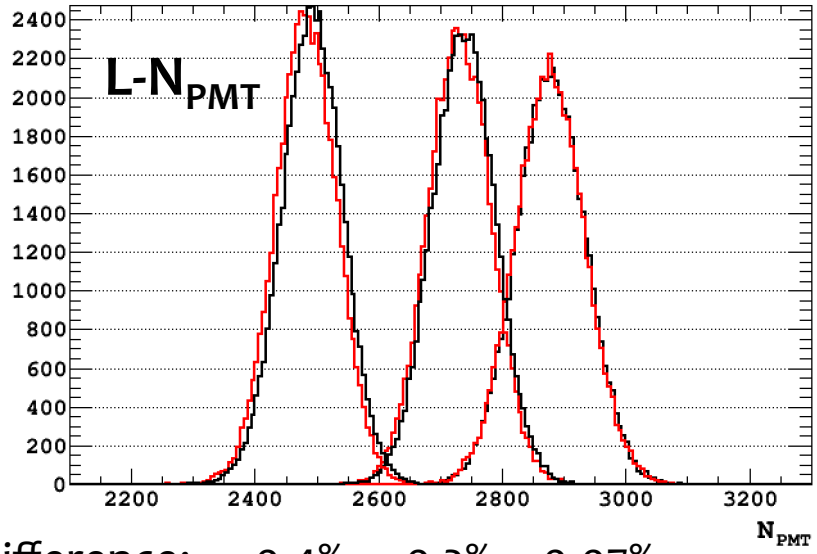
Moved forward about 5cm, the number of total photons of PMT is the largest.

Guo Rupan

S-PMT position impact on L-N_{PE} & L-N_{PMT}? (^{60}Co ~ 2.5 MeV)

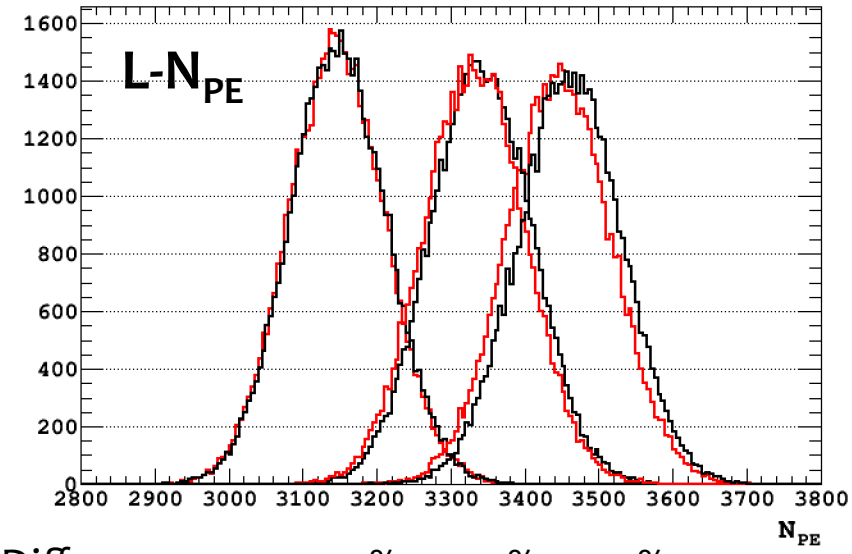
L-PMTs | **S-PMT Normal** | **L-PMTs**

R=15m 10m 2m | **S-PMT +10cm** | R=2m 10m 15m



Difference: - 0.4% - 0.2% -0.07%

(small decreasing of L-N_{PMT})



Difference: -0.07% -0.3% -0.4%

(small decreasing of L-N_{PE})

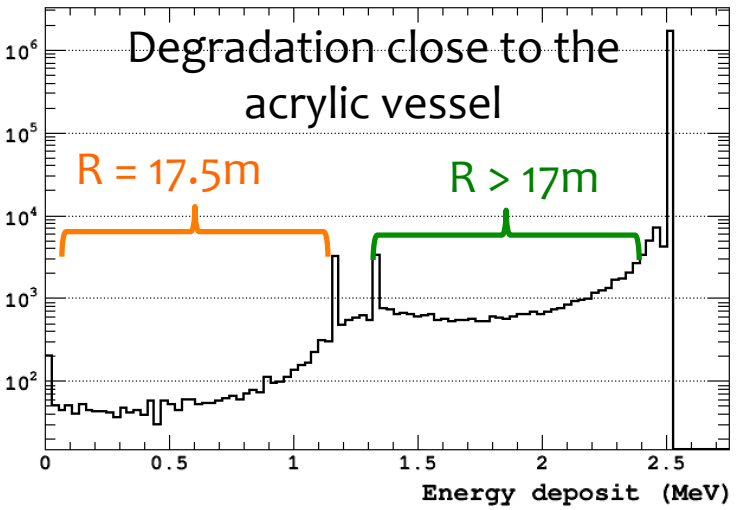
Impact of S-PMT position on L-PMT light detection < 0.4%

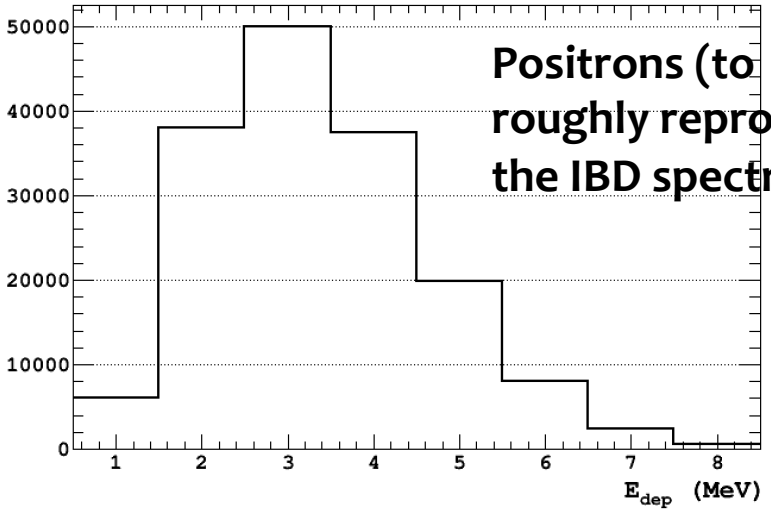
MC Input files

Used Sniper MC production with J15v1r2-Pre1 :

- Positrons uniformely distributed in the CD at different energy
- **^{68}Ge** (2 annihilation γ, ~1MeV) and **^{60}Co** files (2 γ of 1.17 and 1.33 MeV respectively, BR ~ 100%): fixed position with 1m step in radius

^{60}Co



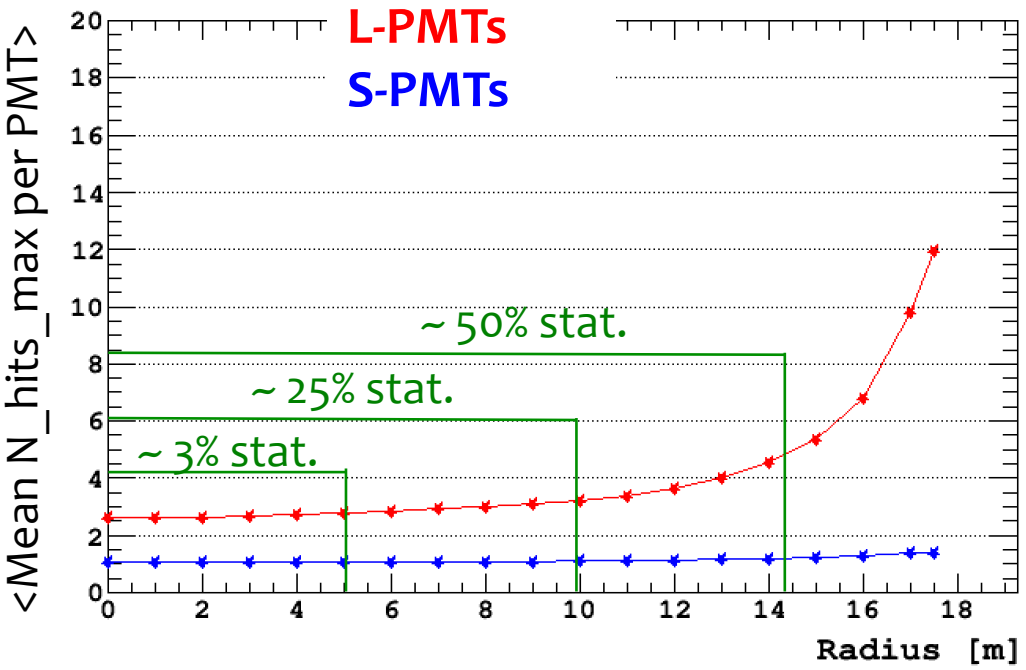


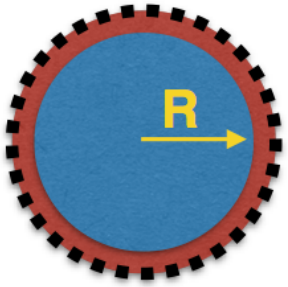
^{68}Ge: Mean dinamic range on PMTs (+10cm)

