Search for short baseline oscillation with the SoLi∂ experiment

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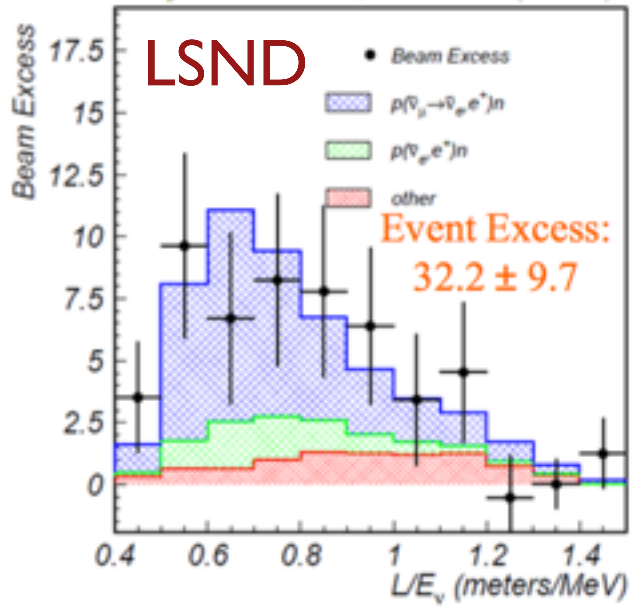
on behalf of the SoLid collaboration

Joint annual HEPP and AAP conference

Neutrino oscillation anomalies

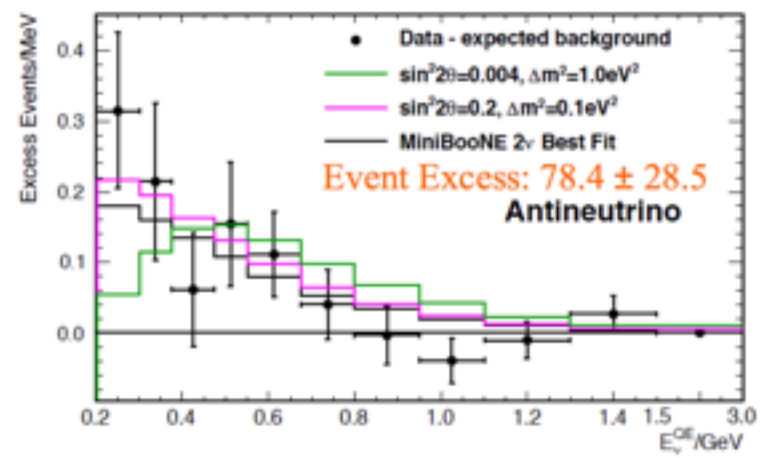
Hints for electron neutrino appearance in muon neutrino beam

Phys.Rev.D64, 112007 (2001)



MiniBooNE

Phys.Rev.Lett. 110, 161801 (2013)



MiniBooNE

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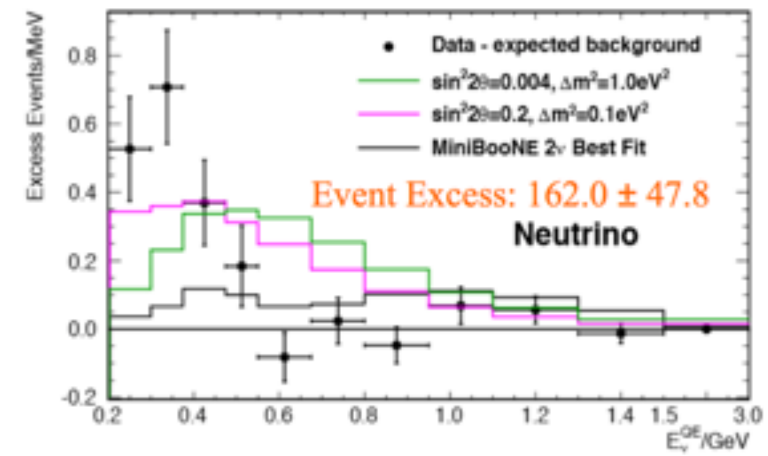
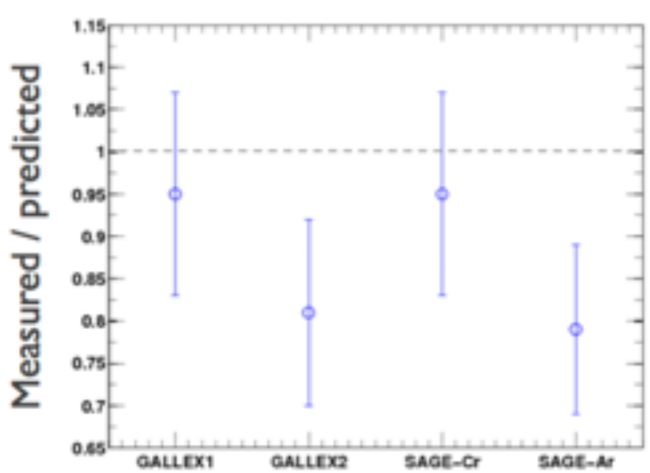
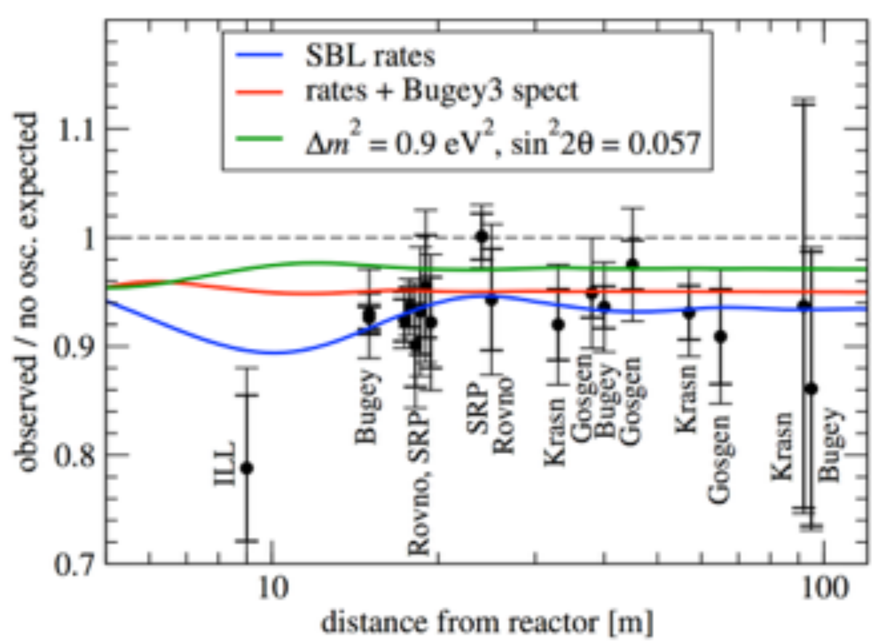


Hints for electron disappearance

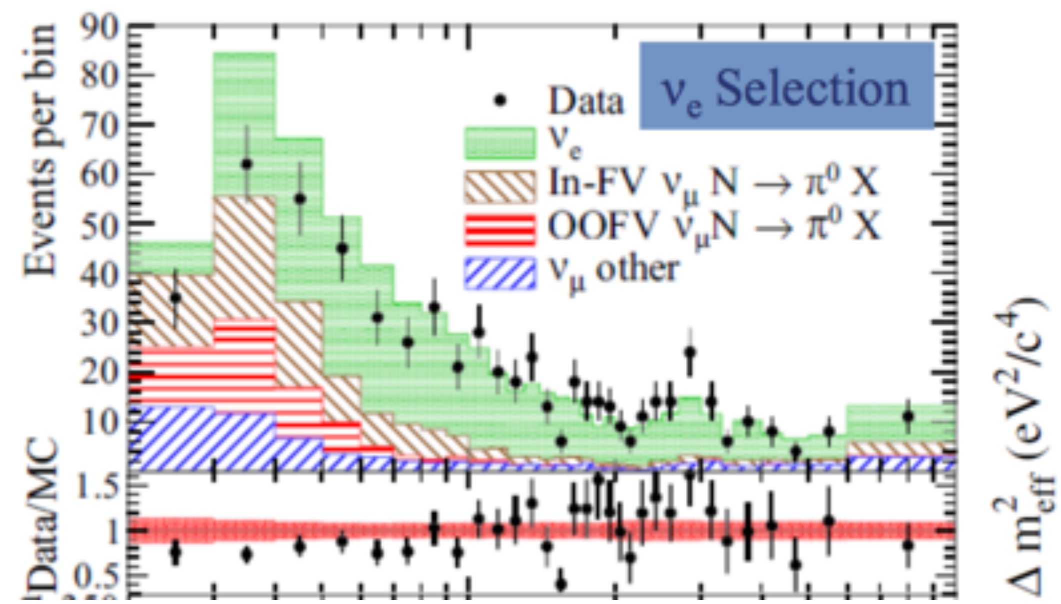


Giunti & Laveder, Phys.Rev.C83, 065504 (2011)

