Discussion points
1/6/2022

- Happy New Year!
- Next meeting January 20 at 12:30 pm Eastern time. Do we want to change the time, day, frequency of this meeting ?
    - Some milestones for next year
        - Snowmass write-ups due in January
            - FPF “long paper” (first draft to be readied for Jan 31- Feb 1 FPF 4th meeting)
                - Should there be a section connecting to a future collider also ?
            - Tau neutrino white paper. (can first draft be ready for Jan 31-Feb 1 FPF 4th meeting ?)
                - Schedule a talk at the Jan 20 meeting.
                - Should there be a section connecting to a future collider also ?
        - Snowmass events all through spring and summer. …
        - FPF is in the Energy Frontier territory.
            - FPF is an opportunity for EF to have a new scientific content and technologies.
            - How do we make sure it is also recognized in Intensity Frontier, Cosmic Frontier ?
            - The detector has considerable impact on the Instrumentation Frontier.
- Tentative: Talk next meeting (Jan 20) on the NA48 liquid Krypton detector by Sandro Palestini

Please send comments on this to Mary Hall

https://arxiv.org/abs/2112.11605

Parton distribution function uncertainties in theoretical predictions for far-forward tau neutrinos at the Large Hadron Collider

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New experiments to measure neutrinos in the far-forward region at the Large Hadron Collider (LHC) are under design or already in preparation. Two of them, Faser-ν and SND@LHC, are expected to be active during Run 3 and have the potential to detect neutrinos that come from high-energy collisions in one of the LHC interaction points, extracted along the direction tangent to the beam line. Tau neutrinos and antineutrinos come predominantly from $D_s^\pm$ production in pp collisions, followed by the leptonic decay of these mesons. Neutrino pseudorapidities in the range of $\eta > 6.9$ and $\eta > 8.9$ are relevant to these future experiments. At such large pseudorapidities at high energies, theoretical predictions rely on parton distribution functions (PDFs) in a combination of very small and large parton$-x$ values. We evaluate PDF uncertainties in a next-to-leading order (NLO) QCD calculation of the flux of tau neutrinos plus antineutrinos produced by $D_s^\pm$ decay in the far forward region at the LHC. The theoretical uncertainty associated with the 40 PDF sets of the PROSA19 group amount to $\pm(20-30)$\% for the tau neutrino plus antineutrino number of charged-current events. Scale uncertainties are much larger, resulting into a range of charged-current event predictions from $\sim 70\%$ lower to $\sim 90\%$ higher than the central prediction. A comparison of the predictions with those obtained using as input the central PDFs from the 3-flavour NLO PDF sets of the CT14, ABMP16 and NNPDF3.1 collaborations show that far-forward neutrino energy distributions vary by as much as a factor of $\sim 2-4$ relative to the PROSA19 predictions at TeV neutrino energies. The Forward Physics Facility in the high luminosity LHC era will provide data capable of constraining NLO QCD evaluations with these PDF sets.

Comparison of basic properties.

	Liquid Argon	Liquid Krypton
Z, A	**18, 39.9**	**36, 83.8**
Density	1.4 gm/cc	2.4 gm/cc
Radiation Length	14 cm	4.7 cm
Moliere Radius	9 cm	5.8 cm (NA48 says 4.7)
nuclear interaction length	119.7 gm/cm2, 85.8 cm	149.7 gm/cm2, 61.8 cm
pion interaction length	149.0 gm/cm2, 106.7 cm	177.6 gm/cm2, 73.47 cm
critical energy e (mu)	32 MeV (485 GeV)	17 MeV (277 GeV)
Minimum ionization	2.105 MeV/cm	3.28 MeV/cm
Ionization (eV) (atom)	15.8 eV	14.0 eV
Boiling point	87.3 K	119.9 K
index of refraction	1.23	1.3
scintillation wavelength	125 nm	147 nm
Yield	40000/MeV	25000/MeV
Triplet lifetime	1. 6 micros	0.09 micros
Drift velocity at 500 V/cm	1.6 mm/micro-sec	2.1 mm/micro-sec
Radioactiviity	Ar39, Ar42	Kr81, Kr85
Air abundance (ppm)	9300	1.14

https://pdg.lbl.gov/2012/AtomicNuclearProperties/HTML_PAGES/289.html
https://periodictable.com/Isotopes/018.42/index2.dm.html