Light collected by the PMT with MAX number of pe **(@ ~1 MeV)**

<Max pe>:
L-PMT: ~ 12 p.e. (RMS 3 pe)
S-PMT: 1.4 p.e. (RMS 0.5 pe)

Range edge/center
L-PMT: ~ 12/2.6~ 5
S-PMT: ~ 1.4/1.0 ~ 1.4



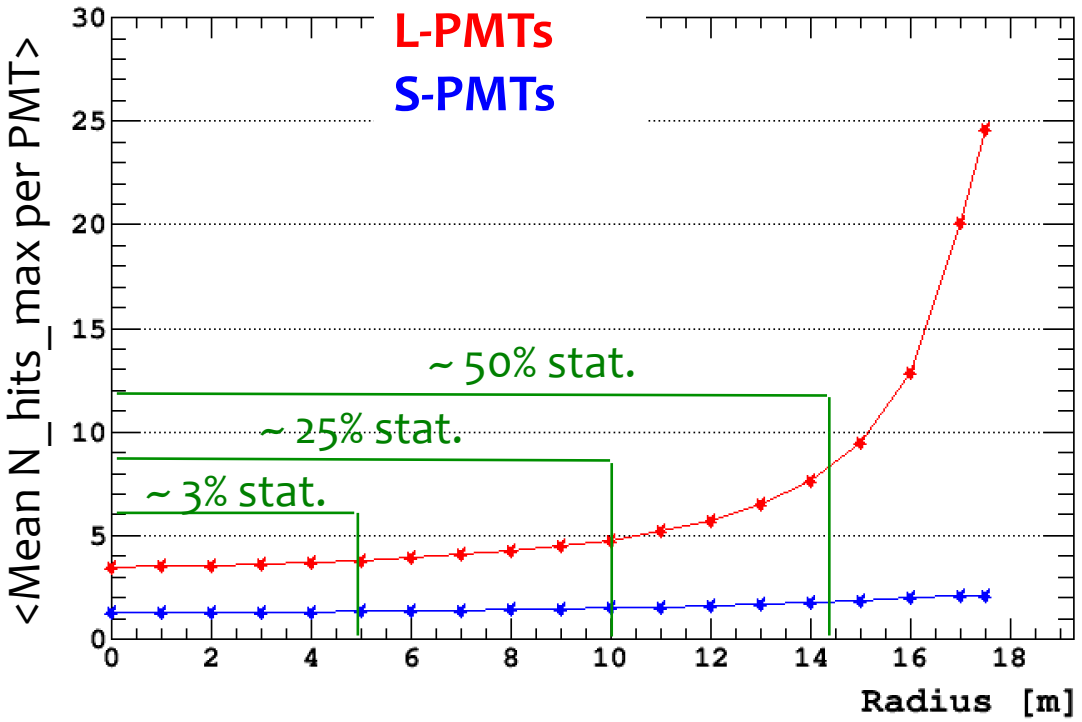


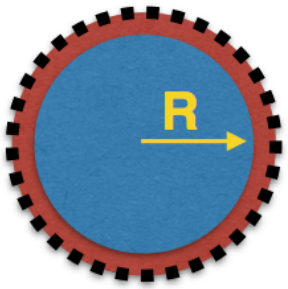
^{60}Co: Mean dinamic range on PMTs (+10cm)

Light collected by the PMT with MAX number of pe **(@ ~2.5 MeV)**

<Max pe>:
L-PMT: ~ 25 p.e. (RMS 6 pe)
S-PMT: 2.1 p.e. (RMS 0.5 pe)

Range edge/center
L-PMT: ~ 25/3.4 ~ 7
S-PMT: ~ 2.1/1.3 ~ 1.5



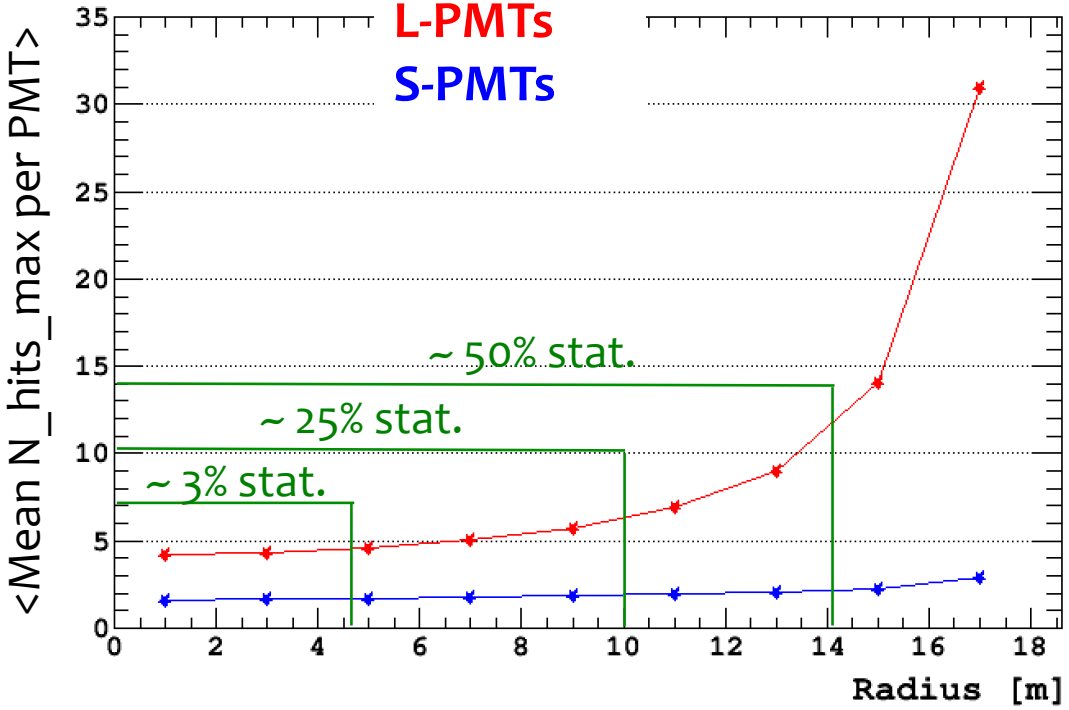


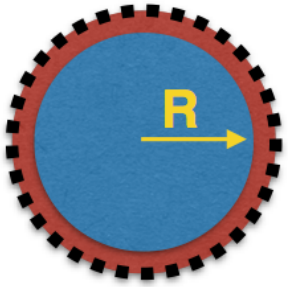
4MeV e^+: Mean dinamic range on PMTs (+10cm)