Gallium Anomaly

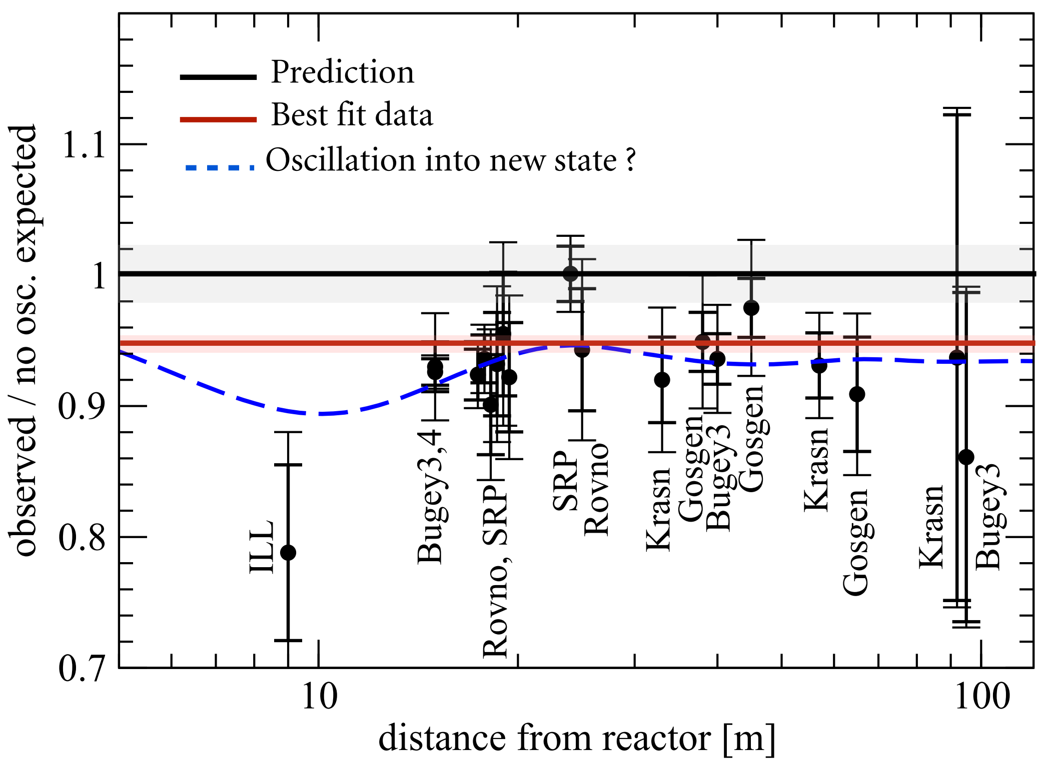


Reactor anomaly



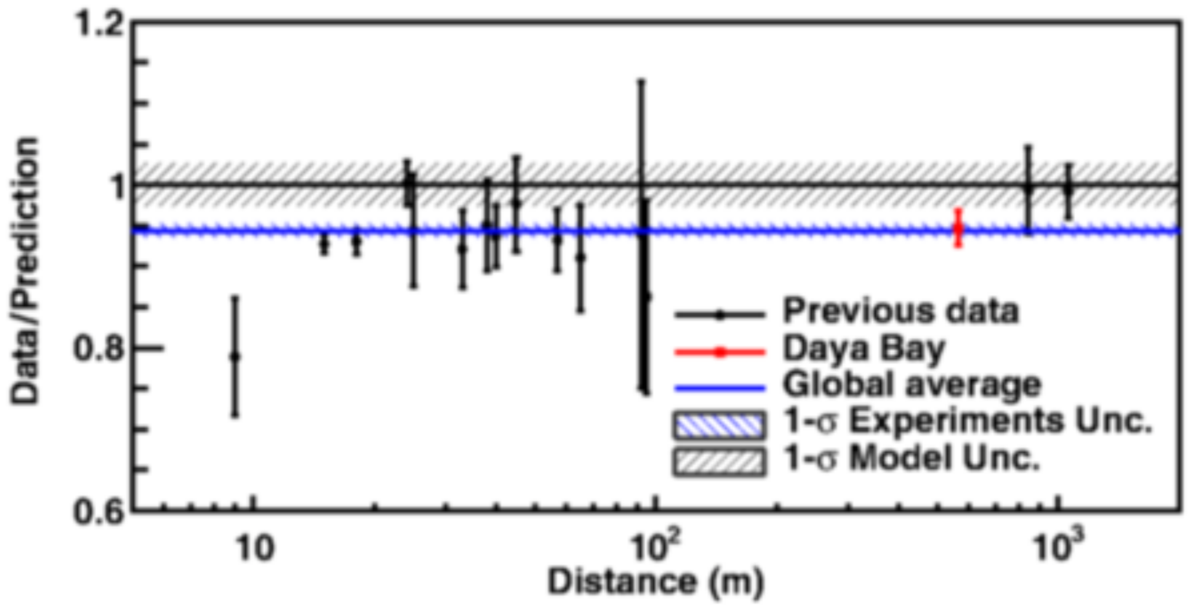
T2K near detector nue deficit

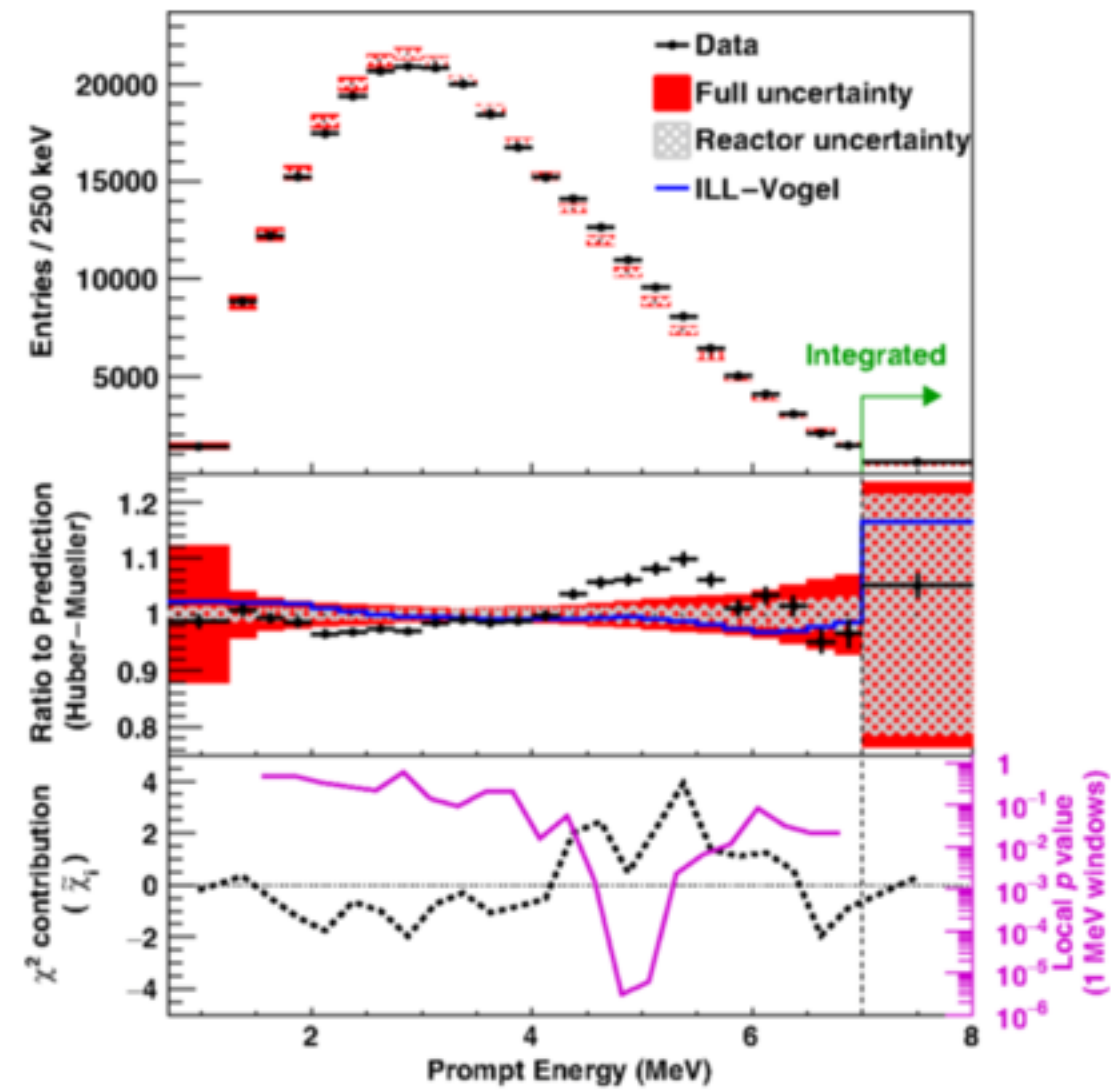
Reactor anomalies



Reactor anomalies

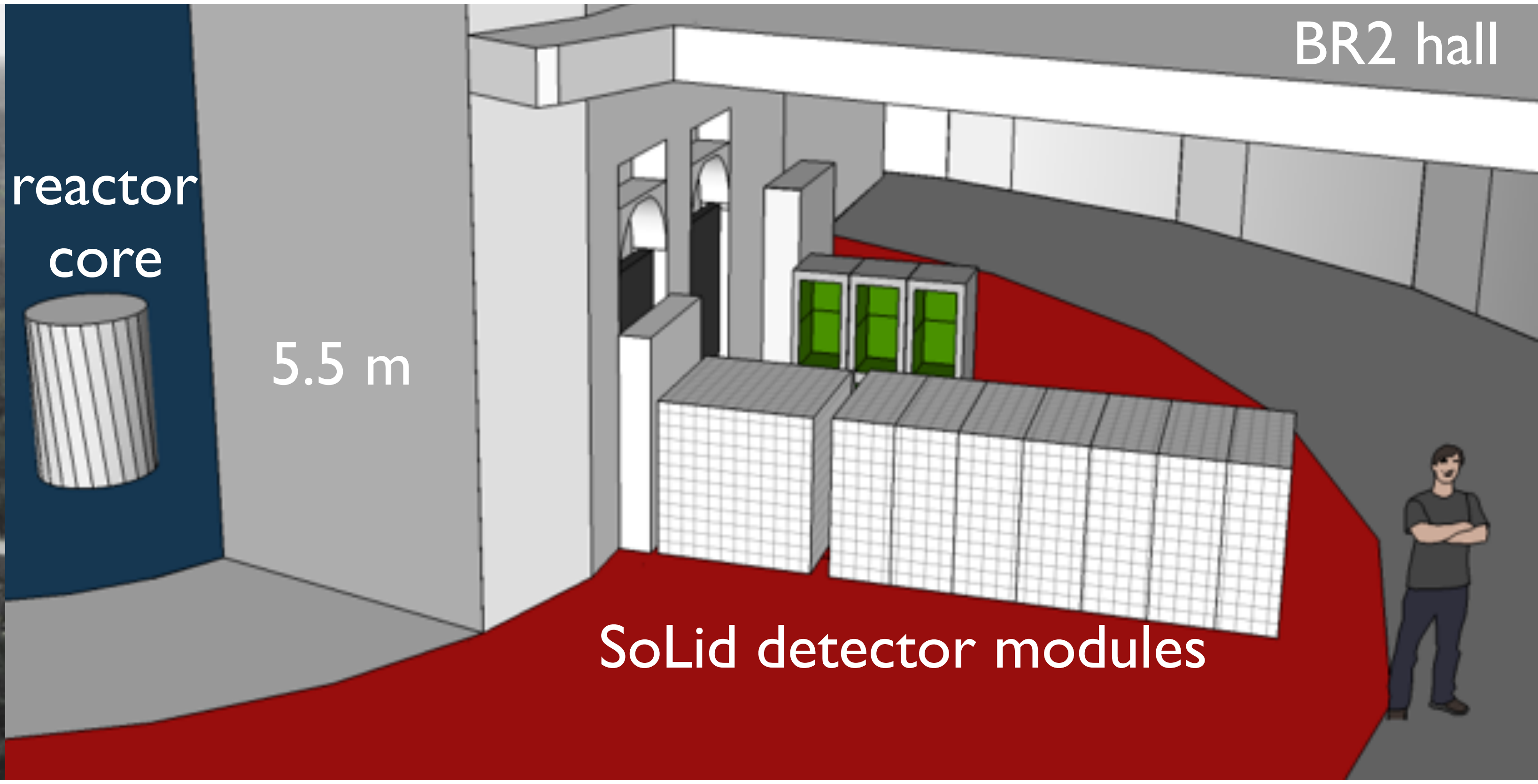
Daya Bay Phys. Rev. Lett. **116**, 061801



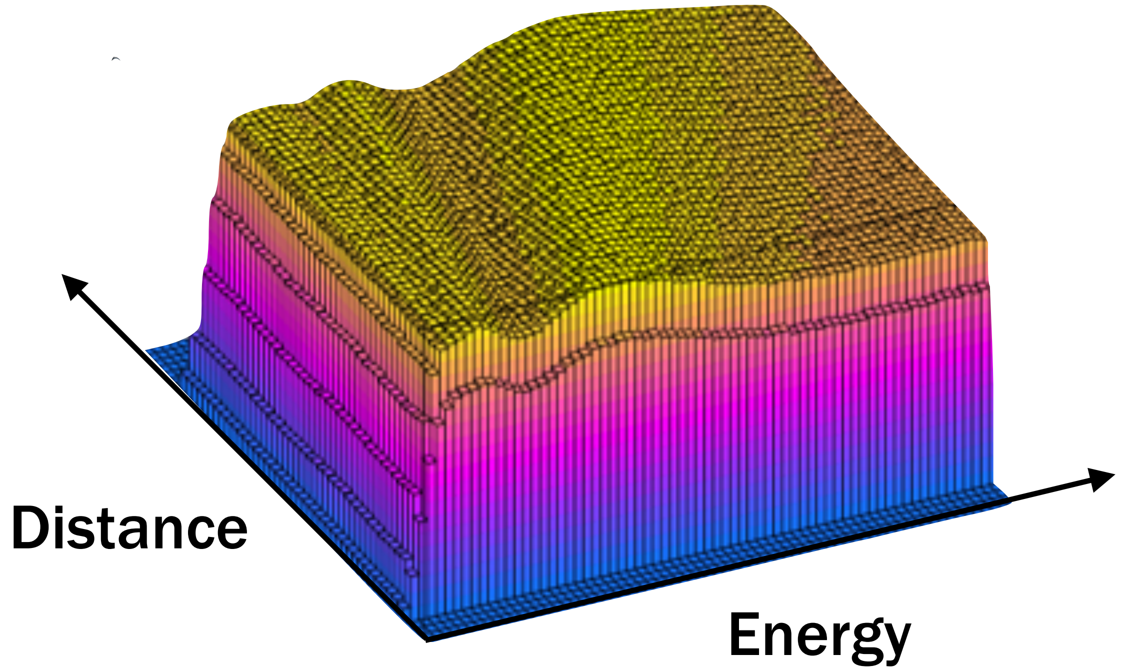


- Rate deficit compatible with previous data
- but a new “bumpy” feature at 5 MeV measured
    - doesn’t rule out possible new sterile state
    - but put in question the precision of model
- Need to adress these anomalies with new precise measurements

The SoLid experiment



- shortest distance most sensitive oscillometry experiment
- measure with high resolution in position and energy
- only way to demonstrate new oscillation
- HEU reactor core measurement will complement PWR data

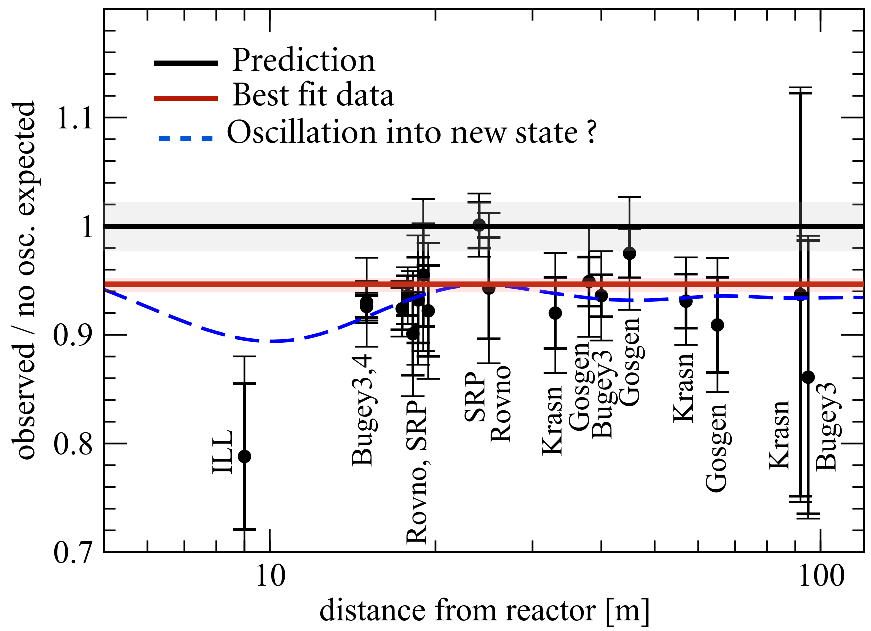


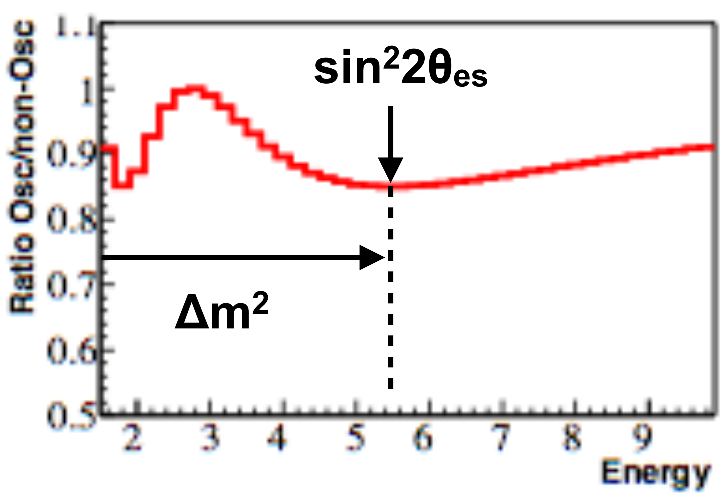
SoLid collaboration

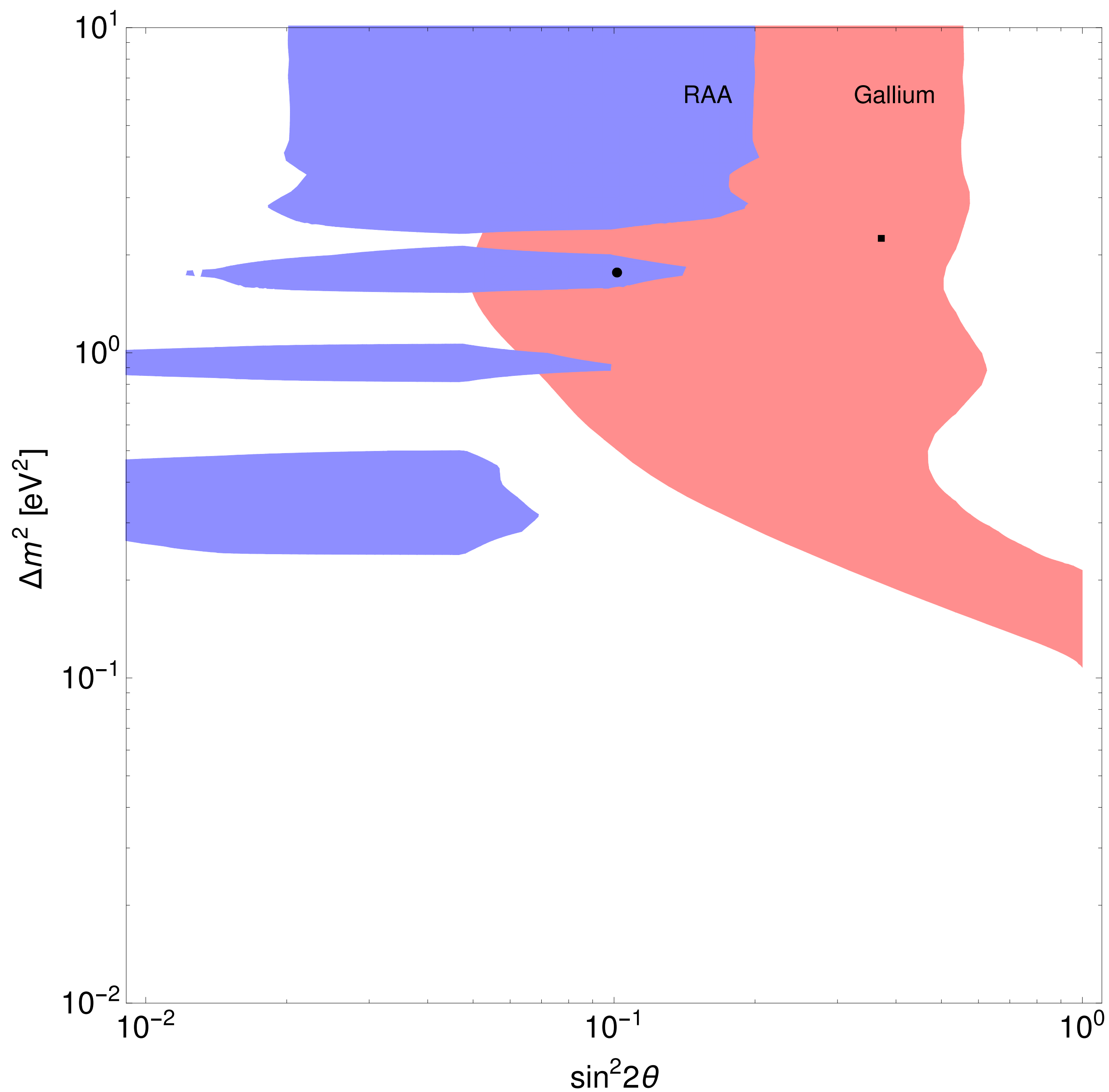
- 4 countries, 11 institutes, ~ 50 people

SCK•CEN
Universiteit Antwerpen
Vrije Universiteit Brussel
Universiteit Gent
LAL Laboratoire de l'Accélérateur Linéaire
lpc caen
Subatech
Imperial College London
University of Bristol
University of Oxford
VirginiaTech Invent the Future

Sensitivity to a new eV state

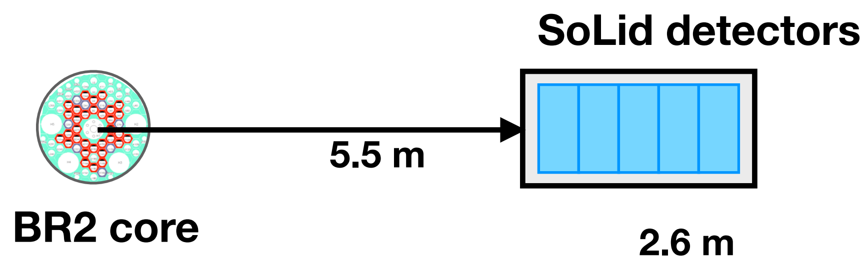






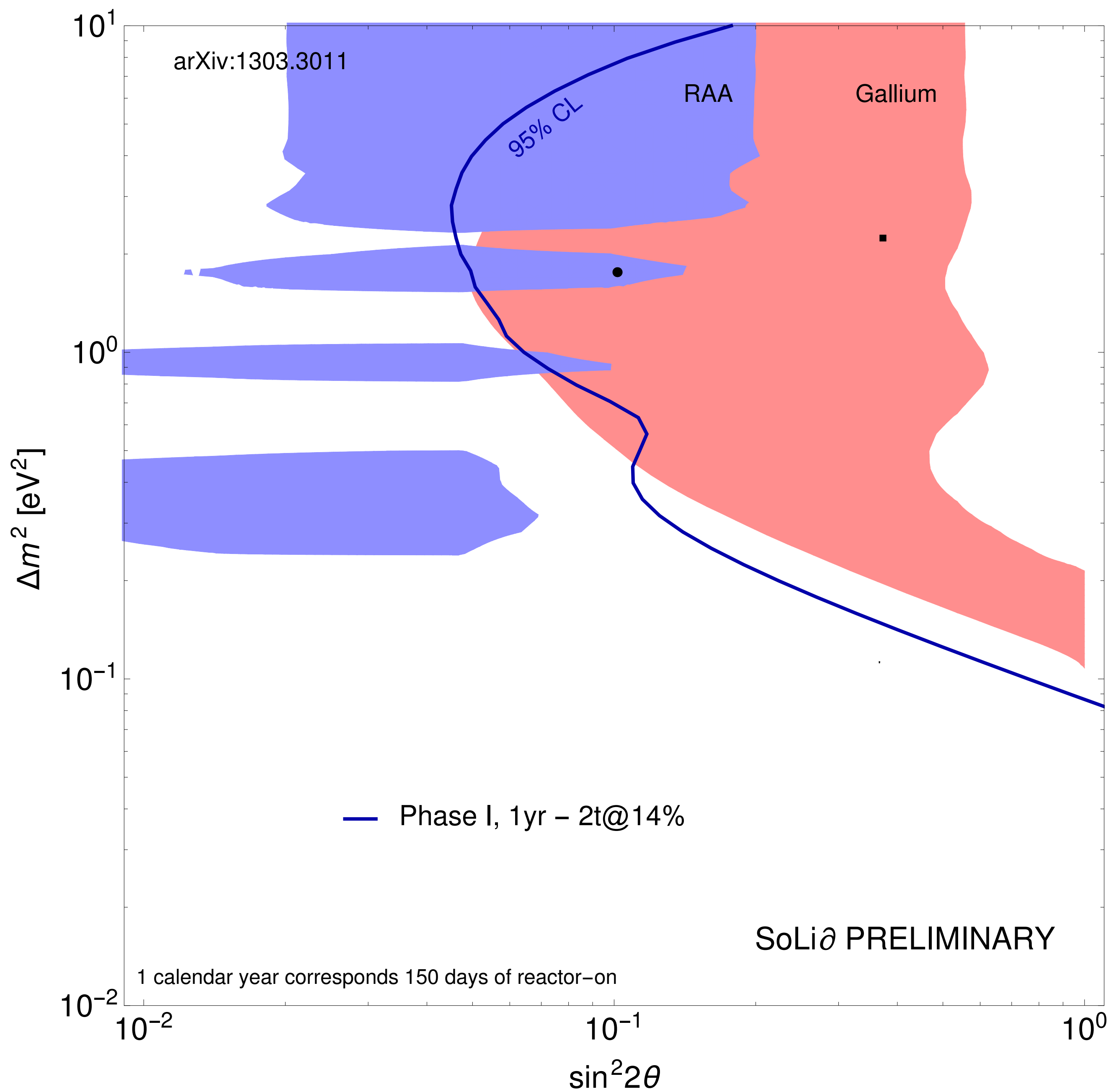
Sensitivity Phase I

Phase I



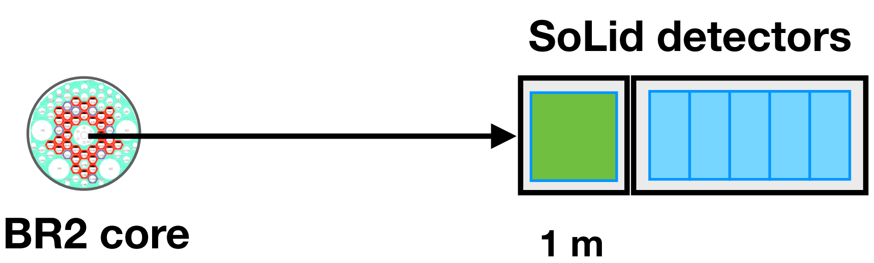
8x submodules
PVT cubes + WLS fibres
1.5-2 tonnes fiducial