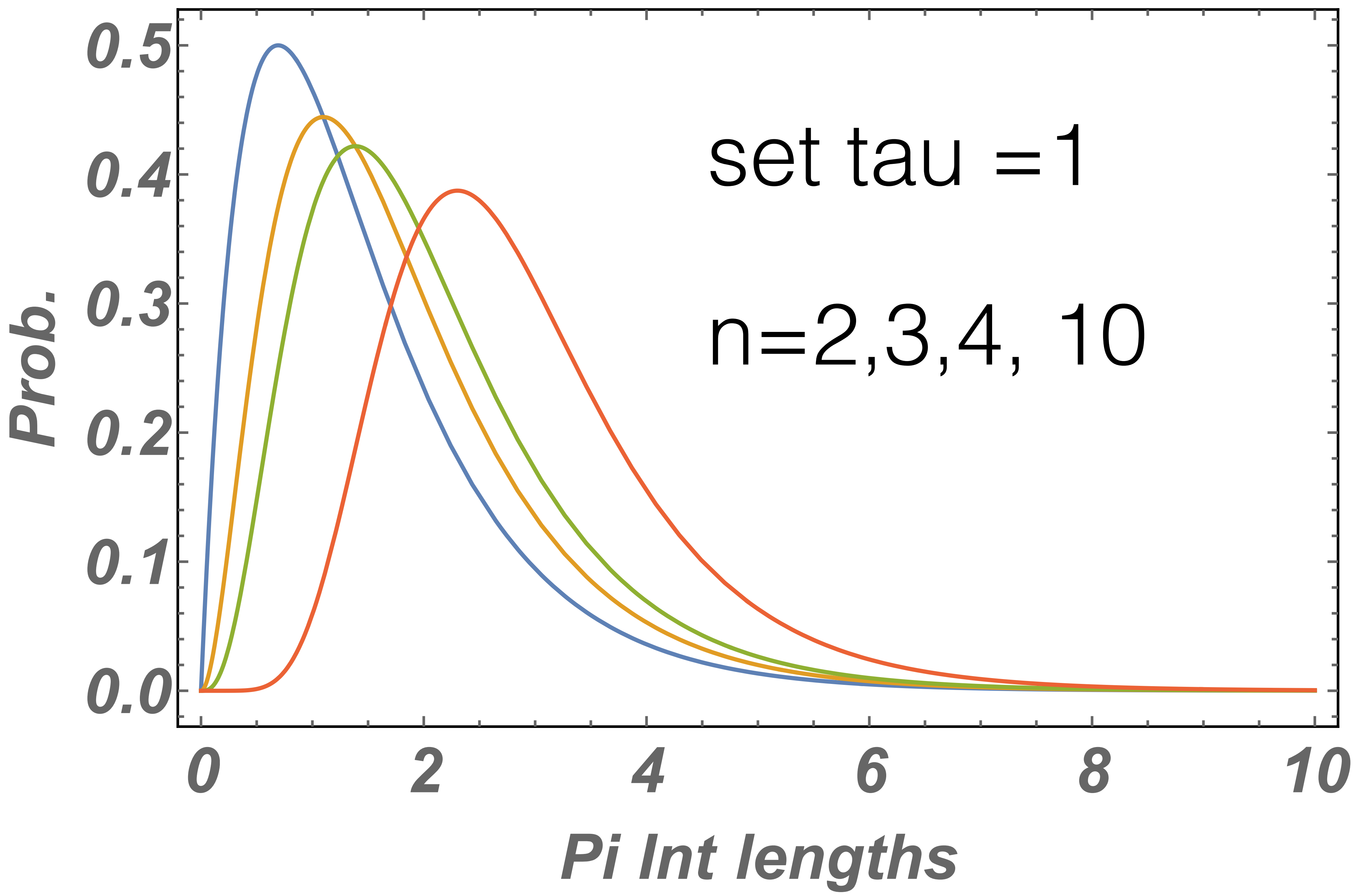
$$R_M \approx 0.0265 X_0 (Z + 1.2)$$

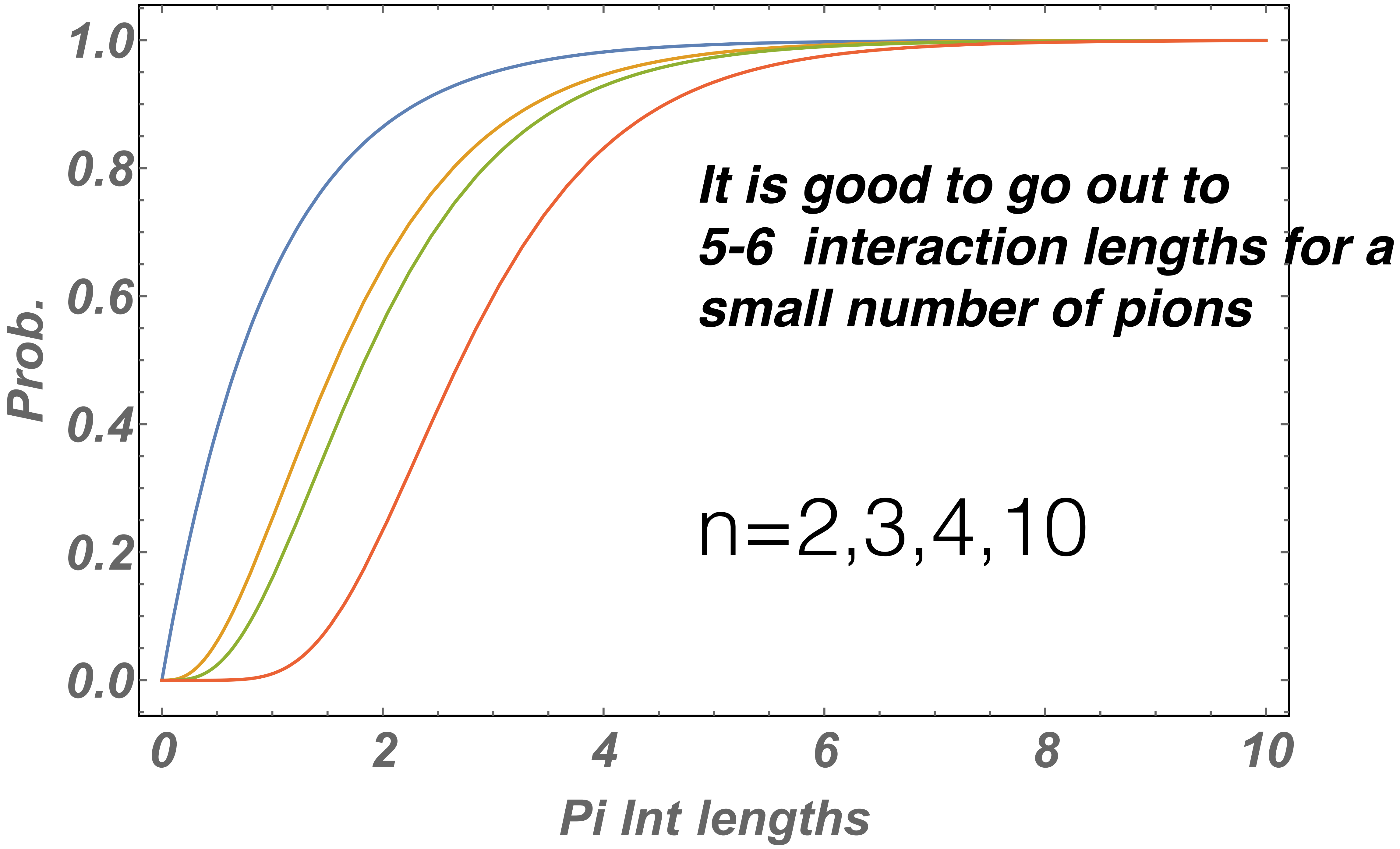
Last pion

PDF for each pion interaction with interaction length τ: $P_X(x) = \frac{1}{\tau} e^{t/\tau}$