Light collected by the PMT with MAX number of pe **(@ 4 MeV)**

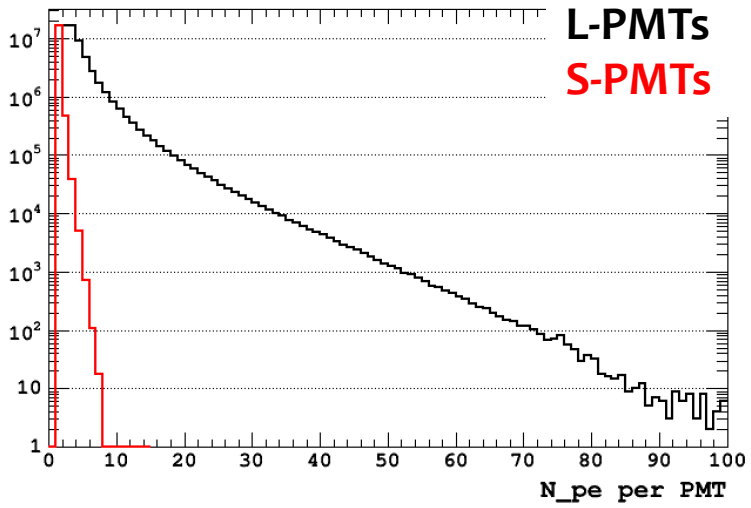
<Max pe>:
L-PMT: ~ 31 p.e. (RMS 6 pe)
S-PMT: 2.9 p.e. (RMS 0.8 pe)

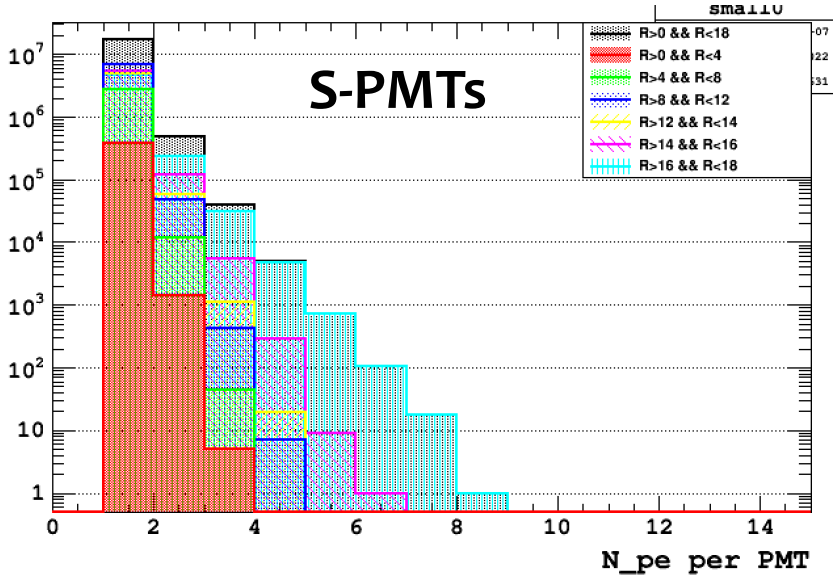
Range edge/center
L-PMT: ~ 31/4 ~ 8
S-PMT: ~ 2.9/1.6 ~ 1.8

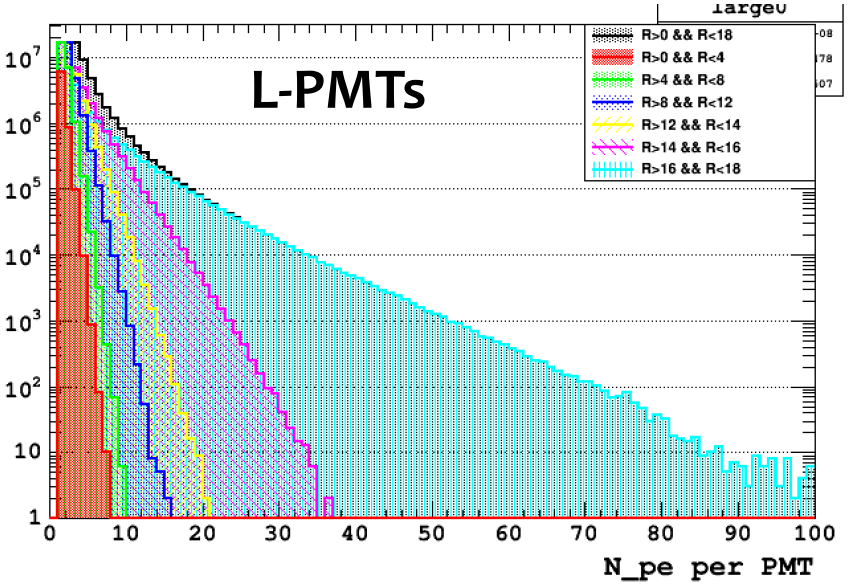




e^+ (~IBD): Number of PE per PMT

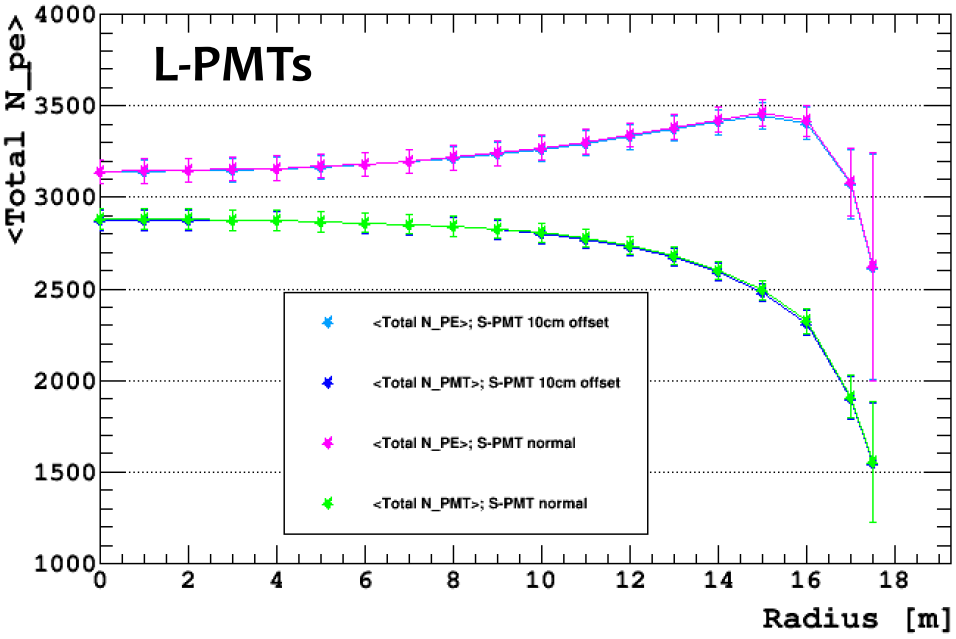




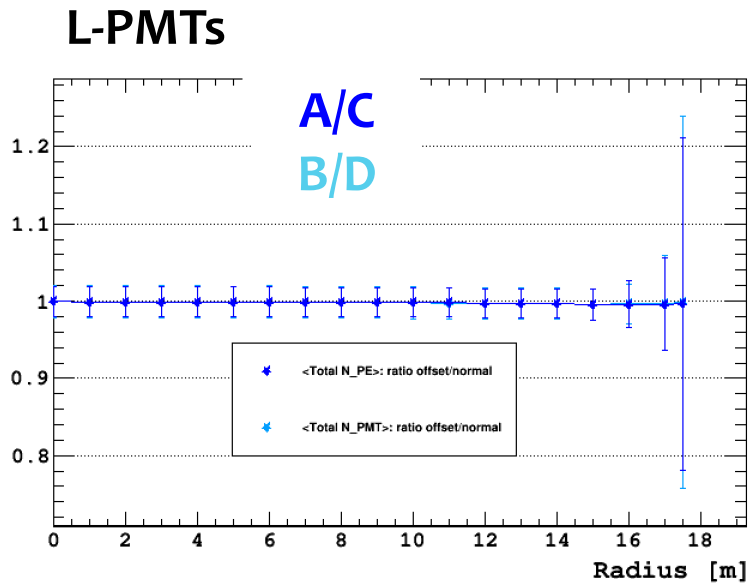


Large PMTs can detect up to 100pe for an IBD event in the last shell (20% of events)

S-PMT position impact on L-N_{PE} & L-N_{PMT}? (^{60}Co ~ 2.5 MeV)