- 40% IBD efficiency
- 14% energy resolution at 1 MeV
- S:B ~ 3 (E > 1 MeV)
- Background combination of $1/E^2$ and flat
- 2% relative energy scale uncertainty
- shape only measurement



Sensitivity phase II

Phase II



HiRes module
WLS PVT cubes + PMTs
1 tonne fiducial

- 40% IBD efficiency
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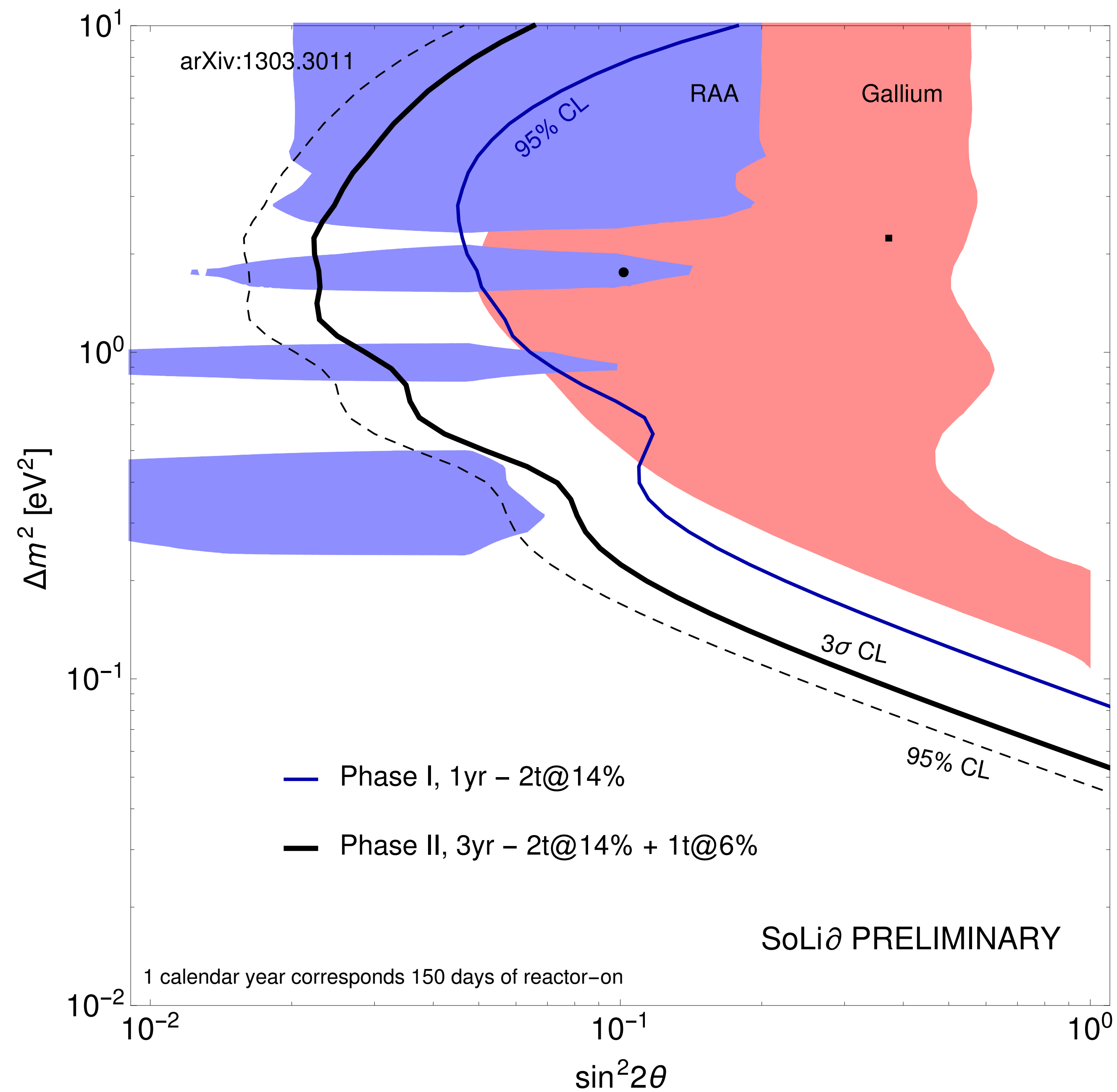
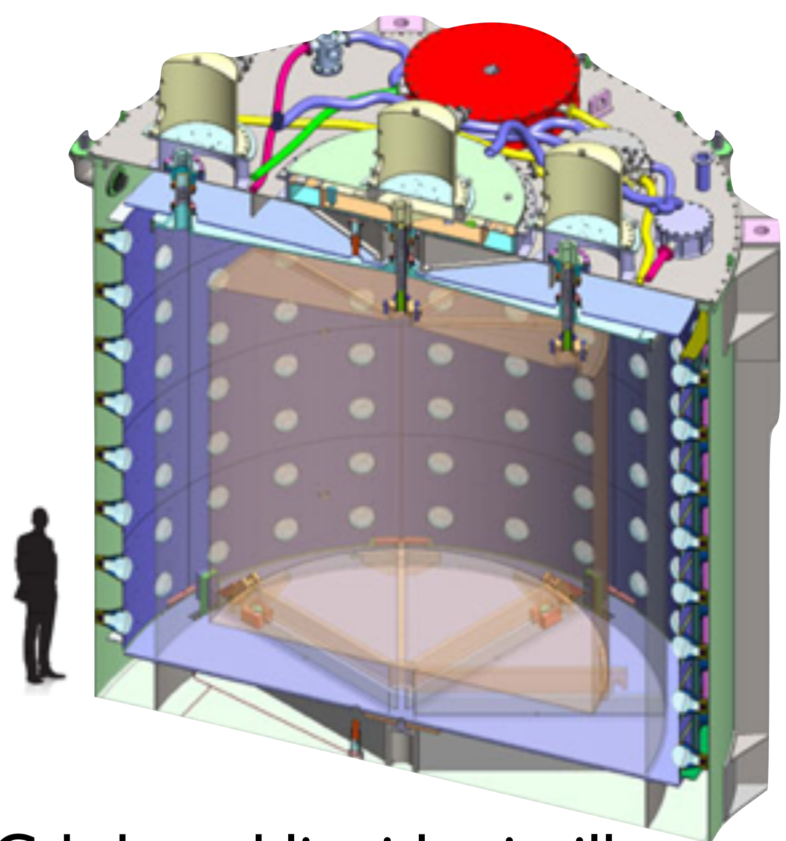
- 2% relative energy scale uncertainty
- shape only measurement

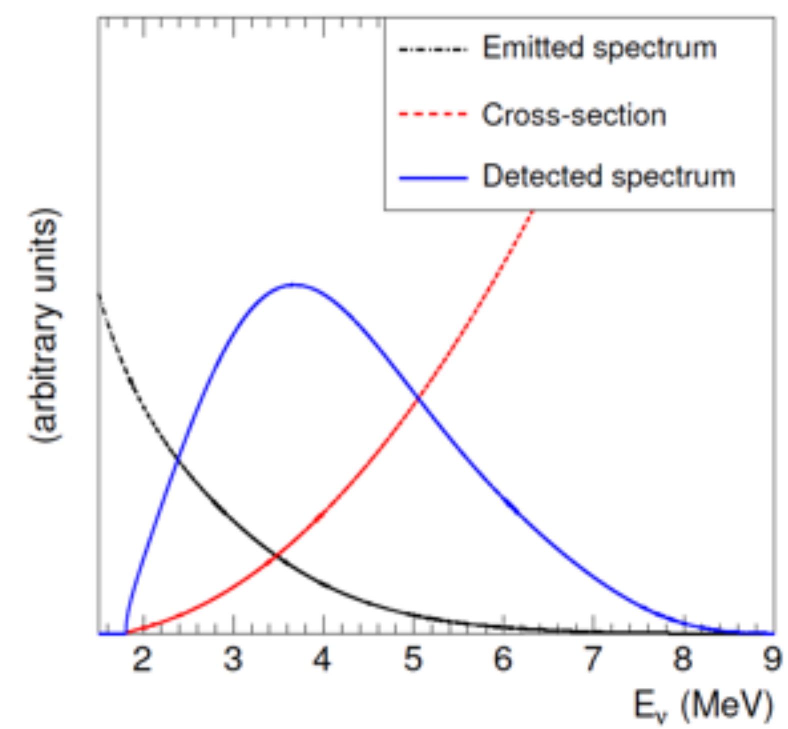


State of the art



Gd-doped liquid scintillator technology

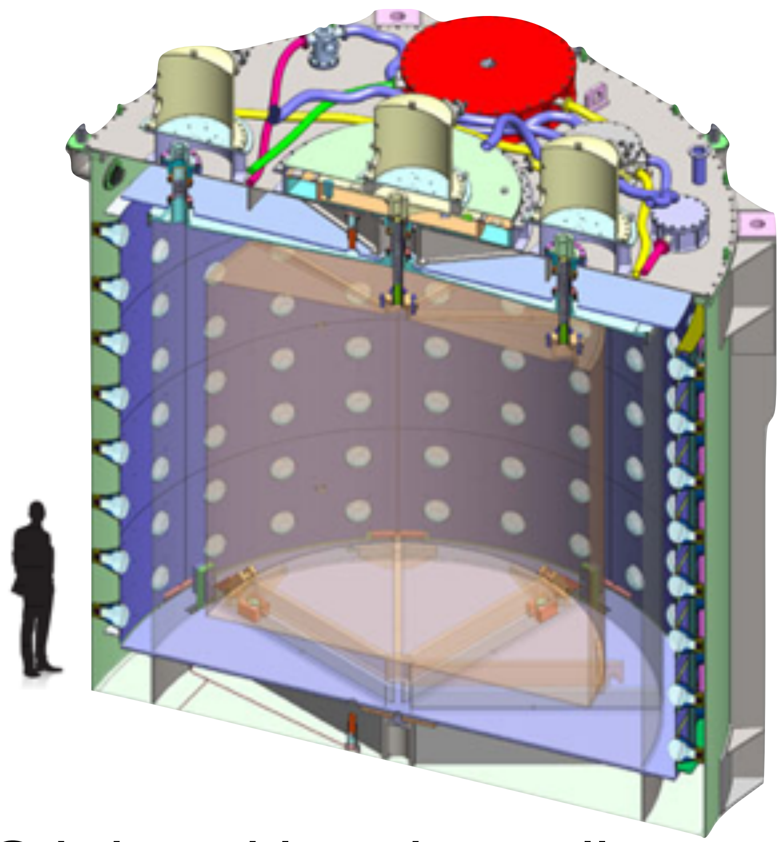
- Underground laboratory
- Large external shielding
- Well contained energy
- achieve percent level measurement of PWR antineutrino flux



$$\bar{\nu}_e + p \rightarrow e^+ + n$$

- Detected using well known inverse beta decay
- Threshold at 1.8 MeV

A new approach



Gd-doped liquid scintillator technology

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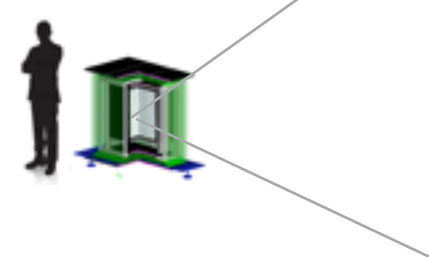
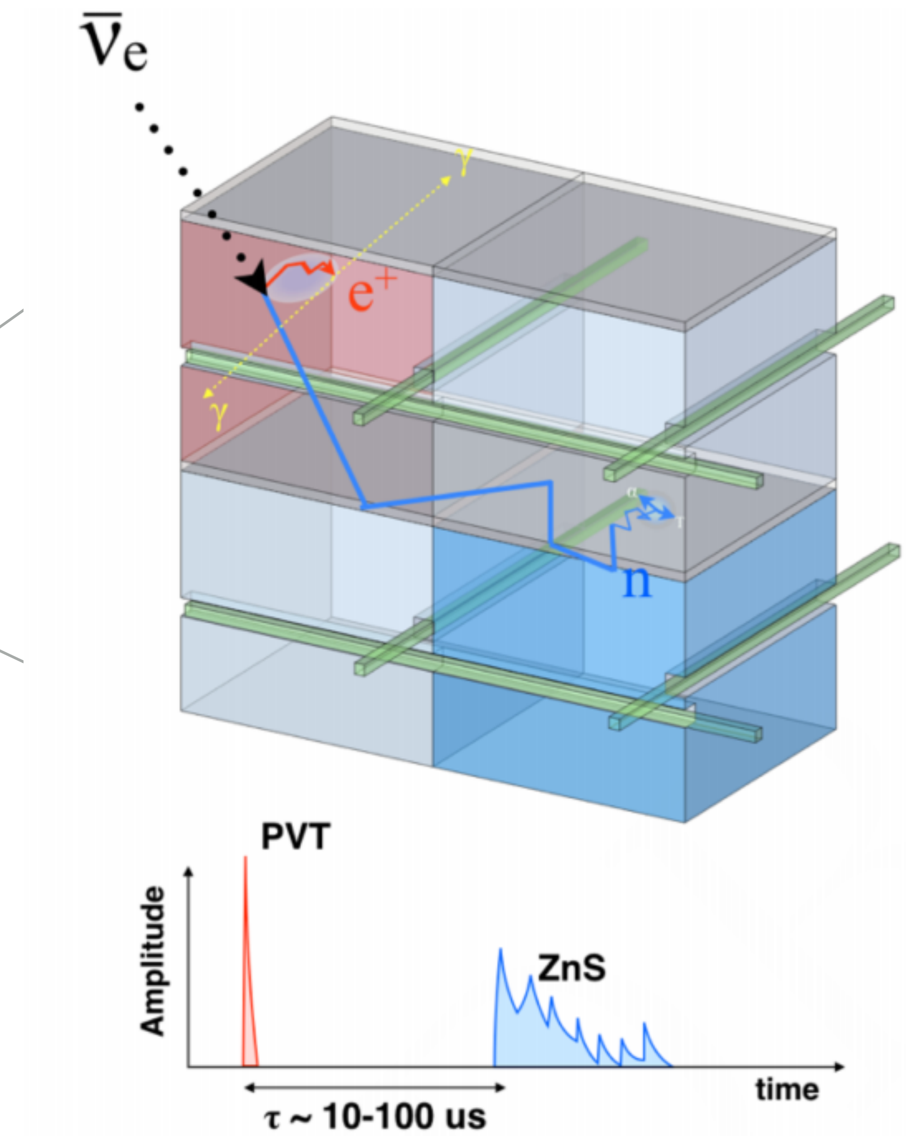


SoLid detector submodule

Challenges :

- At the surface
- Close to reactor
- compact detector : poorly contained energy



- Robust neutron ID
- Imaging of interactions
- Well contained energy

Technological development

2013
Proof of concept **TRL 2-3**

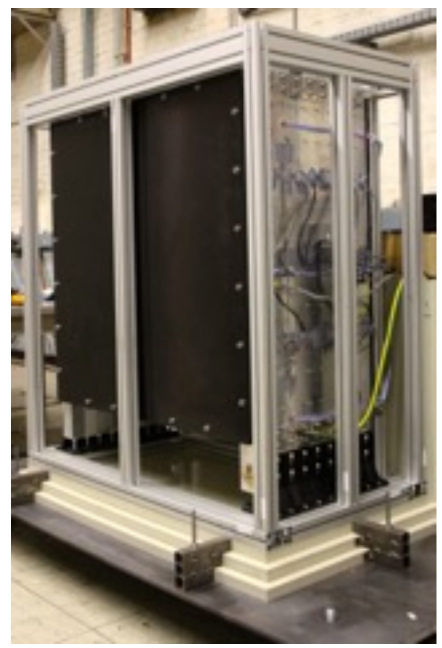
20 cm

20x

2014-2015

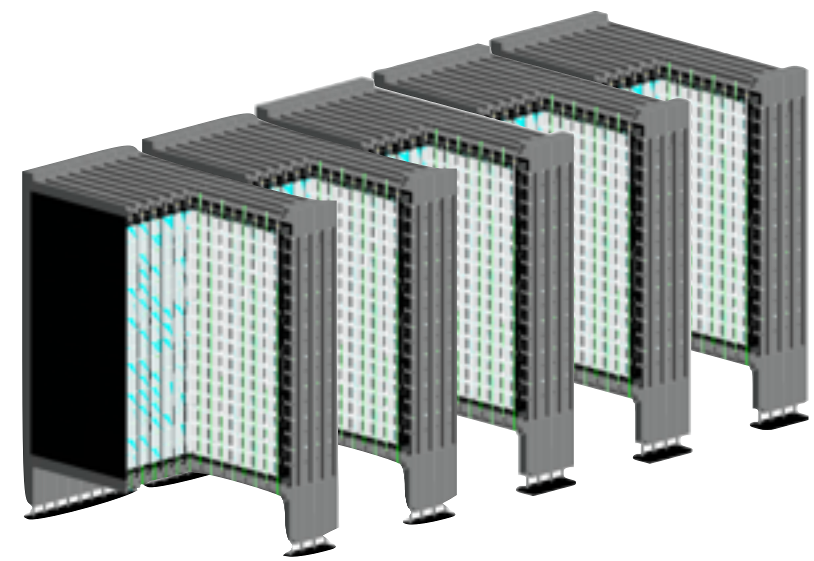
Real scale system **TRL 3-5**

80 cm



5-7x

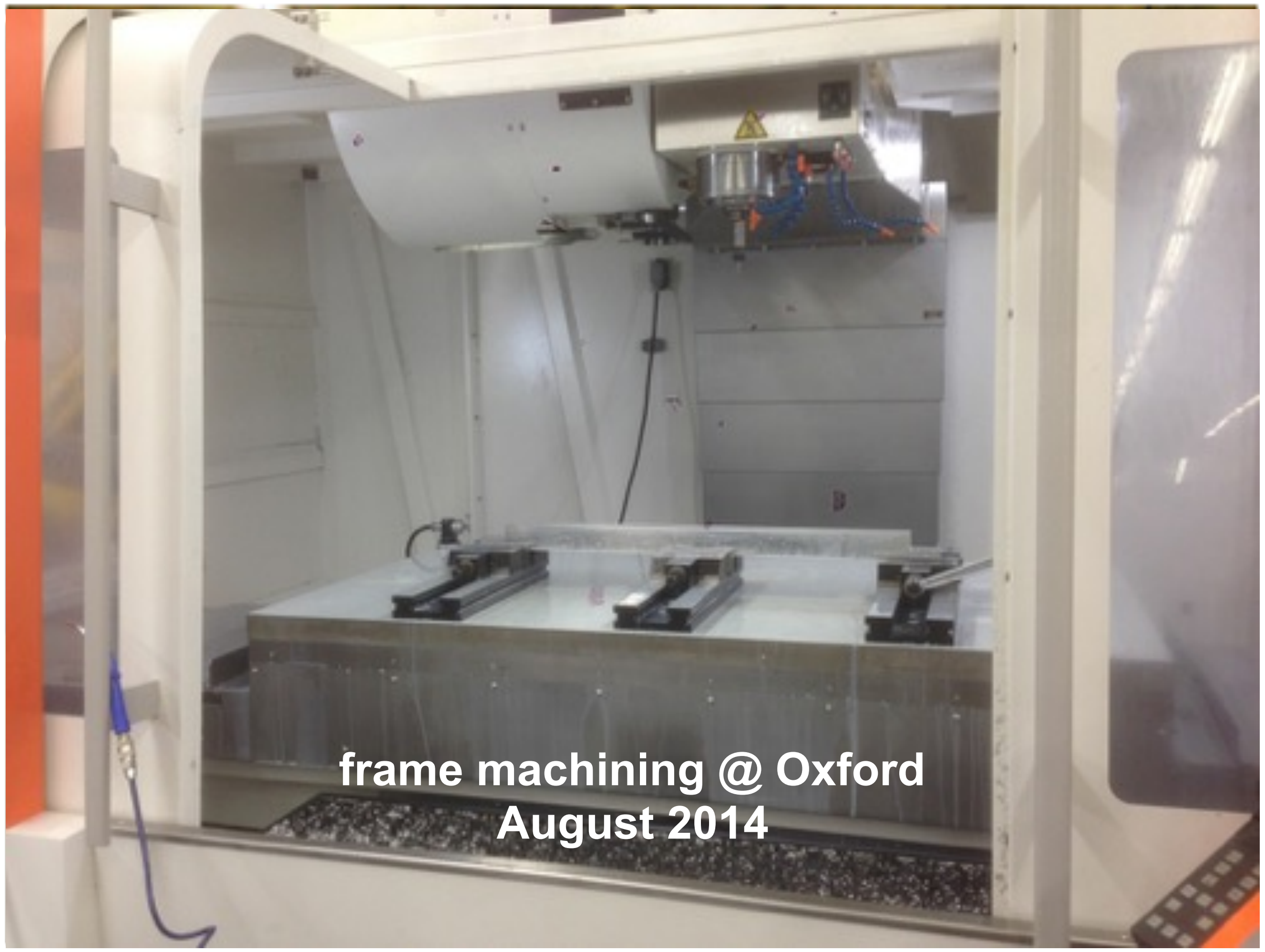
SoLid phase I
2016-2017



- NEMENIX **8kg**
64 voxels, 32 chan.