Cumulative distribution for n interacting pions. $F_Z(t) = (1 - e^{t/\tau})^n$

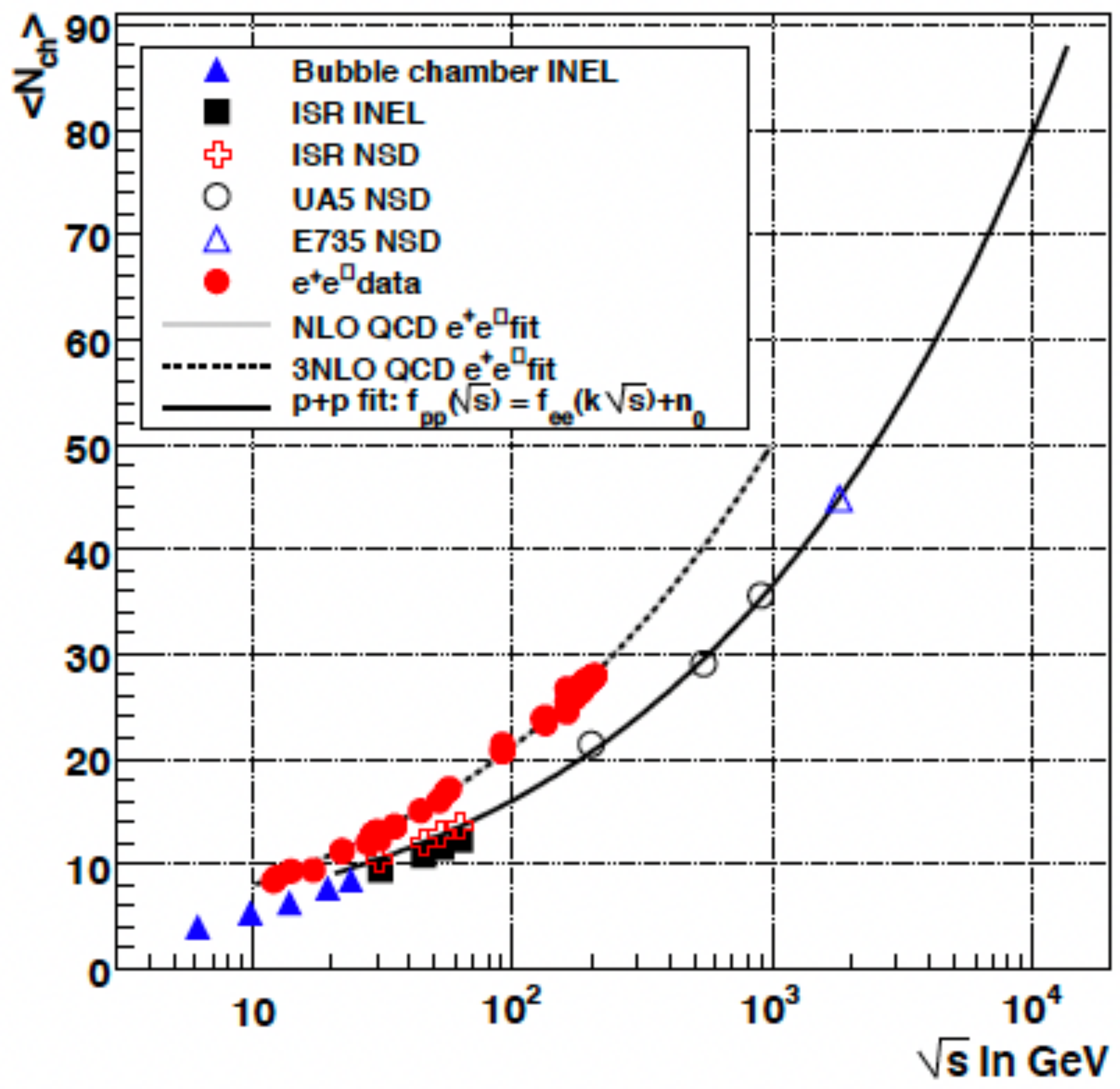
PDF for the last (n'th) pion $P_Z(t) = \frac{n}{\tau} e^{-t/\tau} (1 - e^{-t/\tau})^{n-1}$





Detector neutrino containment.