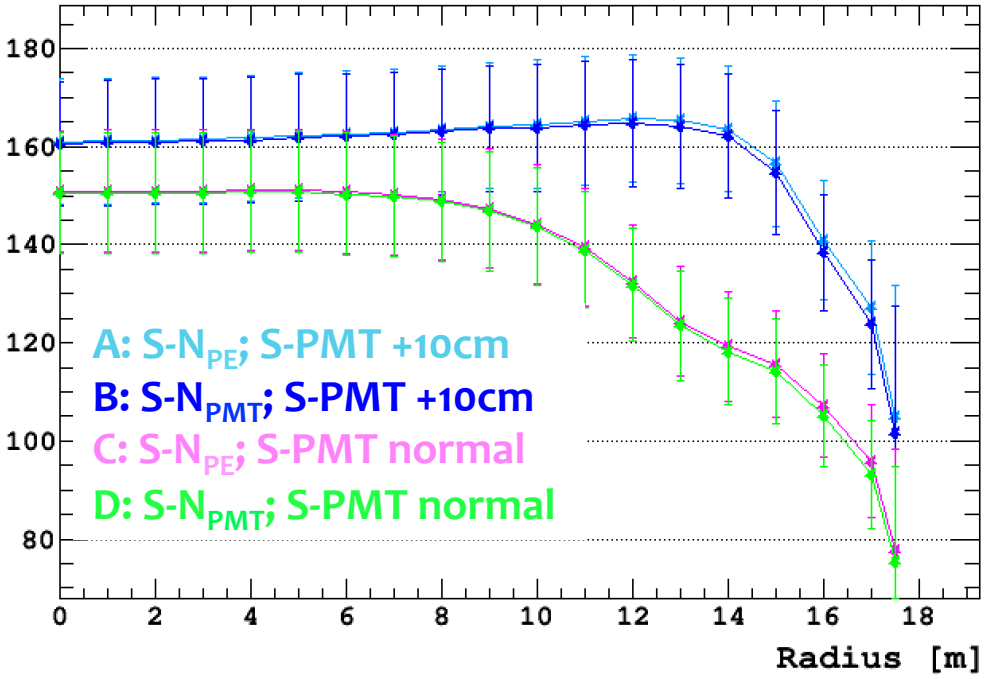
A: L-N_{PE}; S-PMT +10cm
B: L-N_{PMT}; S-PMT +10cm
C: L-N_{PE}; S-PMT normal
D: L-N_{PMT}; S-PMT normal



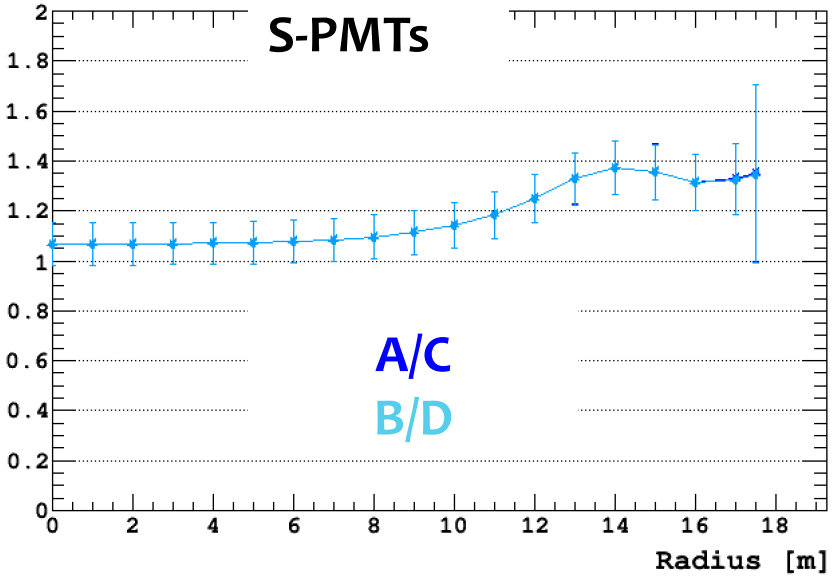
No evident impact of S-PMT position on nor L-N_{PMT} neither L-N_{PE}

S-PMT position impact on S-N_{PE} & S-N_{PMT}? (^{60}Co ~ 2.5 MeV)

S-PMTs



Increasing of light collection in the +10cm configuration



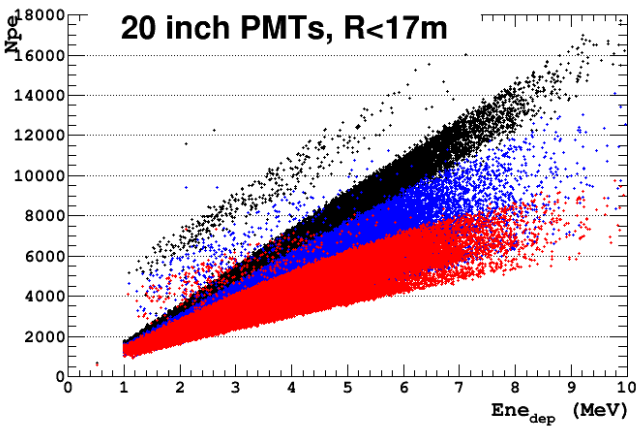
No special impact on single-pe regime (S-N_{PE} always similar to S-N_{PMT})

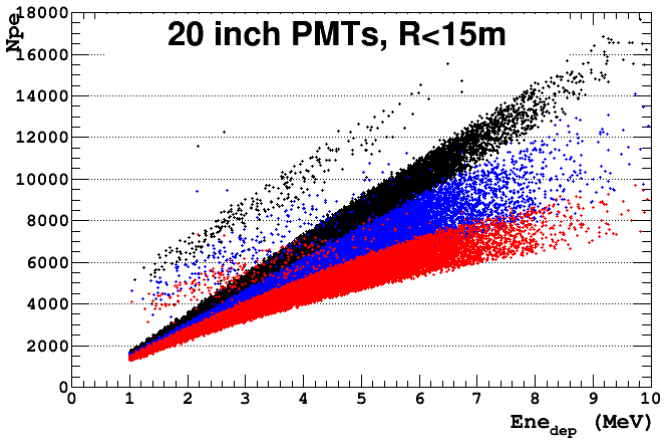
L-PMT: Photon counting?

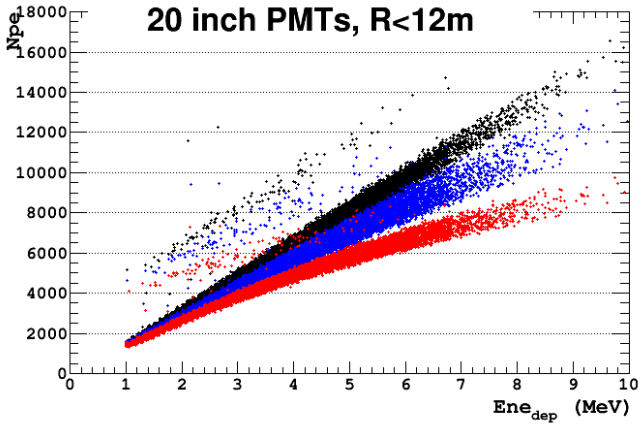
N_PMT = count number of hit PMT = Number of hit PMTs

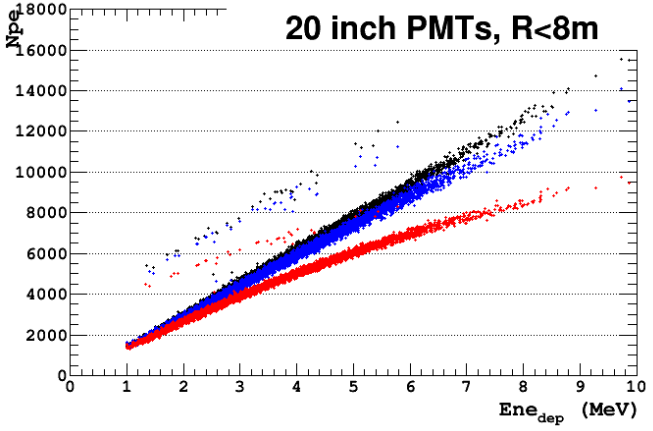
N_PE_corrected = - N_tot_PMT Log(1-N_PMT/N_tot_PMT)

N_PE = True Number of PE = Perfect Charge Integration (no systematics)









Approaching the center ➔ linearity is possible (using N_PE_corrected variable)

S-PMT: Photon counting?