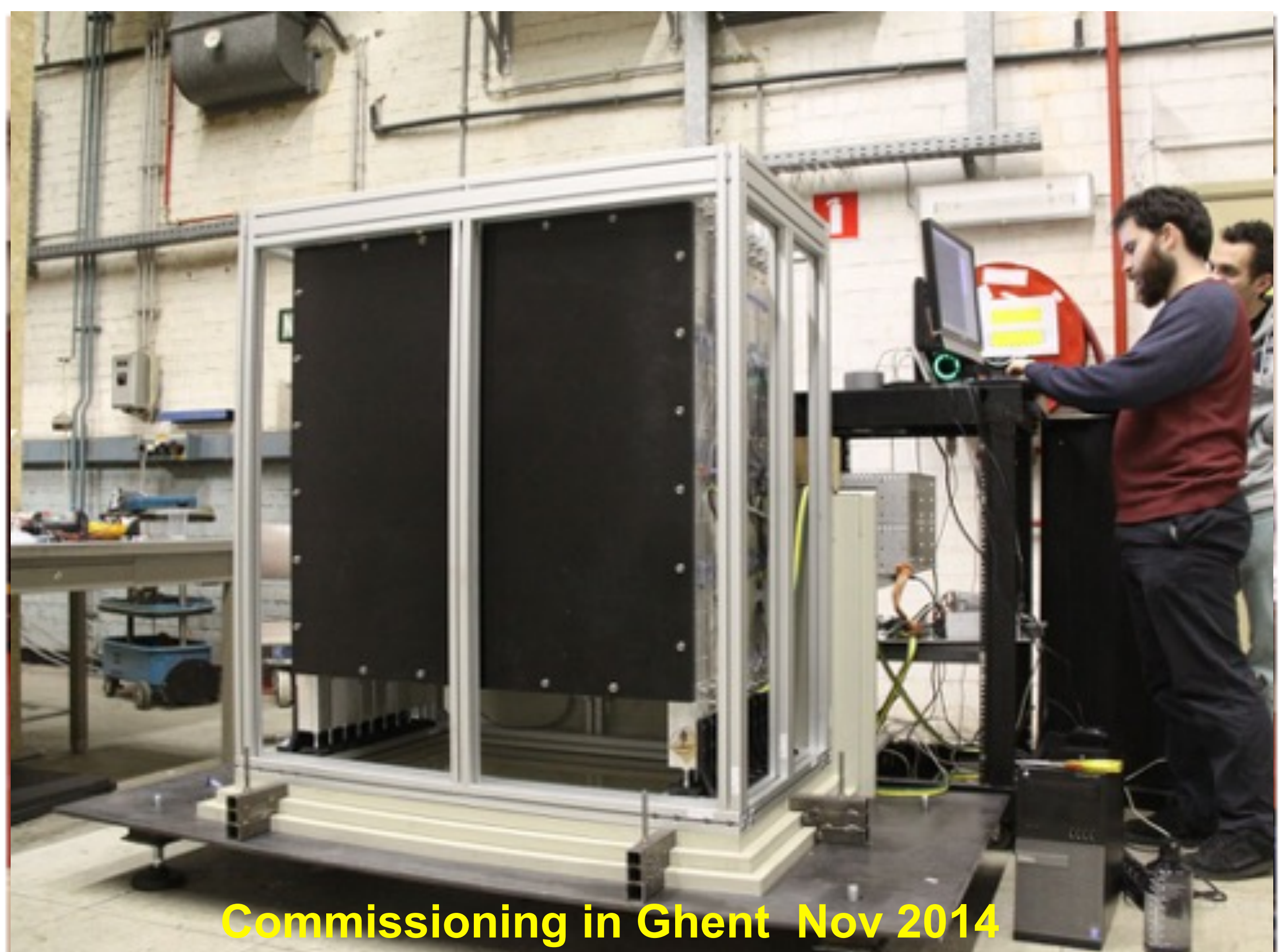
- SoLid Module 1 (SM1)
288kg
2 304 voxels, 288 chan.
9 Detector planes