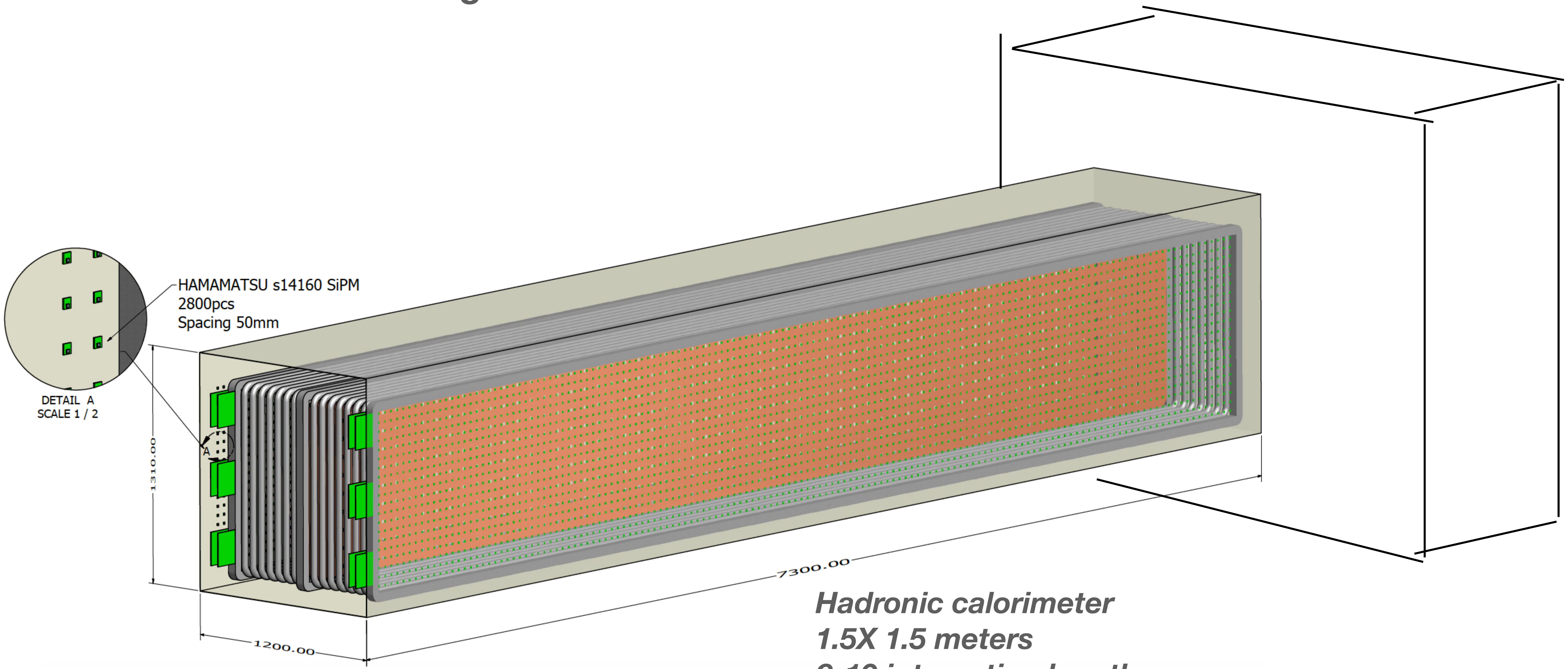
- Multiplicity of pions will rise $< N > \sim \; ln(\sqrt{s})$
- Center of mass for neutrino events
  $E_\nu = 100 - 2000 GeV$ is
  $E_{cm} \approx \sqrt{2 m_N E_\nu} \approx 10 - 50 GeV$
- For neutrino interactions the hadronic mass is much less, but at the highest energies one should expect ~10 hadrons in the final state.
- At 7 meters: LAr/LKr pion interactions lengths: 6.6 / 9.5



If a neutrino interacting the middle or end of the 7meter long detector, it is very likely that the hadronic shower cannot be contained.

Wenjie will have some simulations in the near future.

Possible configuration



Hadronic calorimeter
1.5X 1.5 meters
6-10 interaction lengths
(120 to 200 cm of Fe)

$\sigma_E \sim 20\,\% / \sqrt{E}$

The material of the cryostat at the down stream will need to be kept < 0.1 interaction length. This is possible.