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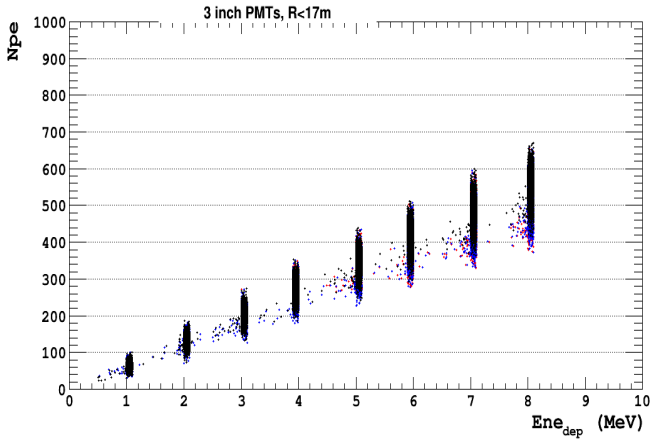
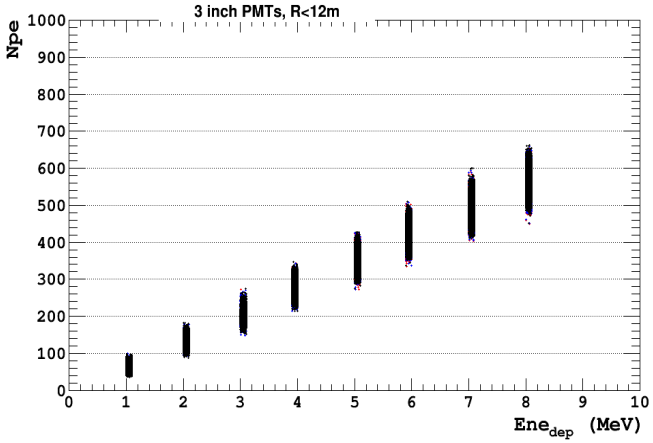
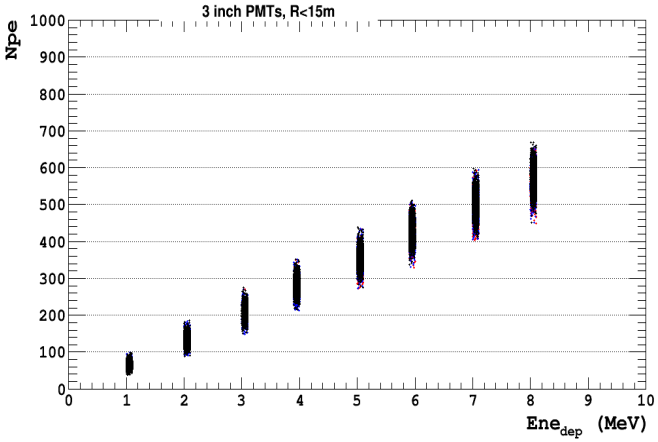
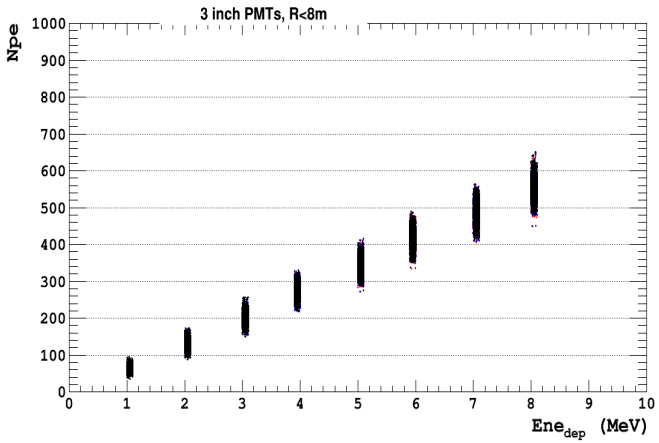








No difference between the 3 variables

L-PMTs: 1pe regime?

PMT fraction	all	R<4m	4m < R < 8m	8m< R < 12m	12m < R < 14m	14m < R < 16m	R > 16m
1pe	0.76	0.88	0.86	0.81	0.76	0.74	0.78
[2,5]pe	0.21	0.12	0.14	0.19	0.23	0.24	0.17
>5pe	0.03	0.00	0.00	0.00	0.01	0.02	0.05

Most (~ 74-88%) of L-PMT see 1 pe per PMT

PE fraction	all	R<4m	4m < R < 8m	8m< R < 12m	12m < R < 14m	14m < R < 16m	R > 16m
1pe	0.52	0.78	0.74	0.66	0.56	0.49	0.45
[2,5]pe	0.35	0.22	0.26	0.34	0.41	0.41	0.27
>5pe	0.15	0.00	0.00	0.01	0.03	0.11	0.28

But a large fraction of the energy (~ 25-60%) is detected by the small fraction of PMT (24%) detecting more than 1 pe

L-PMTs: 1pe regime?

PMT fraction	all	R<4m	4m < R < 8m	8m< R < 12m	12m < R < 14m	14m < R < 16m	R > 16m
1pe	0.76	0.88	0.86	0.81	0.76	0.74	0.78
[2,5]pe	0.21	0.12	0.14	0.19	0.23	0.24	0.17
>5pe	0.03	0.00	0.00	0.00	0.01		

Most (~ 74-88%) of 20" PMT see 1 pe

Strong dependence on the vertex position

PE fraction	all	R<4m	4m < R < 8m	8m< R < 12m	12m < R < 14m	14m < R < 16m	R > 16m
1pe	0.52	0.78	0.74	0.66	0.56	0.49	0.45
[2,5]pe	0.35	0.22	0.26	0.34	0.41	0.41	0.27
>5pe	0.15	0.00	0.00	0.01	0.03	0.11	0.28

But a large fraction of the energy (~ 25-60%) is detected by the small fraction of PMT (24%) detecting more than 1 pe

S-PMTs: fraction on PMT measuring 1pe

PMT fraction	all	R<4m	4m < R < 8m	8m< R < 12m	12m < R < 14m	14m < R < 16m	R > 16m
1pe	0.96	0.99	0.99	0.99	0.99	0.98	0.95
[2,5]pe	0.03	0.01	0.01	0.01	0.01	0.02	0.05
>5pe	0.01	0.00	0.00	0.00	0.00	0.00	0.01

Almost all (~ 92-99%) 3" PMT seen 1 PE per PMT

Almost no dependence on the radius

PE fraction	all	R<4m	4m < R < 8m	8m< R < 12m	12m < R < 14m	14m < R < 16m	R > 16m
1pe	0.93	0.99	0.99	0.98	0.97	0.95	0.89
[2,5]pe	0.07	0.01	0.01	0.02	0.03	0.05	0.11
>5pe	0.03	0.00	0.00	0.00	0.00	0.03	0.03

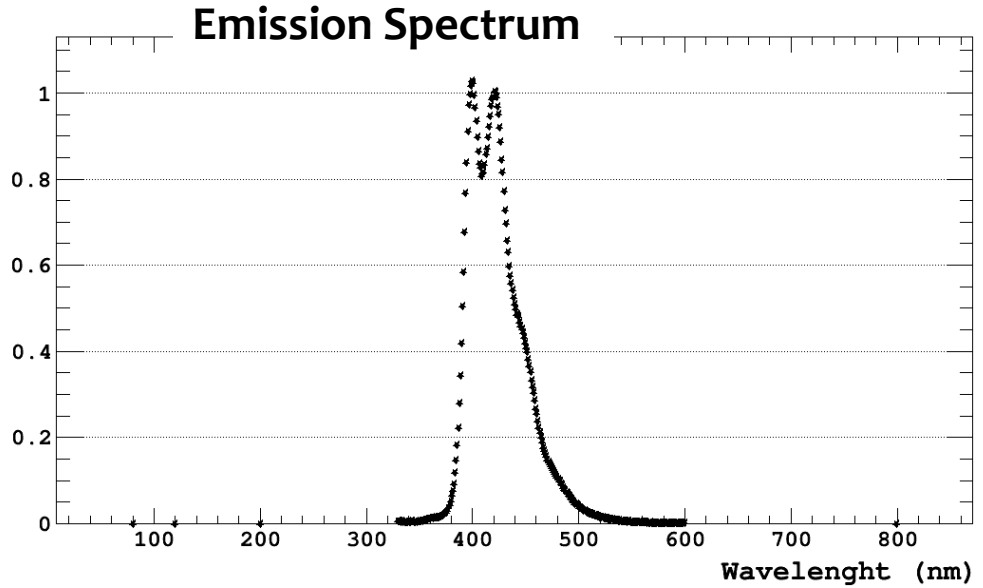
Almost all the energy (87-99%) is detected in the single pe regime