- 5x modules **1.5-2 tonnes**
11 520 voxels,
3 200 chan
50 planes


frame machining @ Oxford
August 2014

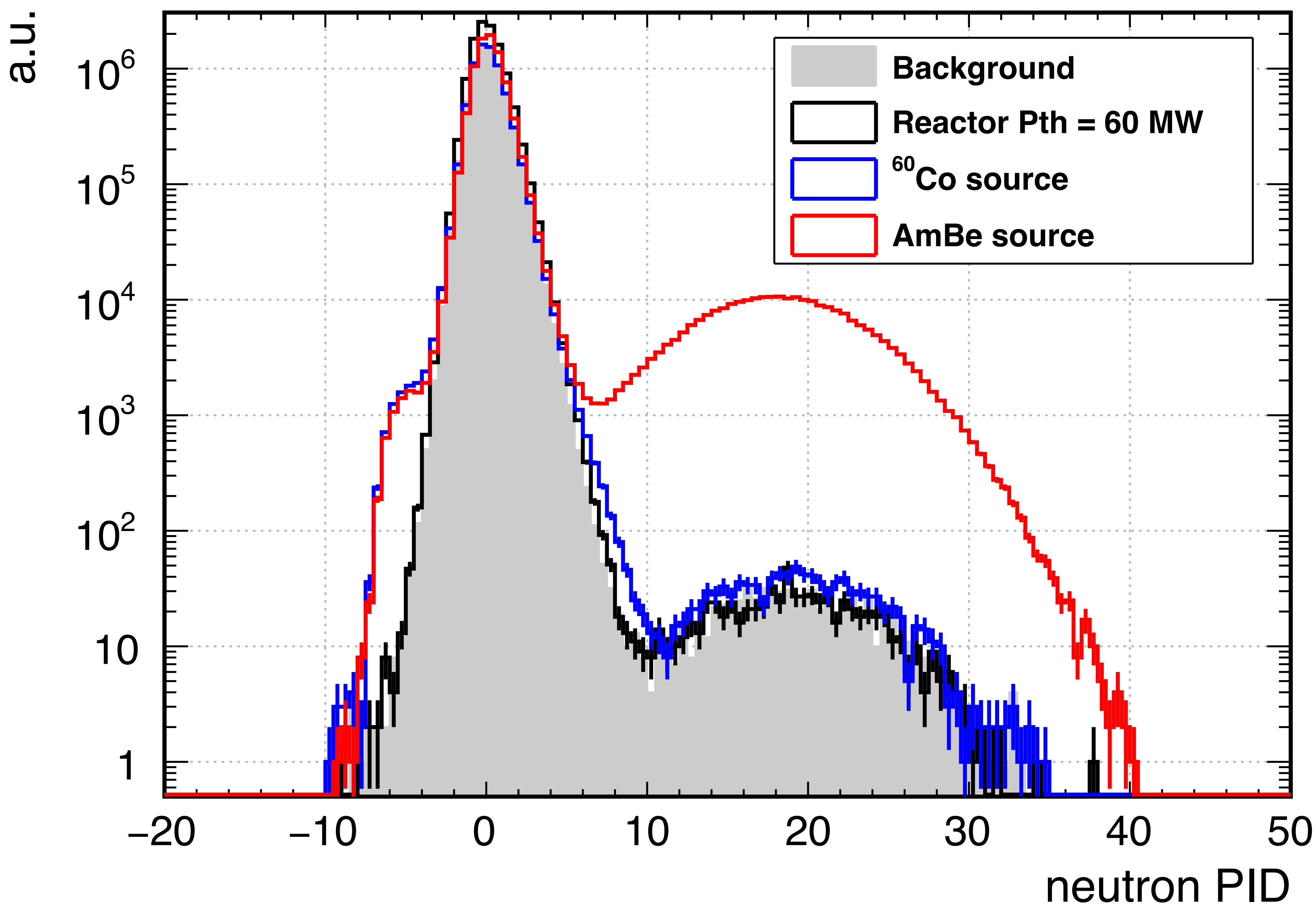

cube filling


Detector assembly
Ghent


Commissioning in Ghent Nov 2014

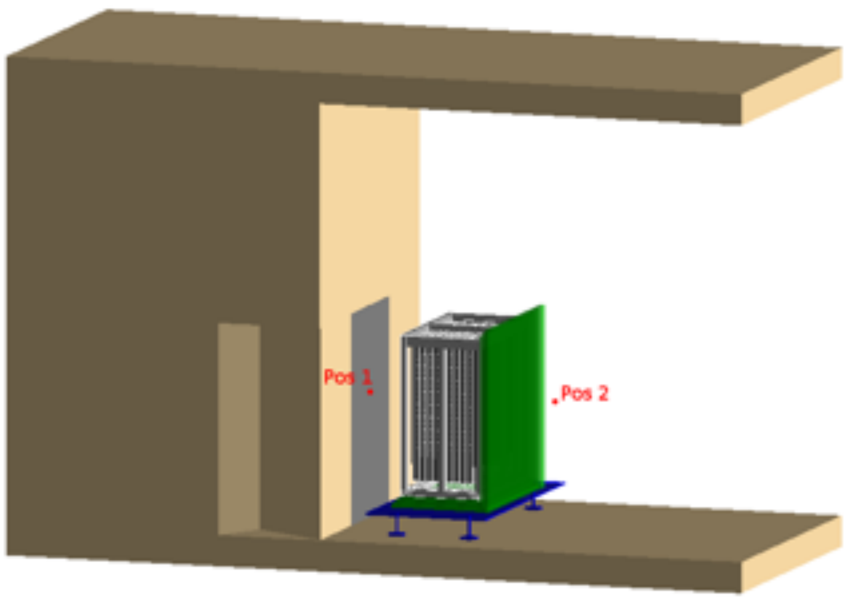

Detector in position at BR2
27th November 2014

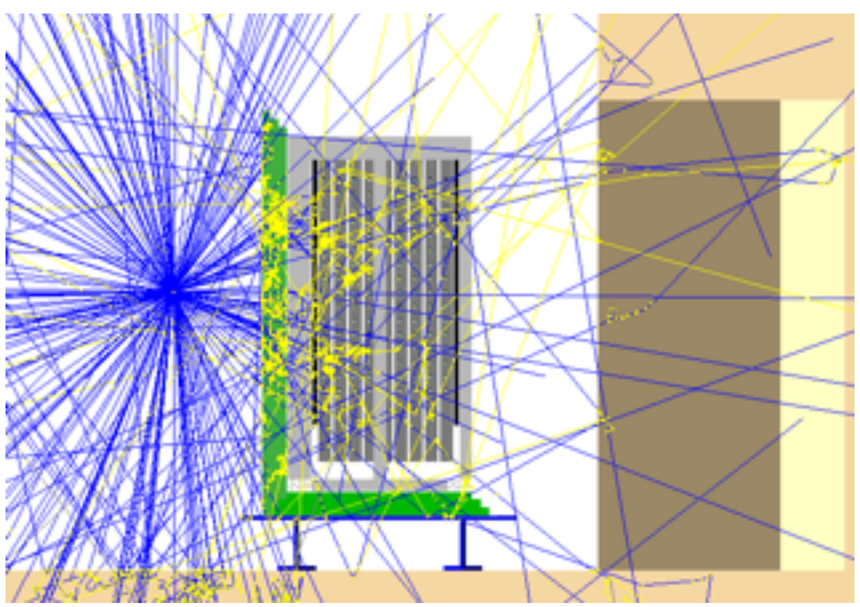
SM1 neutron ID

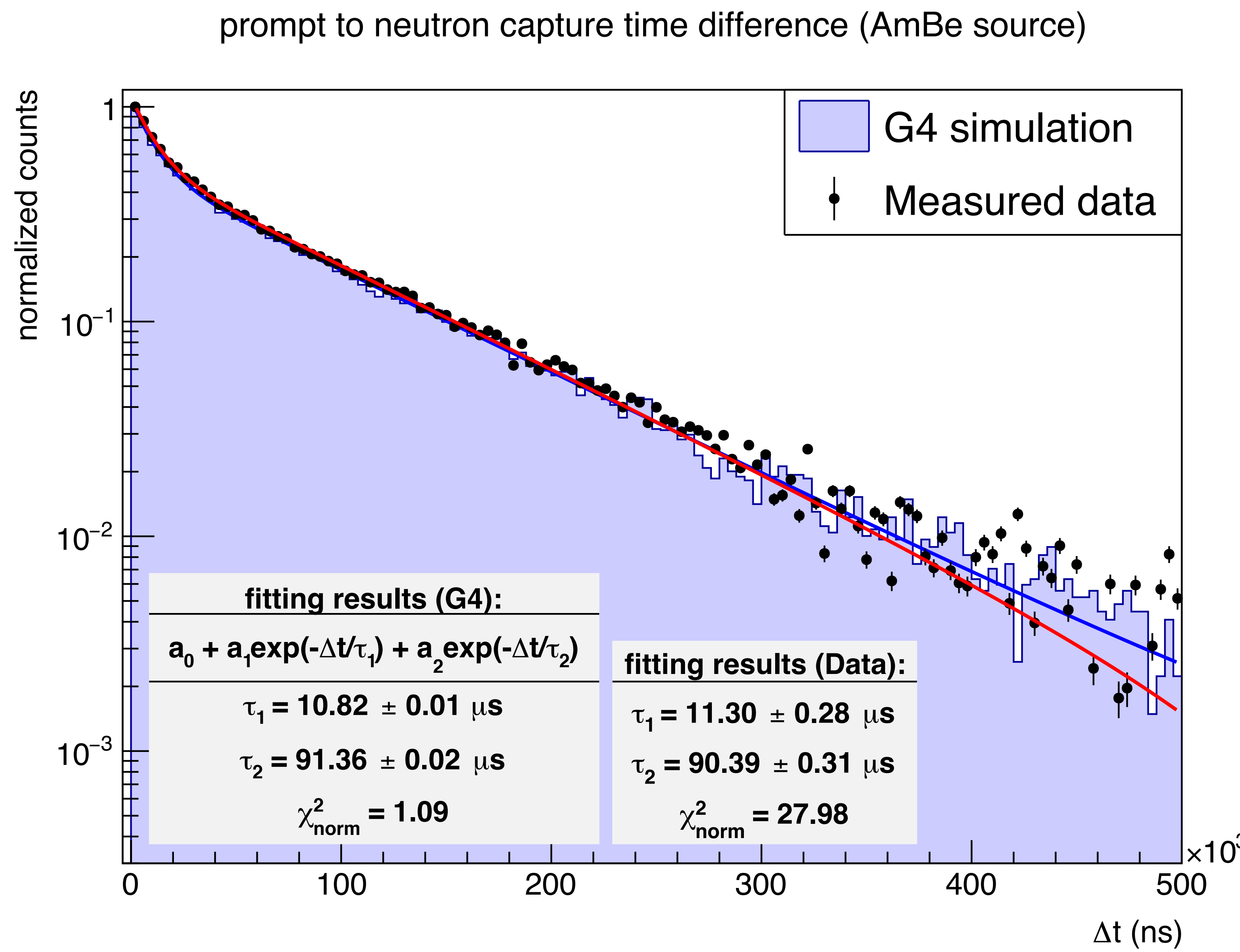


- can distinguish a neutron in millions of events

Detector capture time: AmBe



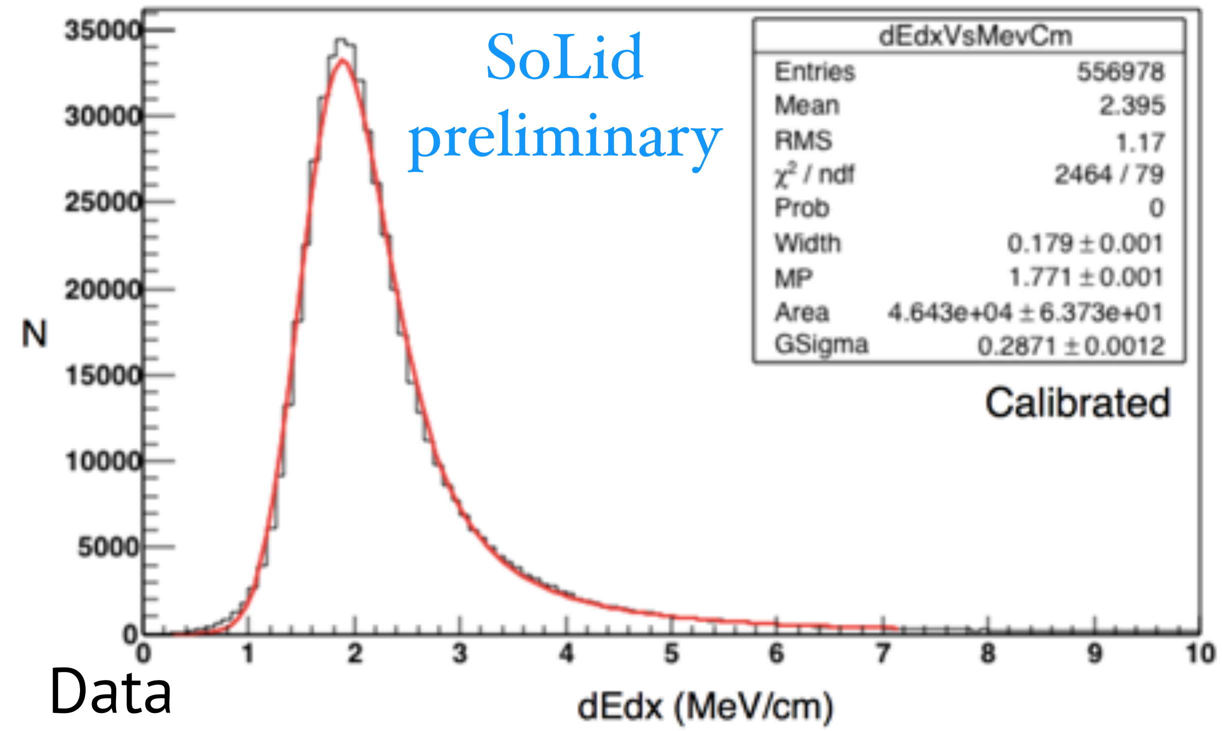




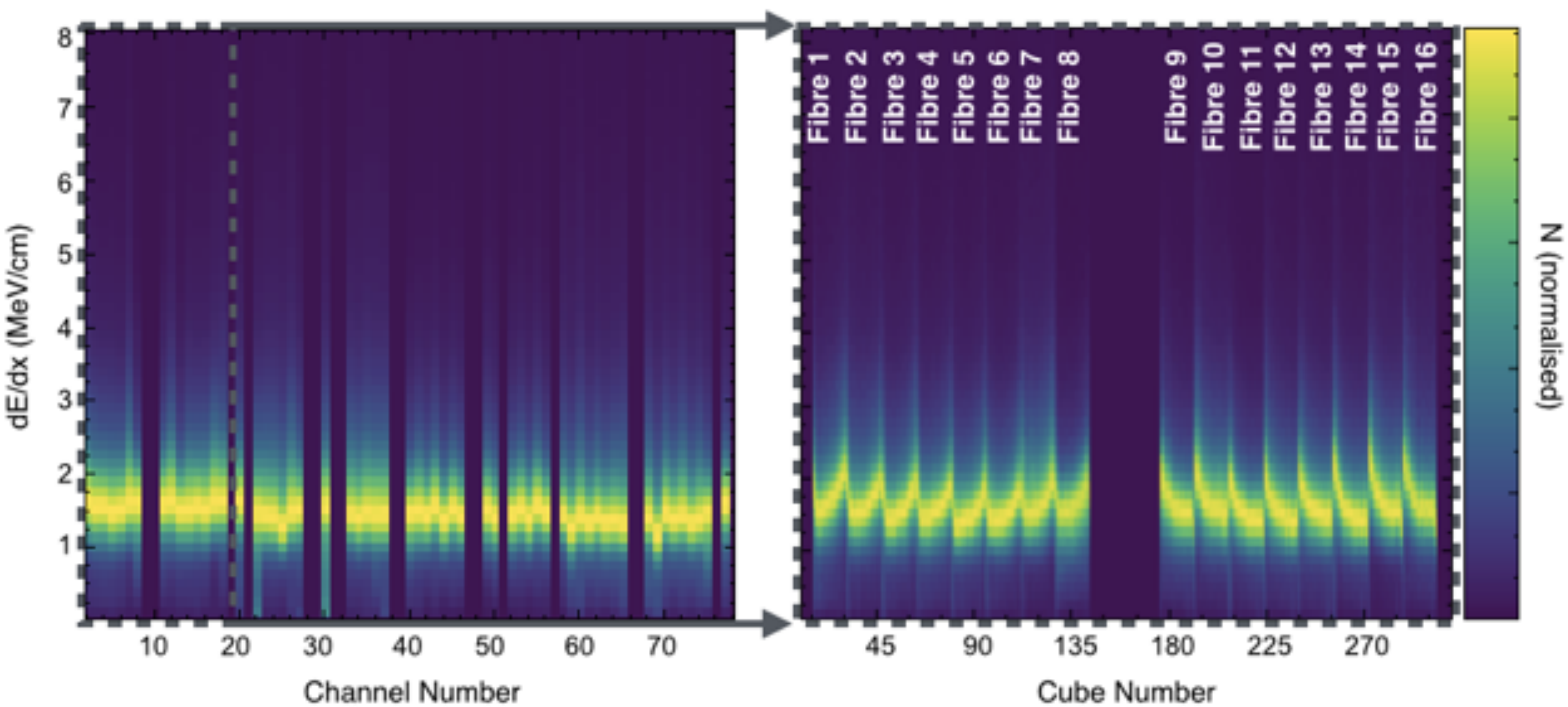
- AmBe source run to study fast neutron signature

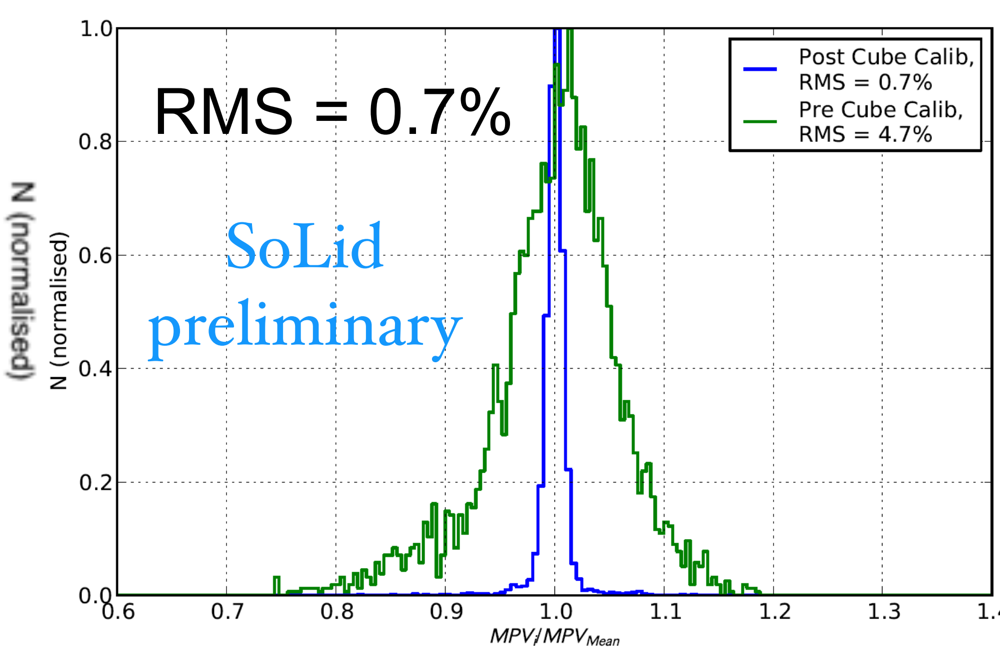
In situ calibration with muons

- in-situ energy calibration using dEdx
  - channels intercalibration
  - cube response equalisation
- Light yield measured : 25 PA/cube
- MPPC gain measured with dark count rate
  - no need for LED system



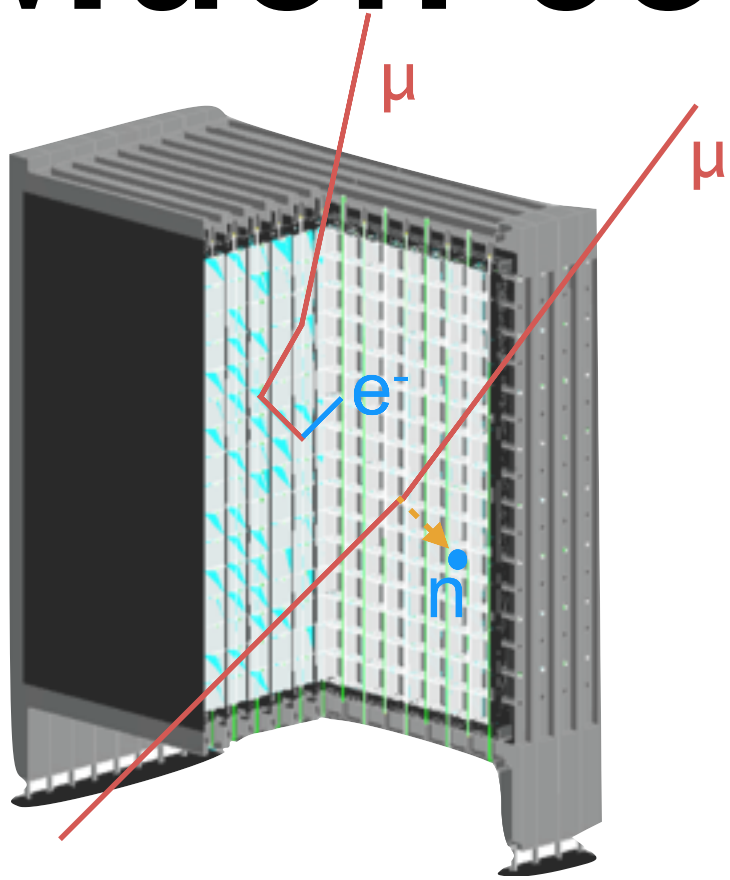
Data

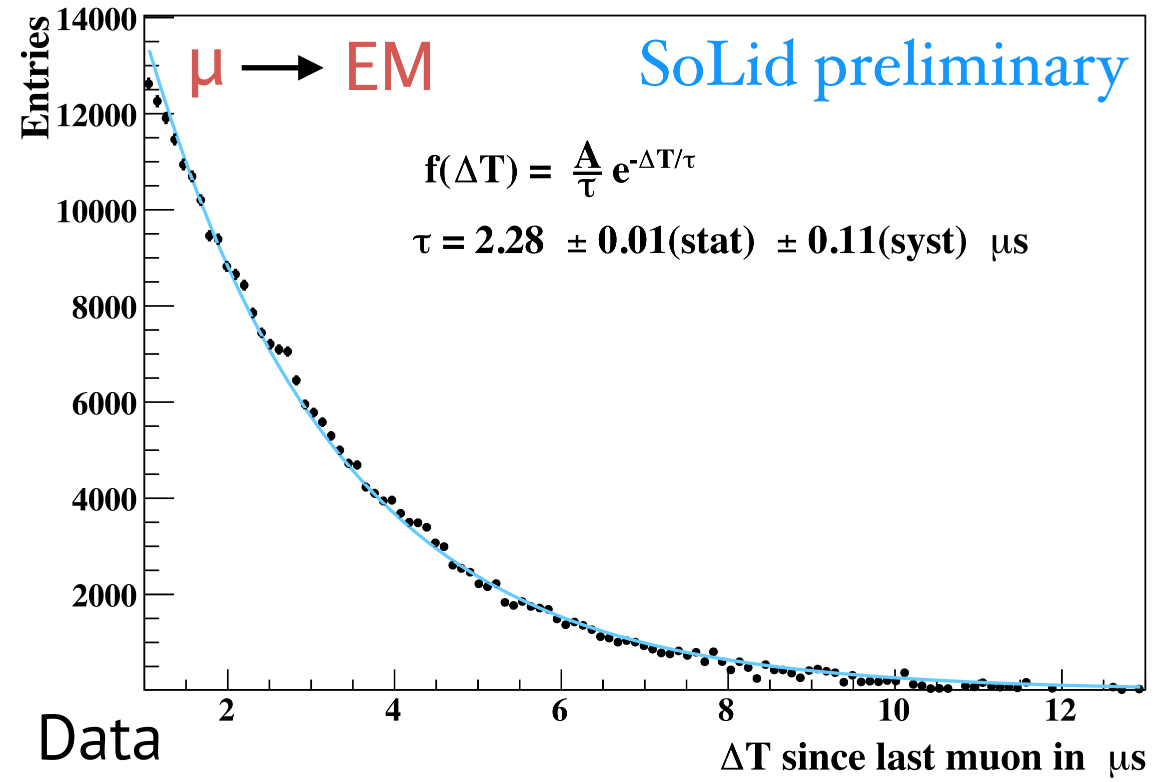


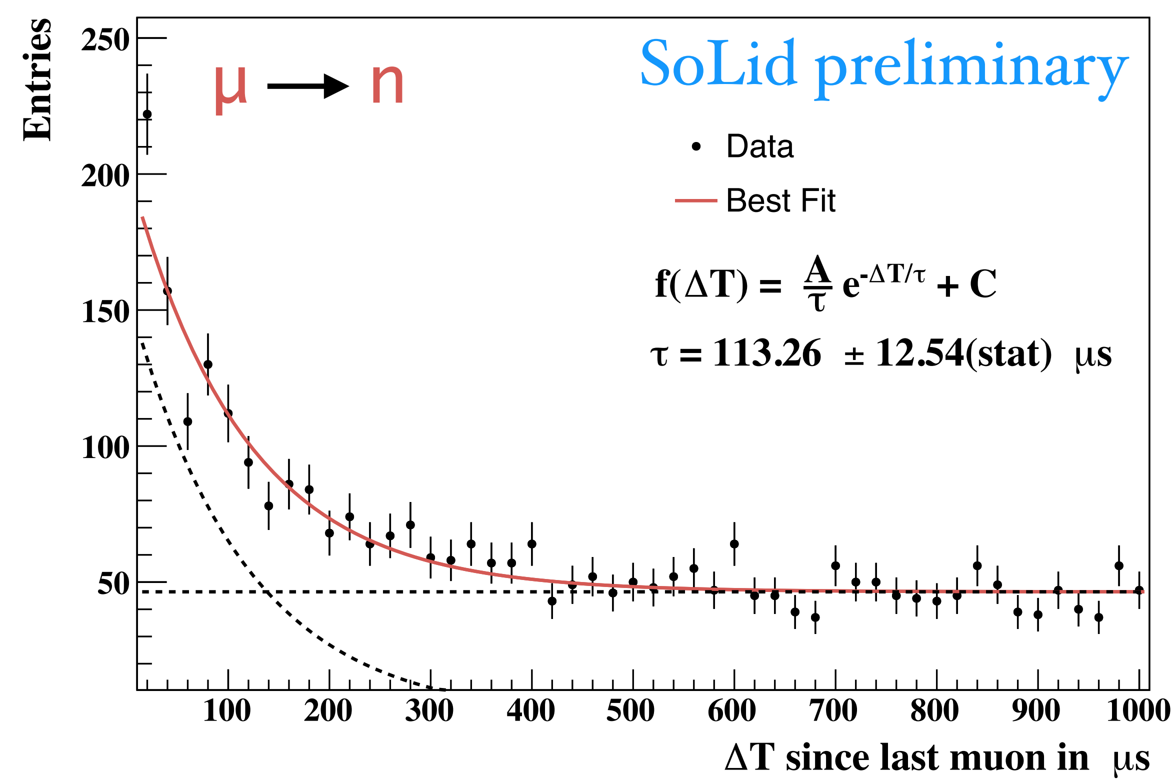


Data

Muon correlated events

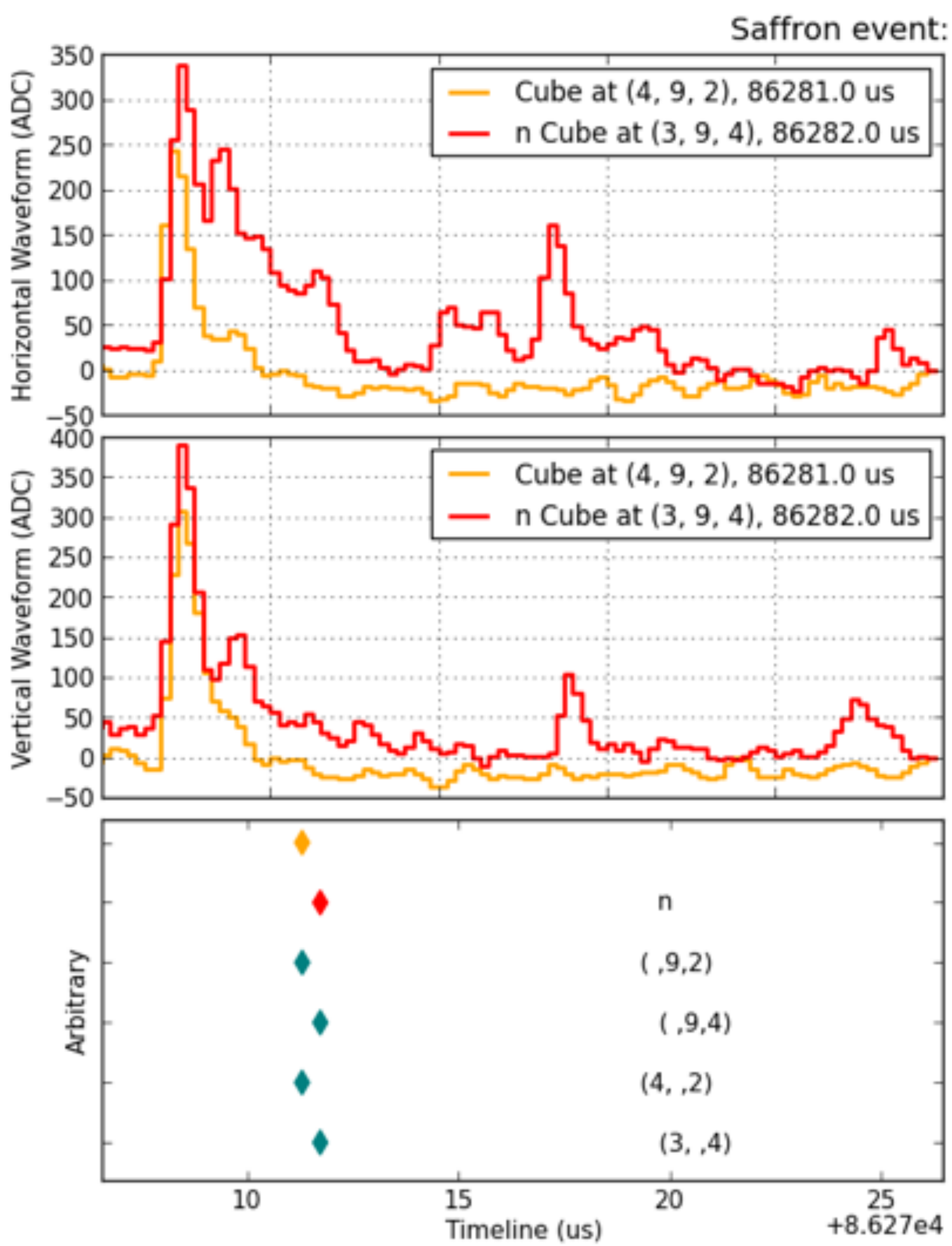


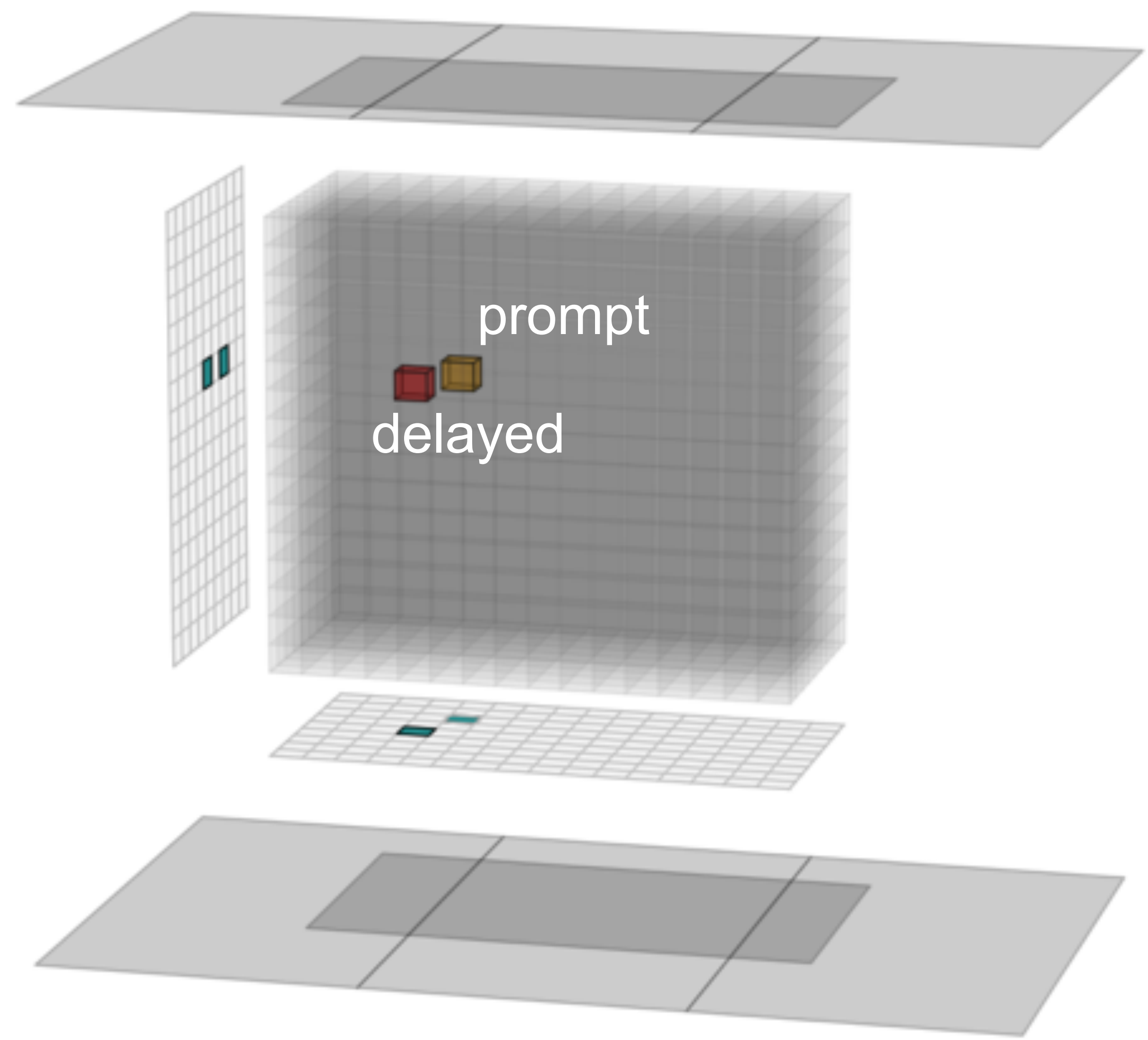




- Michel electrons activity observed
- Muon - neutron-like events correlations observed
- Use for muon veto cut

IBD candidate





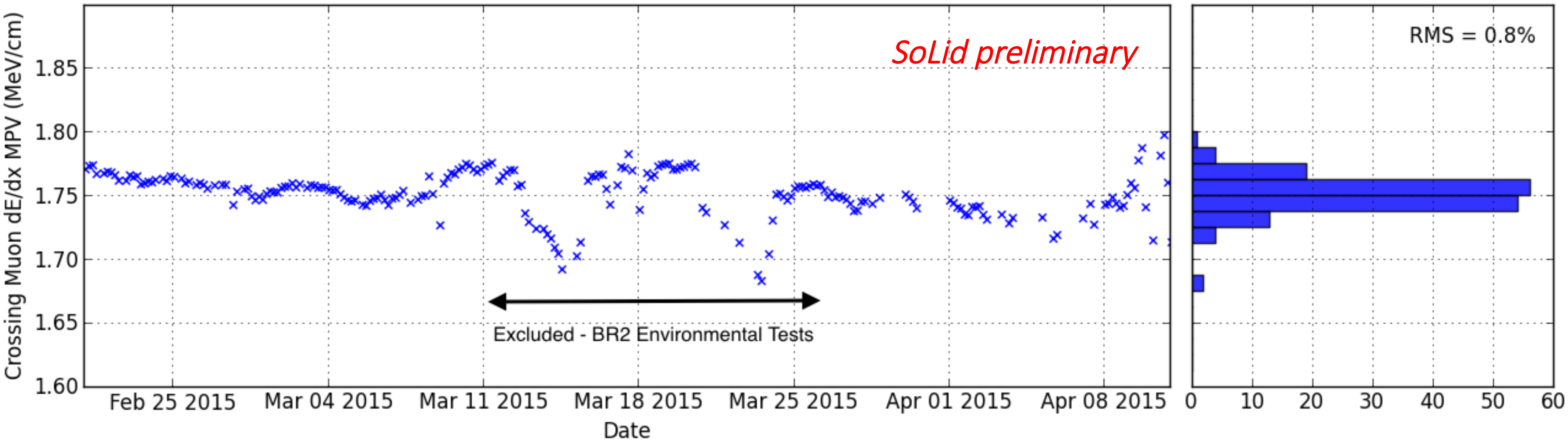
SM1 data
Reactor wall behind

Summary & outlook

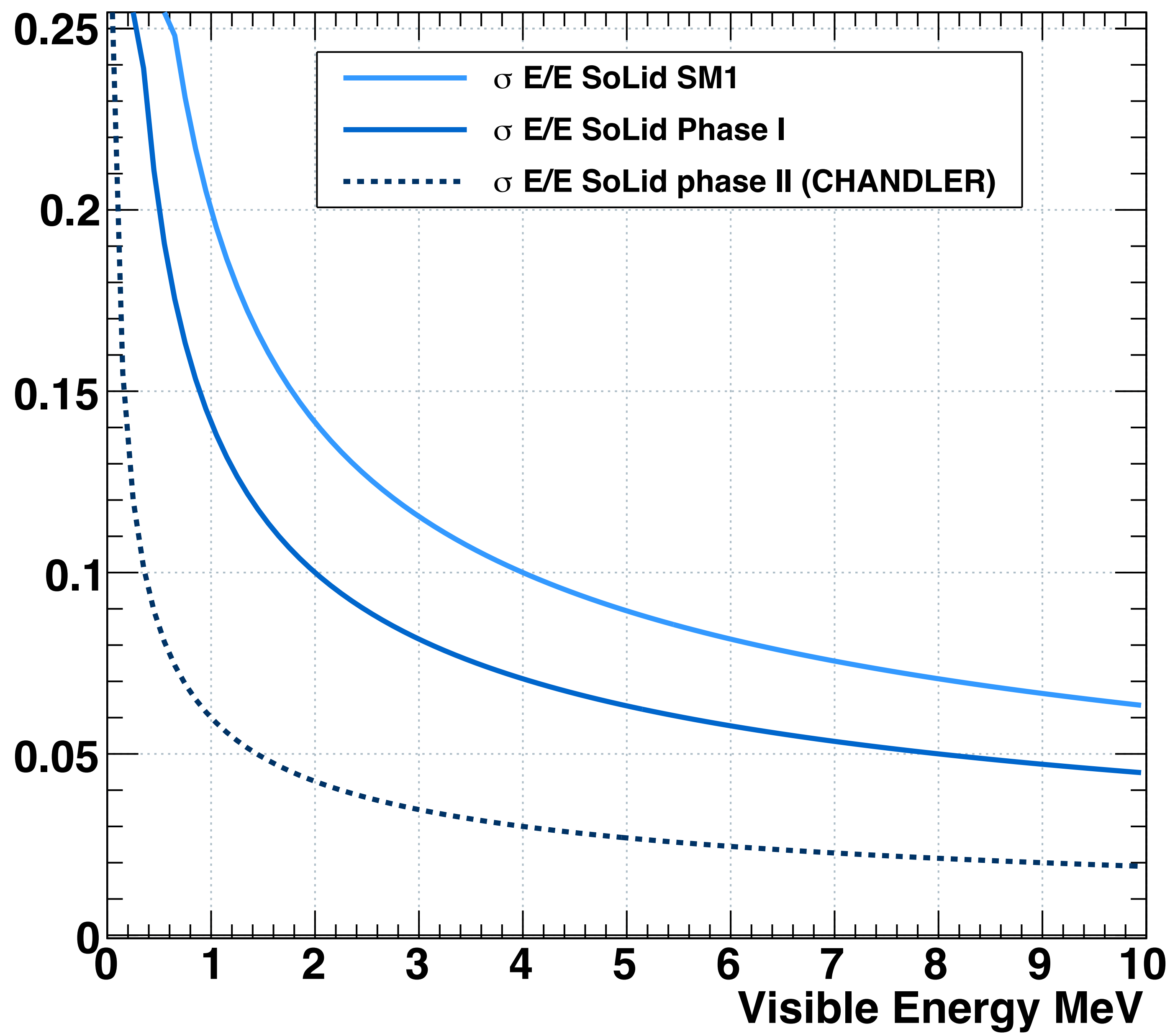
- SoLid will search for new oscillation with a new type of compact detector
  - aim to resolve the anomalies by 2020
  - the BR2 HEU core will add new data for ^{235}U
- A succesful staged R&D demonstrated the technology is ready for high precision measurement
  - Excellent neutron ID
  - Excellent detector uniformity and stability
  - Precise calibration with muons
  - First IBD analysis ongoing (3-5 days of reactor ON data/ ~ 1 month reactor OFF)
- more results in the coming months - stay tuned !

Energy scale stability

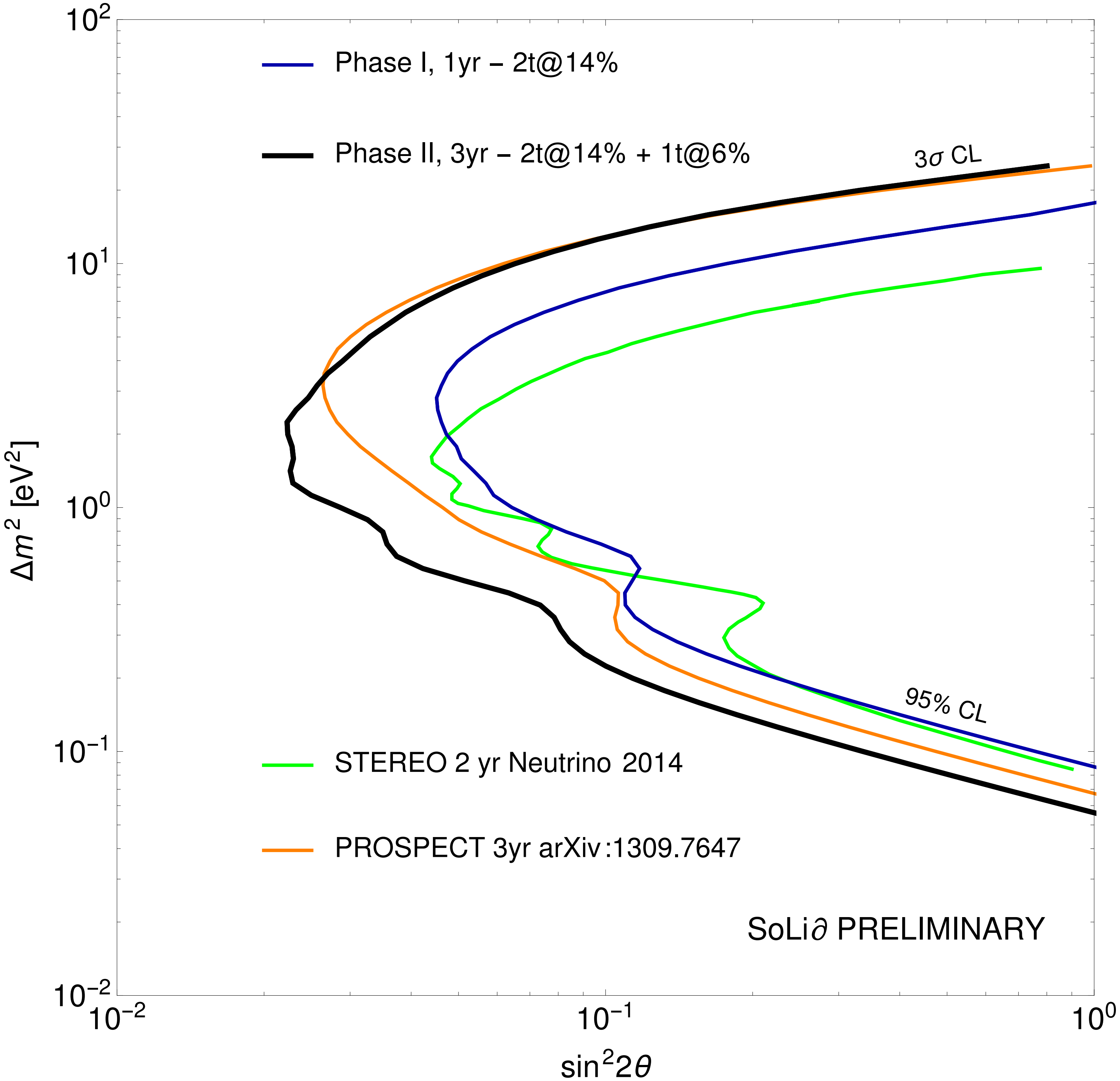
- 1% energy scale stability demonstrated