Ongoing Efforts: JMC

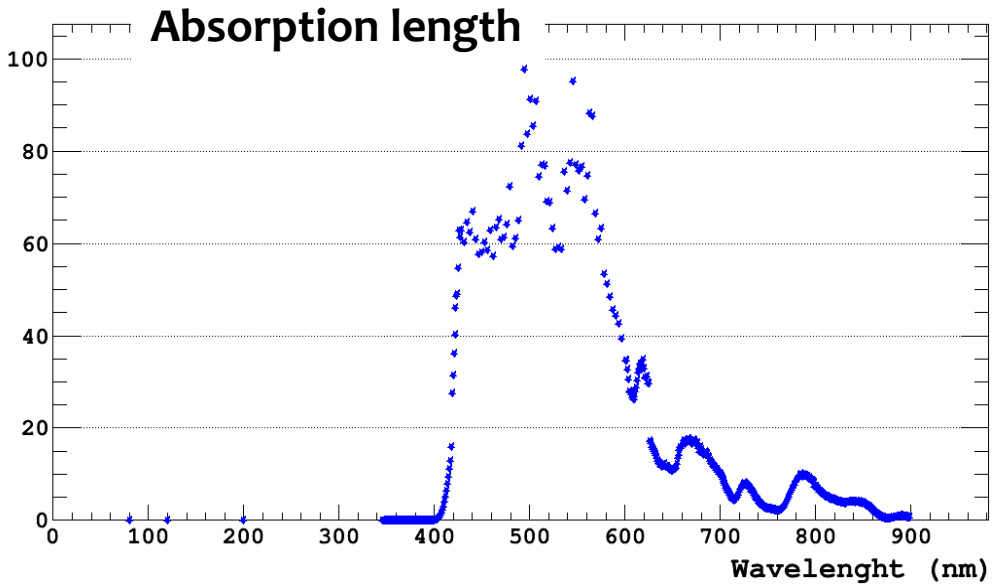
- Preparing a Geant4 based simulation tool (**J**uno **M**ulti-**C**alorimetry)
- Plan to optimize the number of needed S-PMT + multicalorimetry tests
- Geometry (S-PMT + L-PMT) is ready
- Simple physics list (G4scintillation + absorption length, no re-emission for the moment)

JMC – Rough Scintillation

Photon Yield: 11520 ph/MeV
G4Scintillation

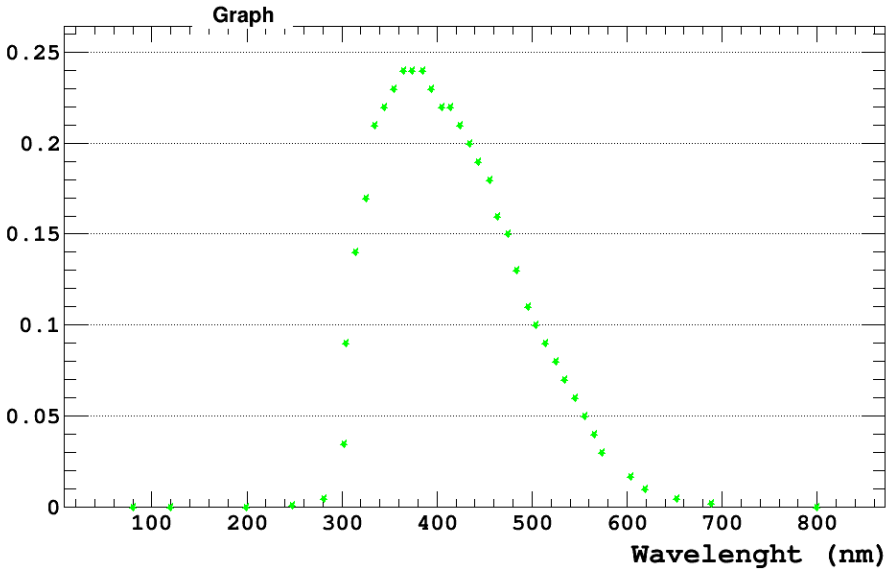


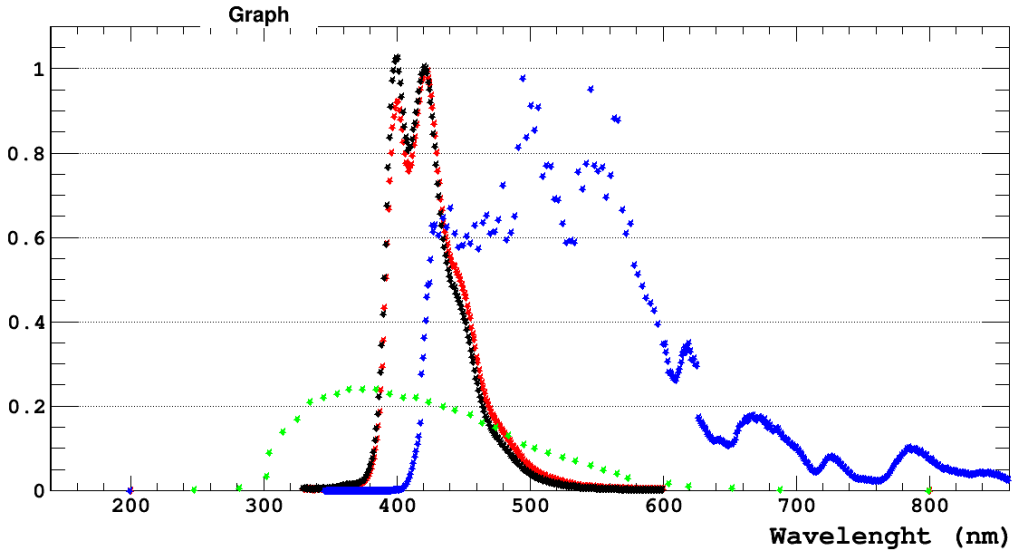
Absorption length



JMC – LPMT QE

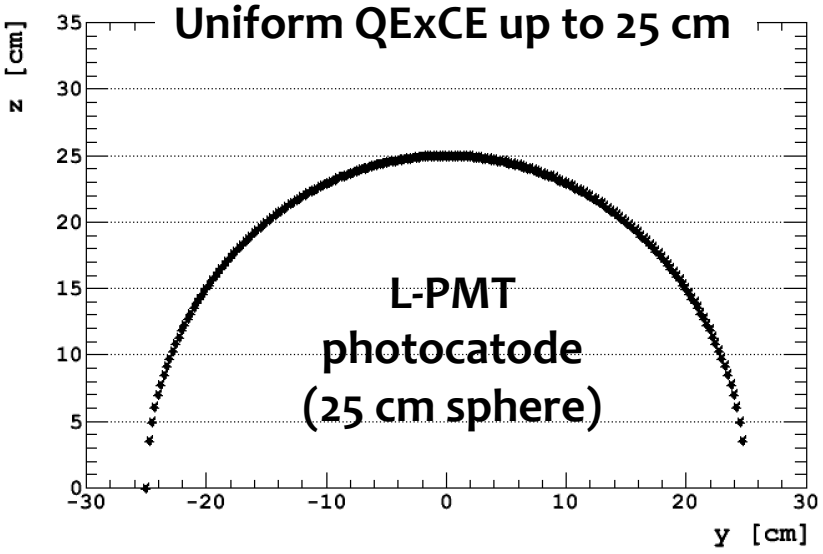
L-PMT & S-PMT QE
(+ CE = 0.9)