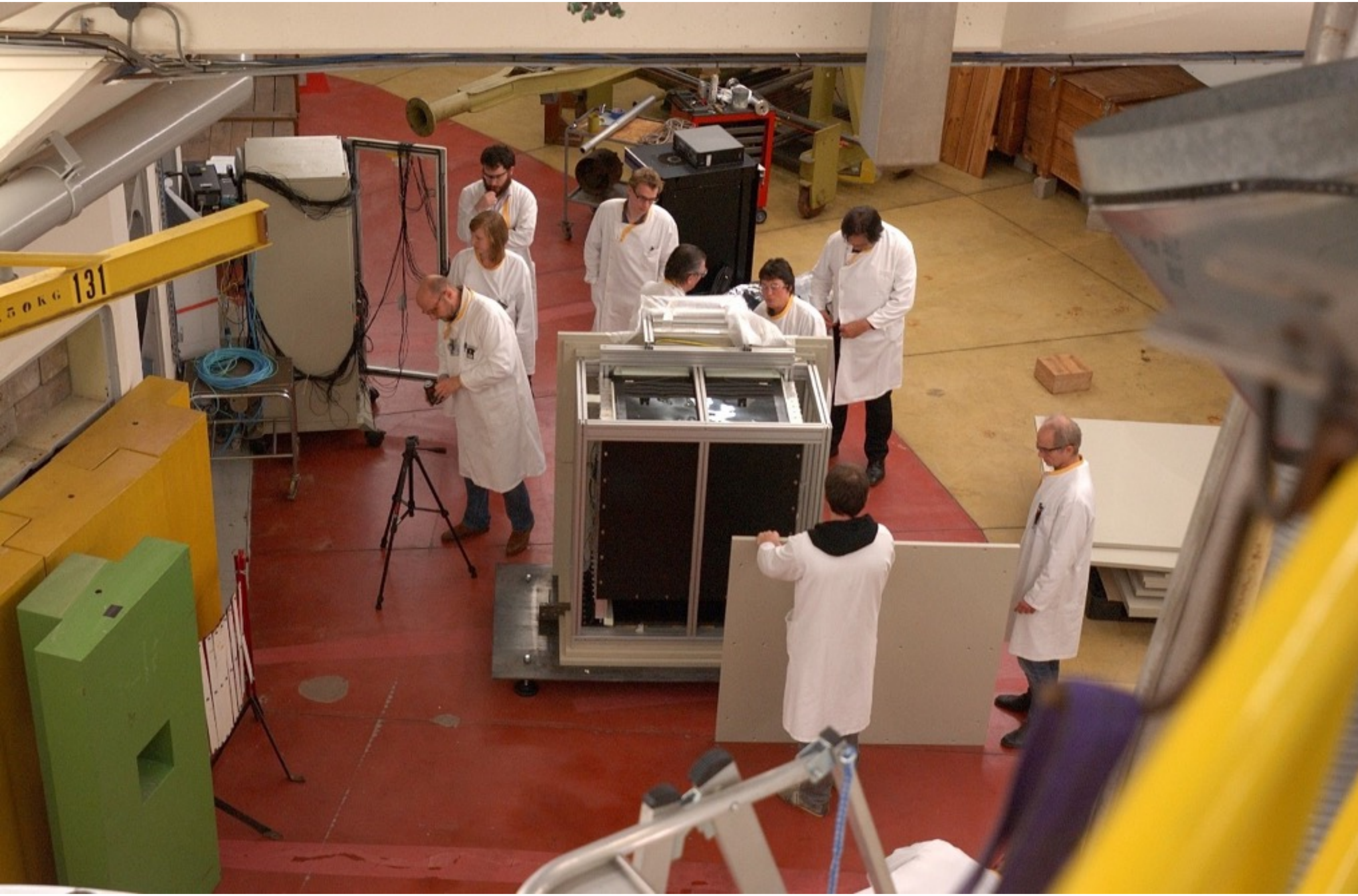


Energy resolution



Sensitivity comparison

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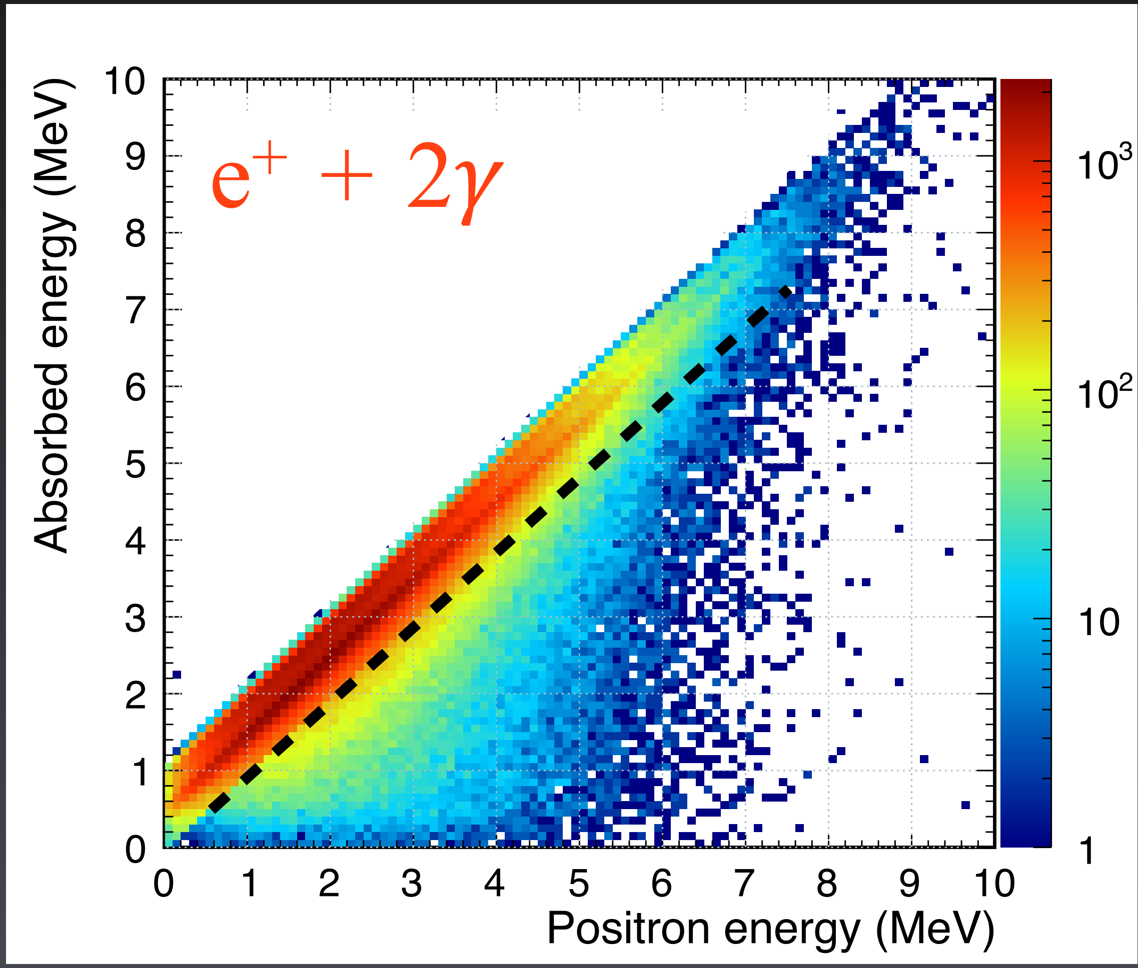
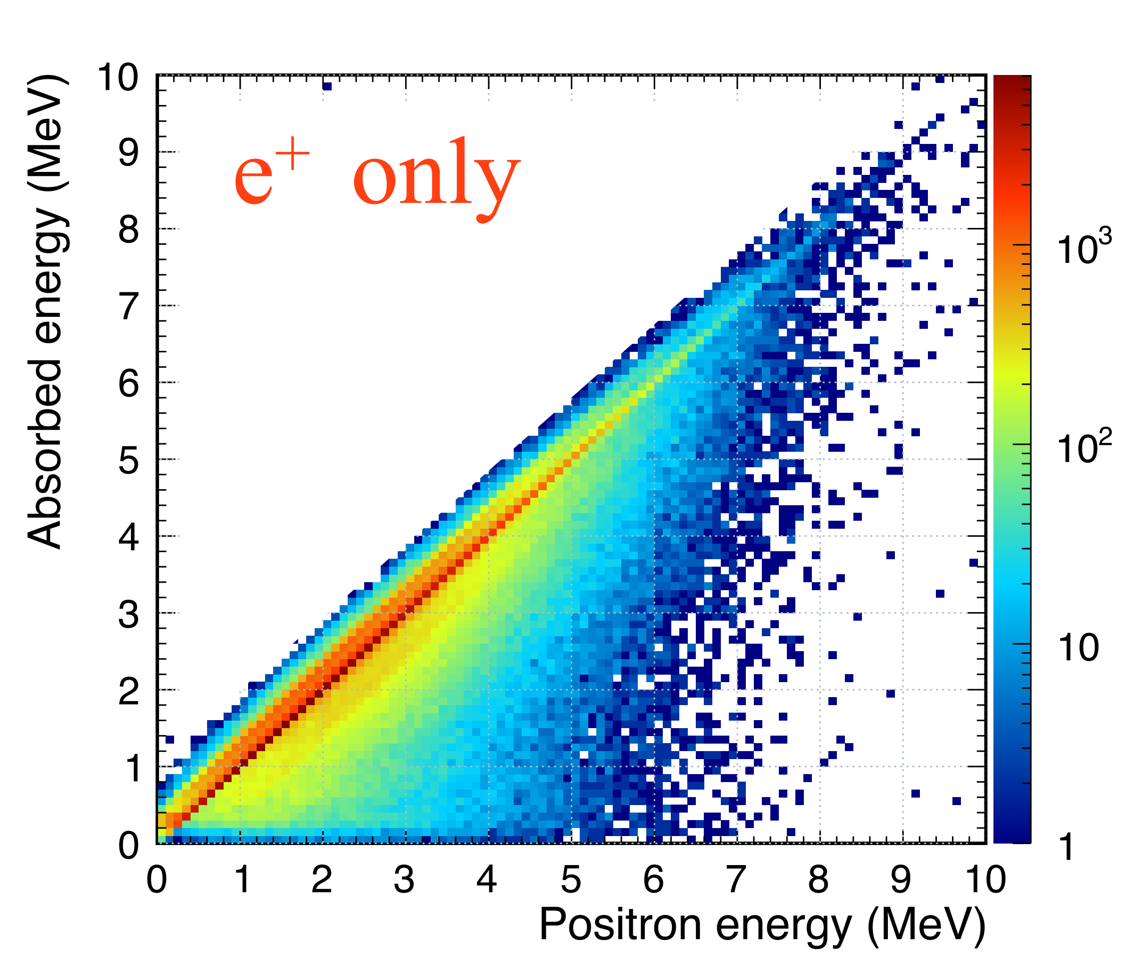
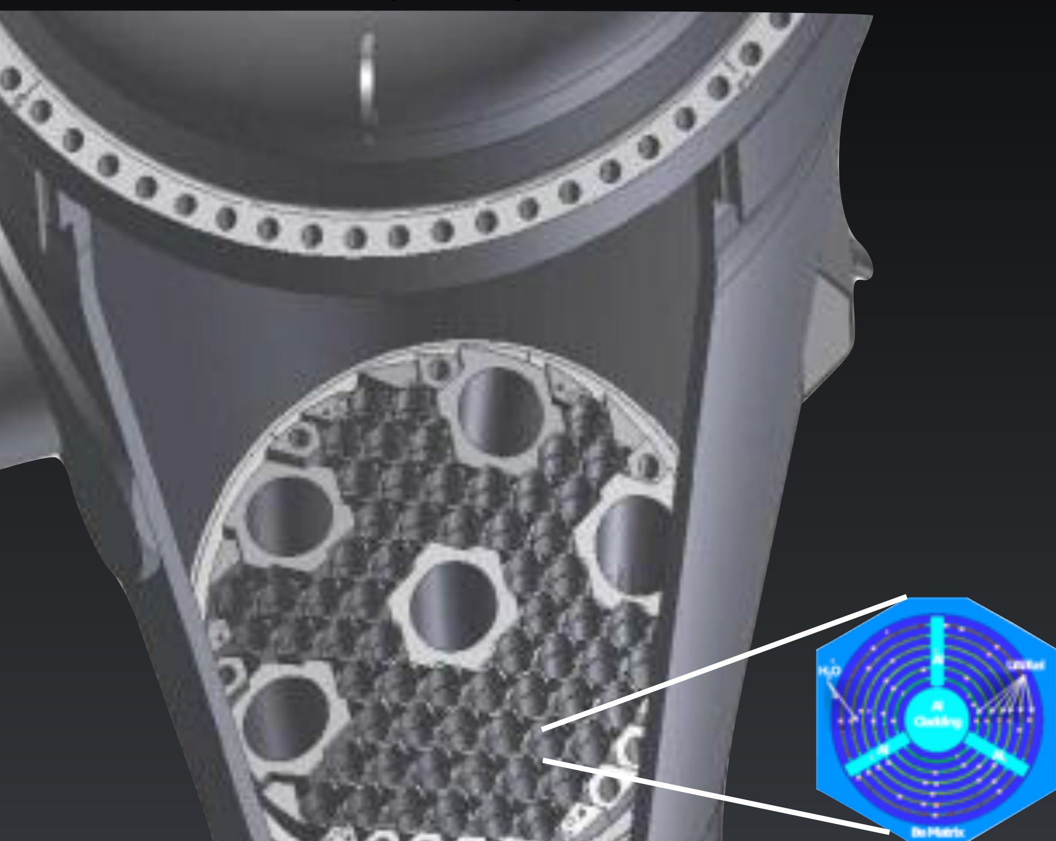
Precise energy reconstruction



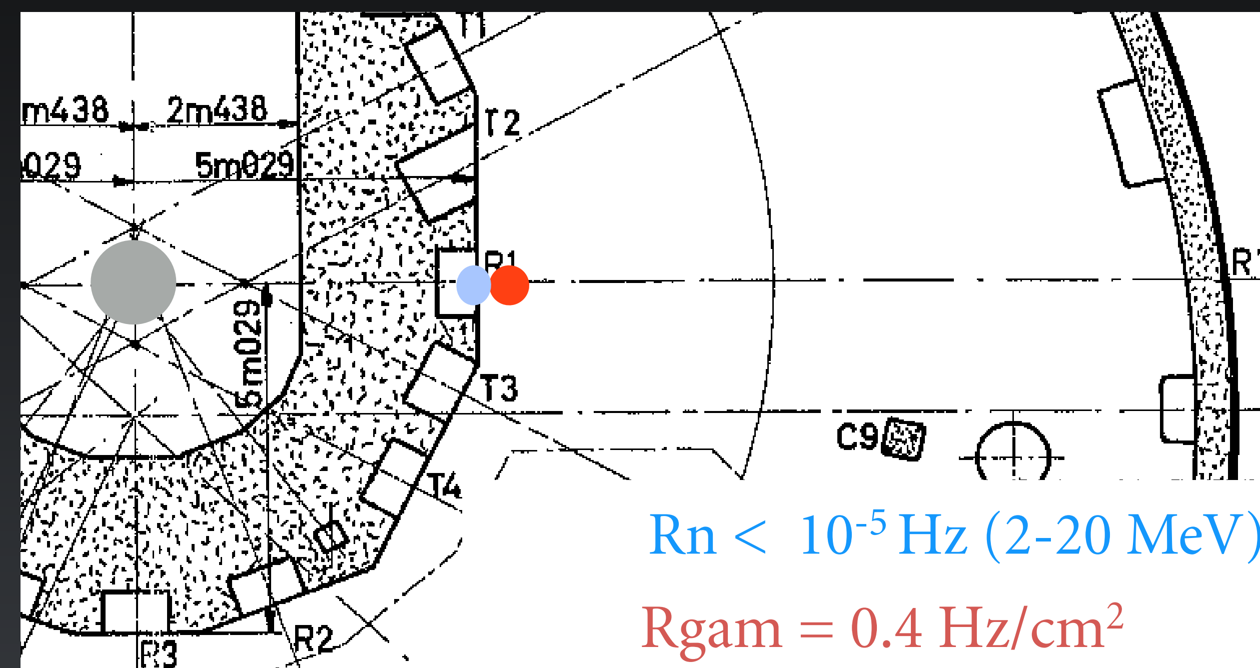


The neutrino source : BR2

Personal communication. By courtesy of SCK•CEN



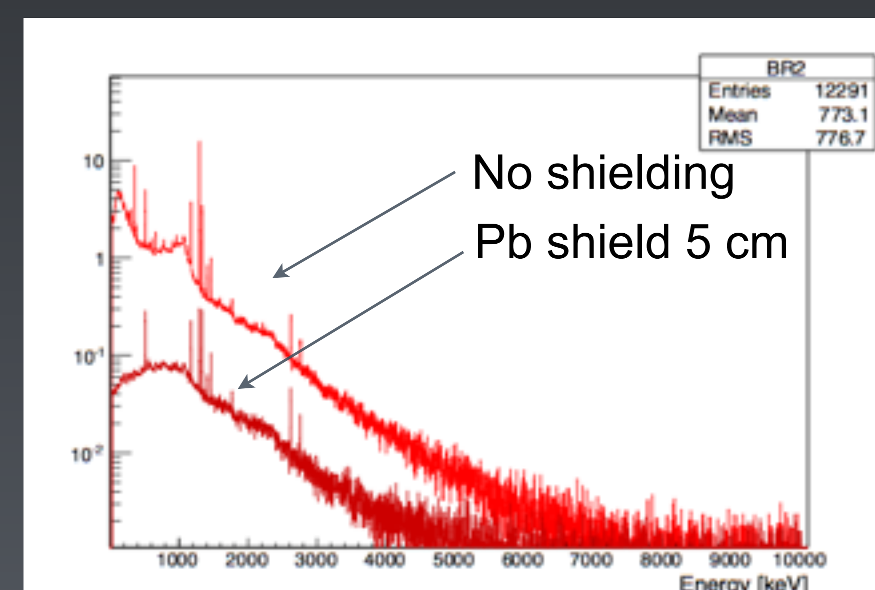
- Careful assessment of reactor backgrounds reveals low energy gamma-rays and very low neutron rate



Rn < 10^{-5} Hz (2-20 MeV)