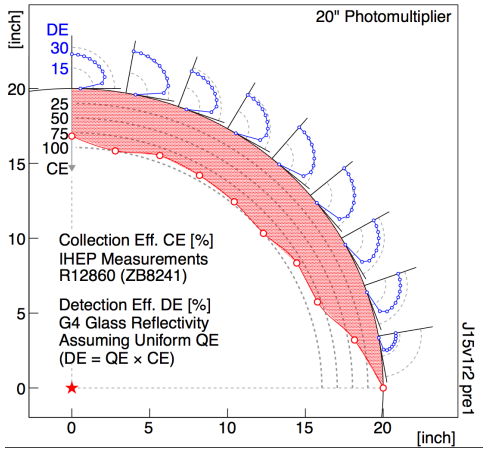


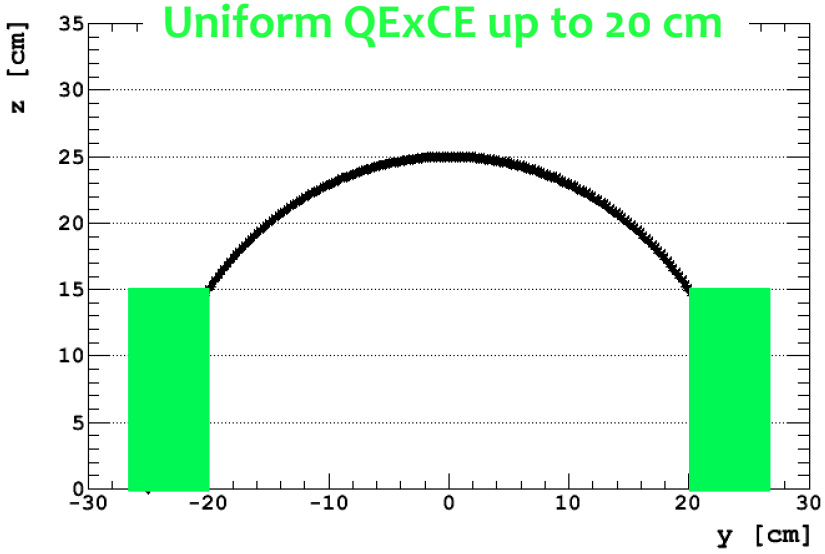


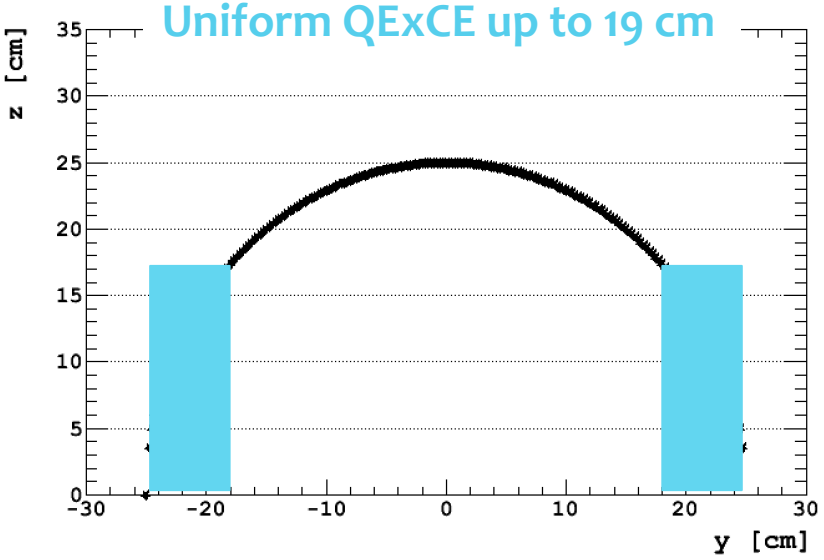
Emission
Re-emission (not used yet)
Abs. Length /100.
LPMT - QE

LPMT - Detection Efficiency





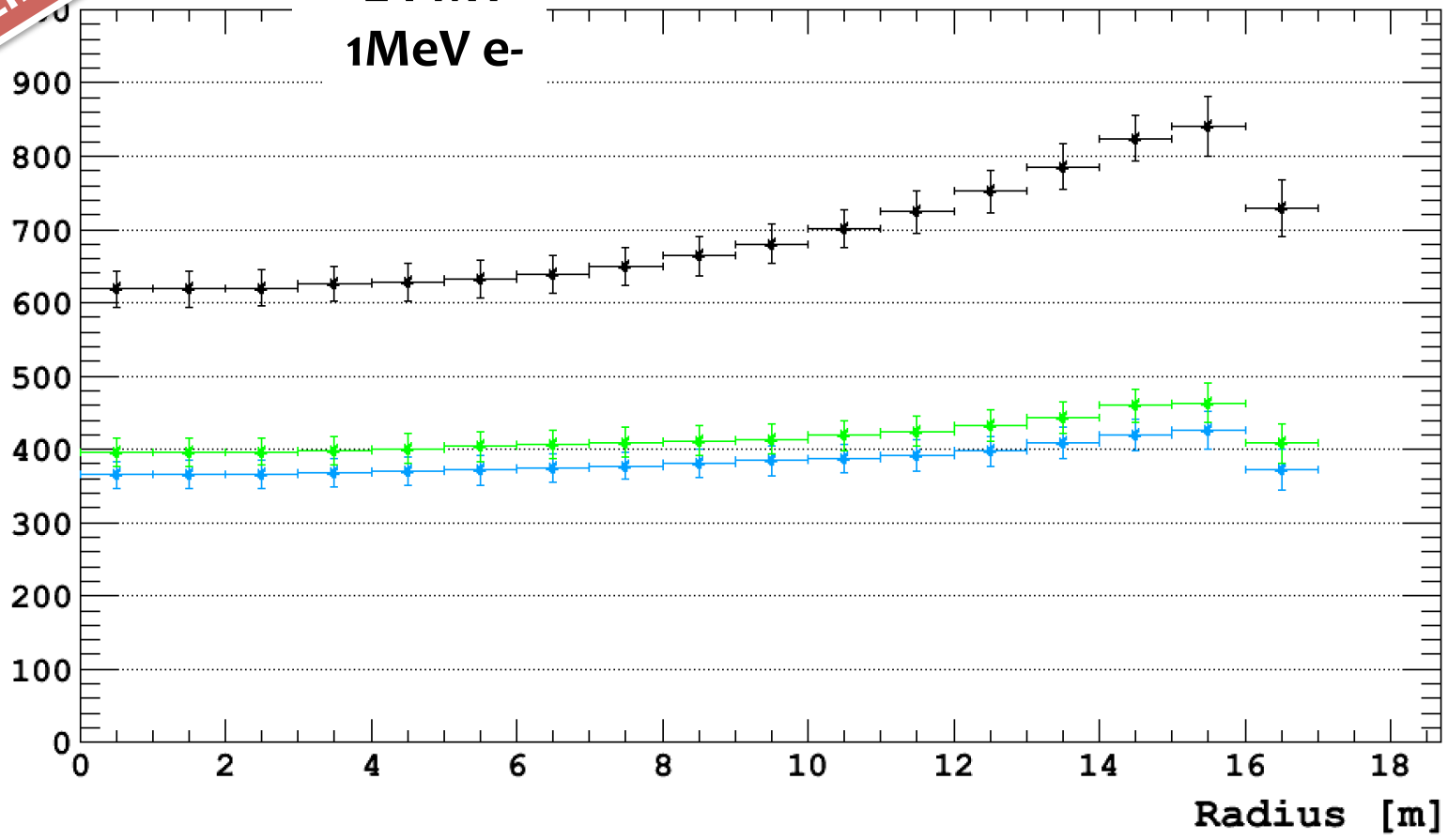




L-PMT: Photocathode quantum efficiency

PRELIMINARY

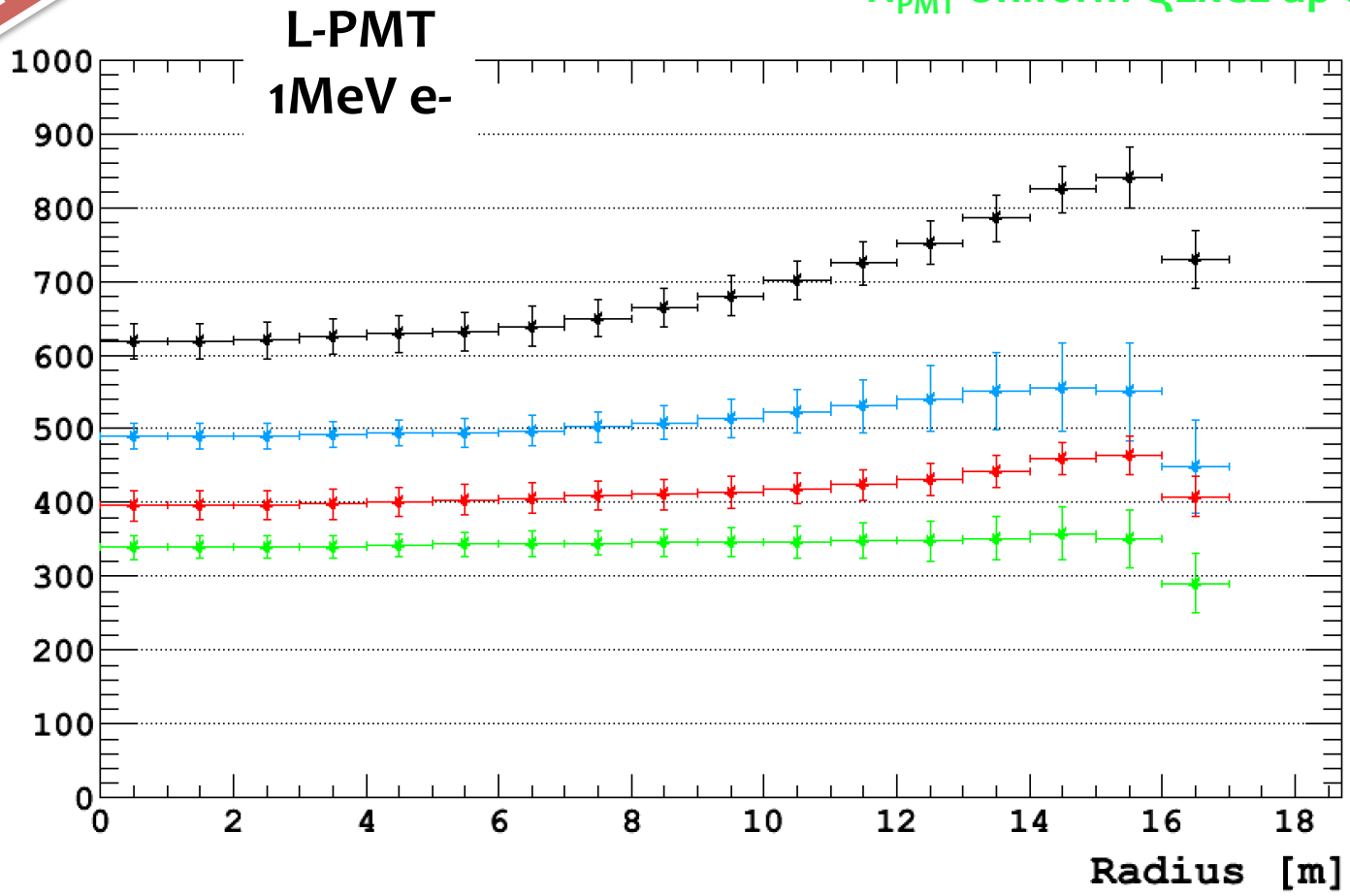
N_{PE} Uniform QExCE up to 25cm
N_{PE} Uniform QExCE up to 20 cm
N_{PE} Uniform QExCE up to 19 cm



L-PMT: N_{PE} & N_{PMT}

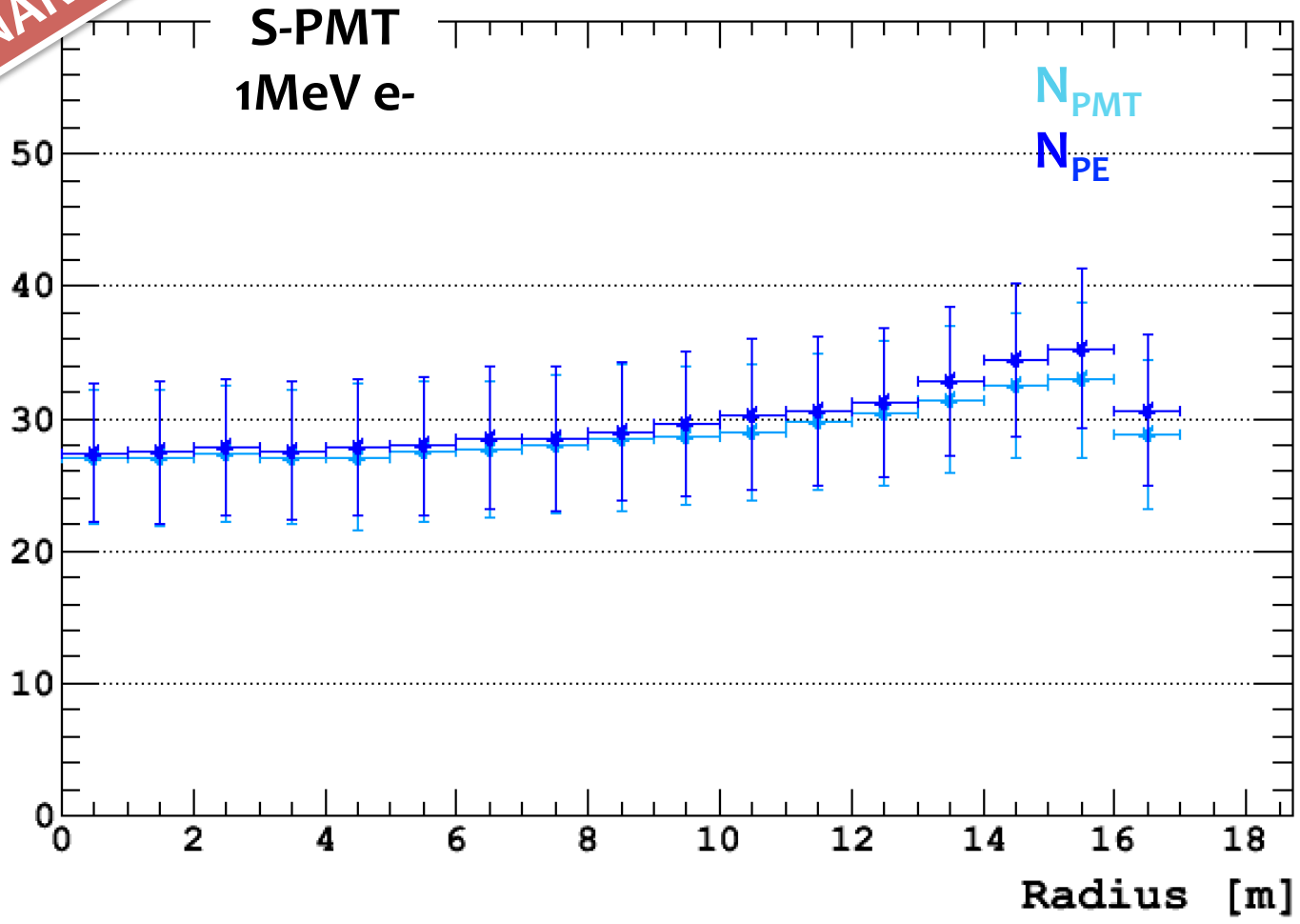
PRELIMINARY

N_{PE} Uniform QExCE up to 25cm
N_{PMT} Uniform QExCE up to 25 cm
N_{PE} Uniform QExCE up to 19cm
N_{PMT} Uniform QExCE up to 19 cm



S-PMT: N_{PE} & N_{PMT}

PRELIMINARY



Summary

… Work in progress…