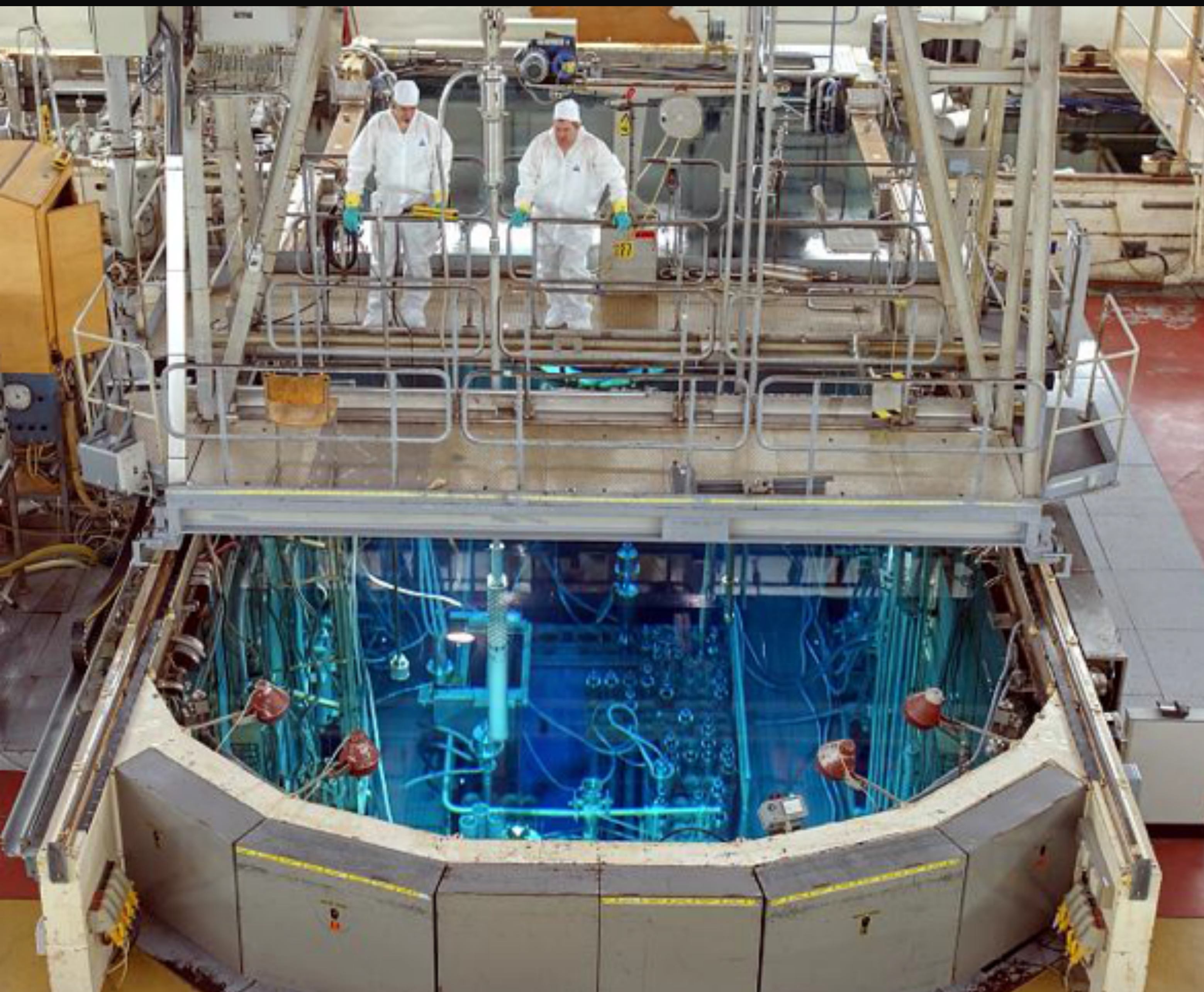
Rgam = 0.4 Hz/cm^2

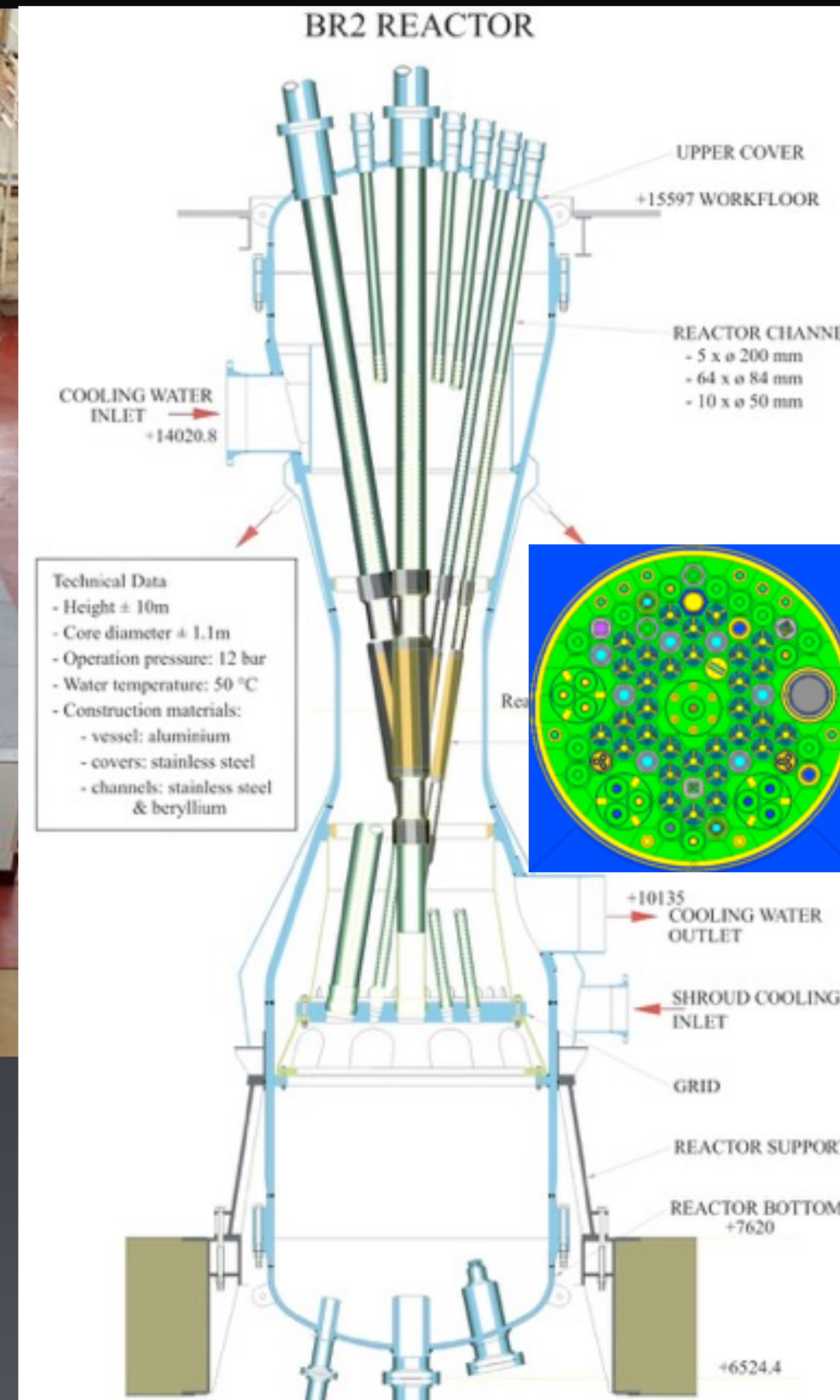
- Pth = 72 MW at R1 port 5.0 m from core



- Compact source
- Highly enriched Uranium
  - pure ^{235}U antineutrino flux
- High Power (40-80) MW
- duty cycle : 150 days / year

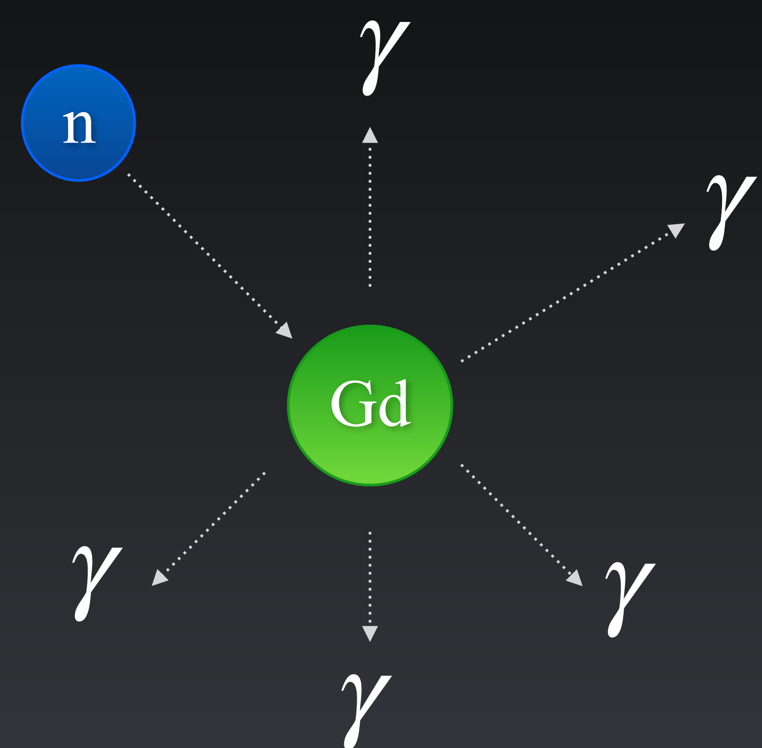
BR2 MTR reactor

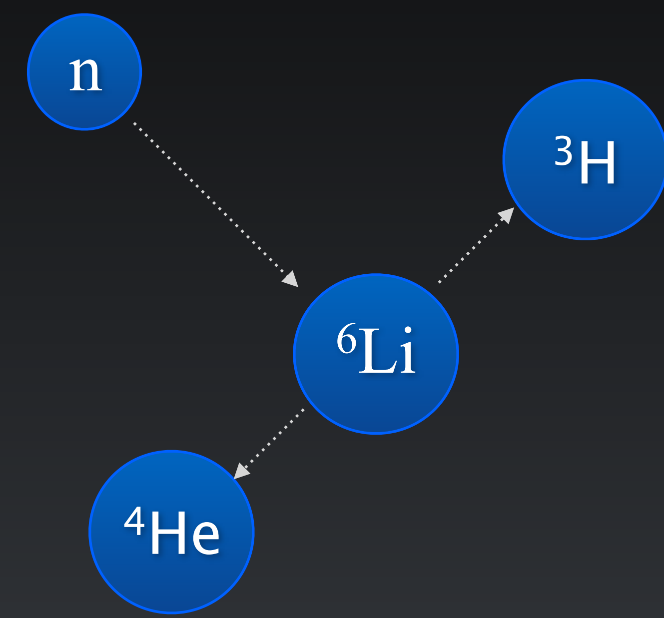




- tank in Pool reactor
- operating power (Pth = 40-80 MW)
- relatively low reactor background and stable conditions
- excellent for anitneutrino measurement

Neutron capture

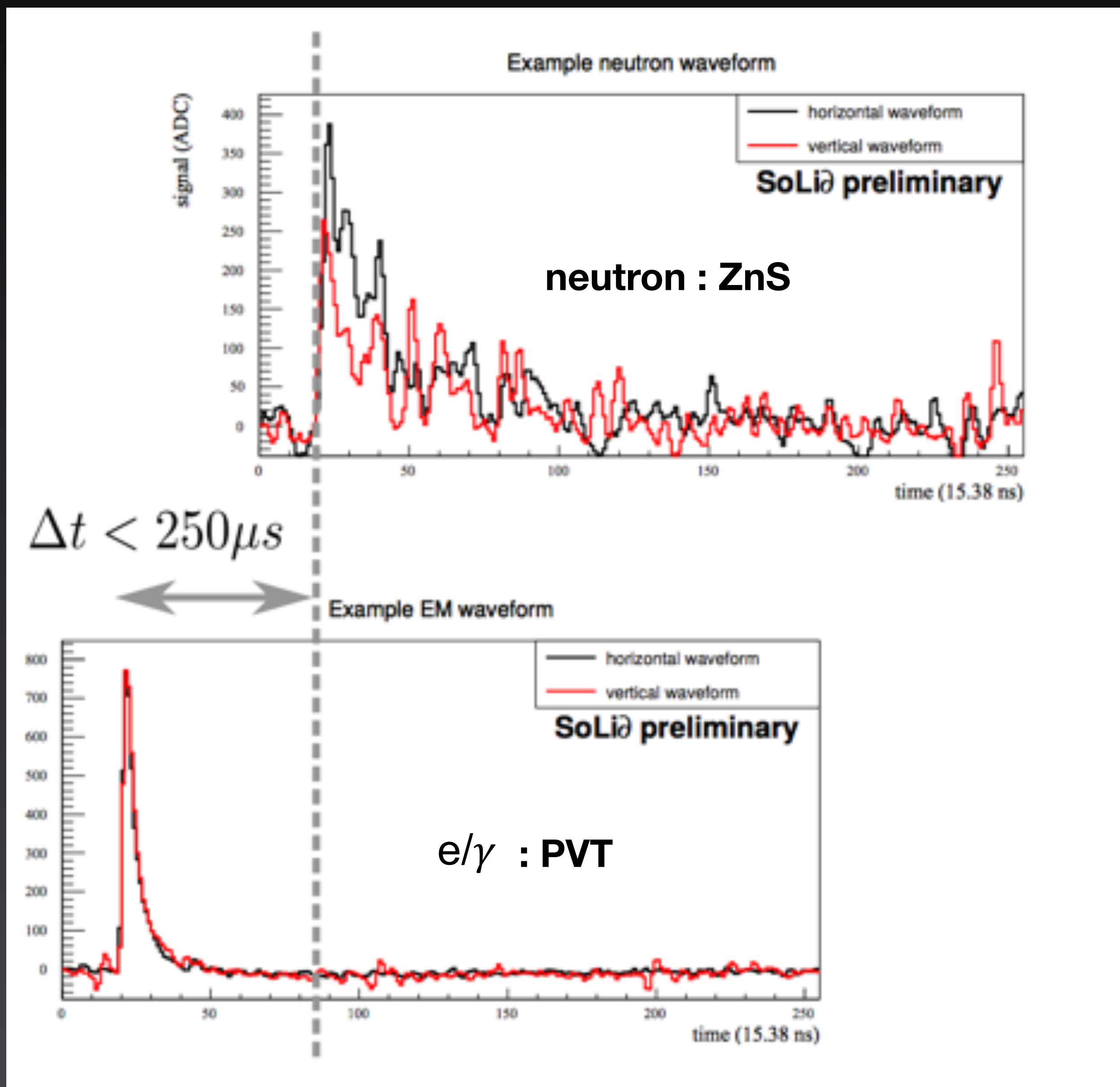


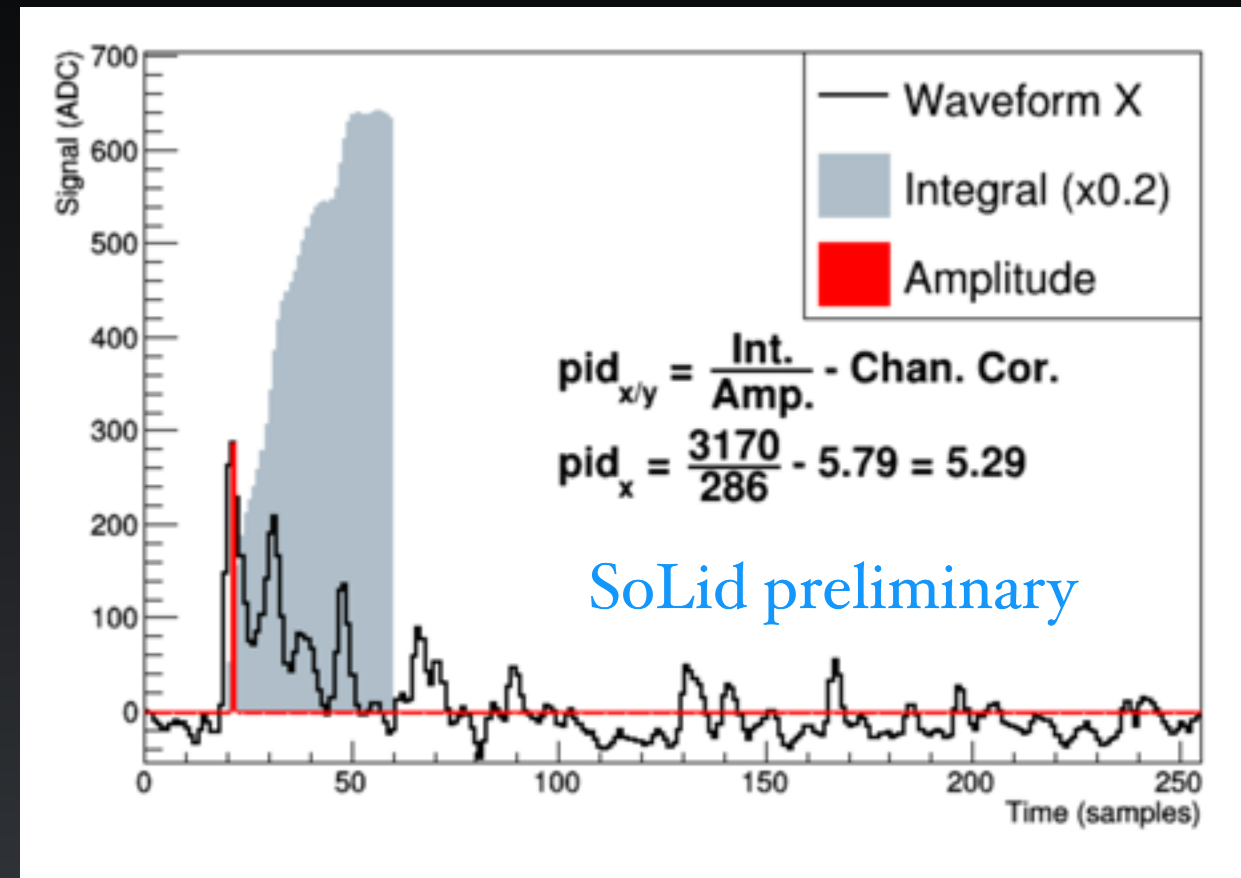


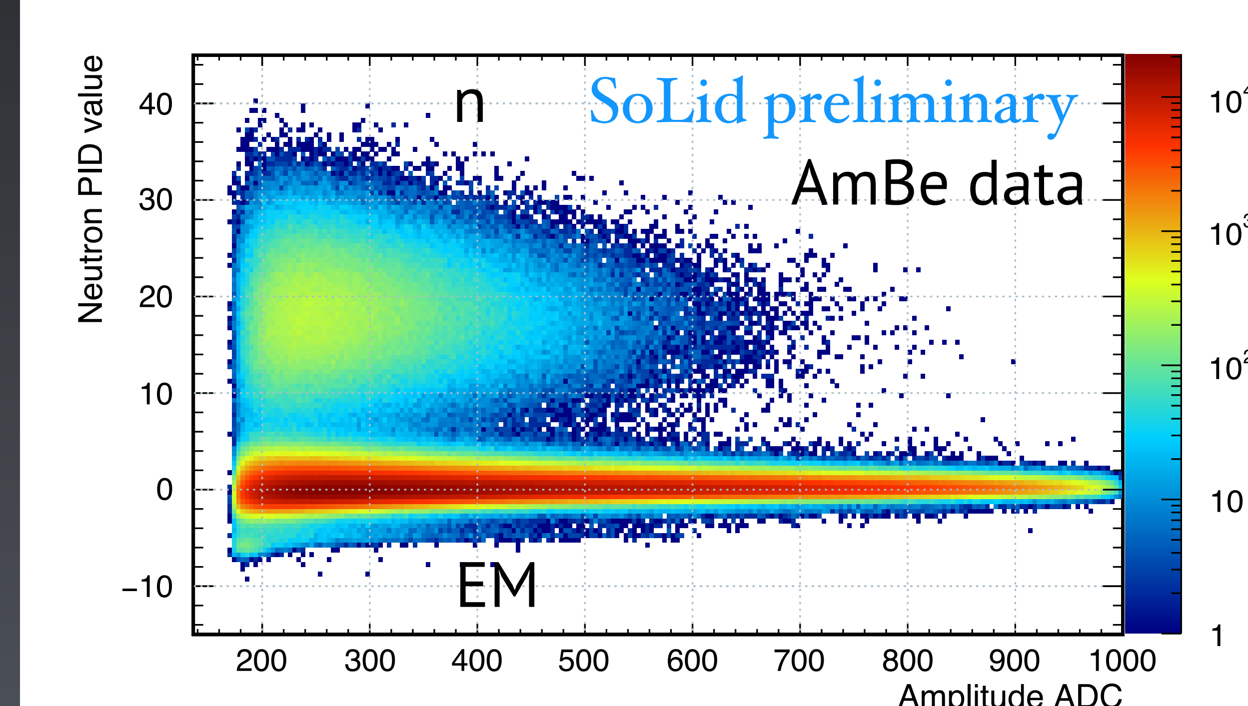
- E ~ 8 MeV of gamma-ray energy
- ~ 30-40 cm int length
- poorly contained in small detector

- E ~ 4.78 MeV nuclear reaction
- few tens of microns

LiF:ZnS(Ag) neutron ID



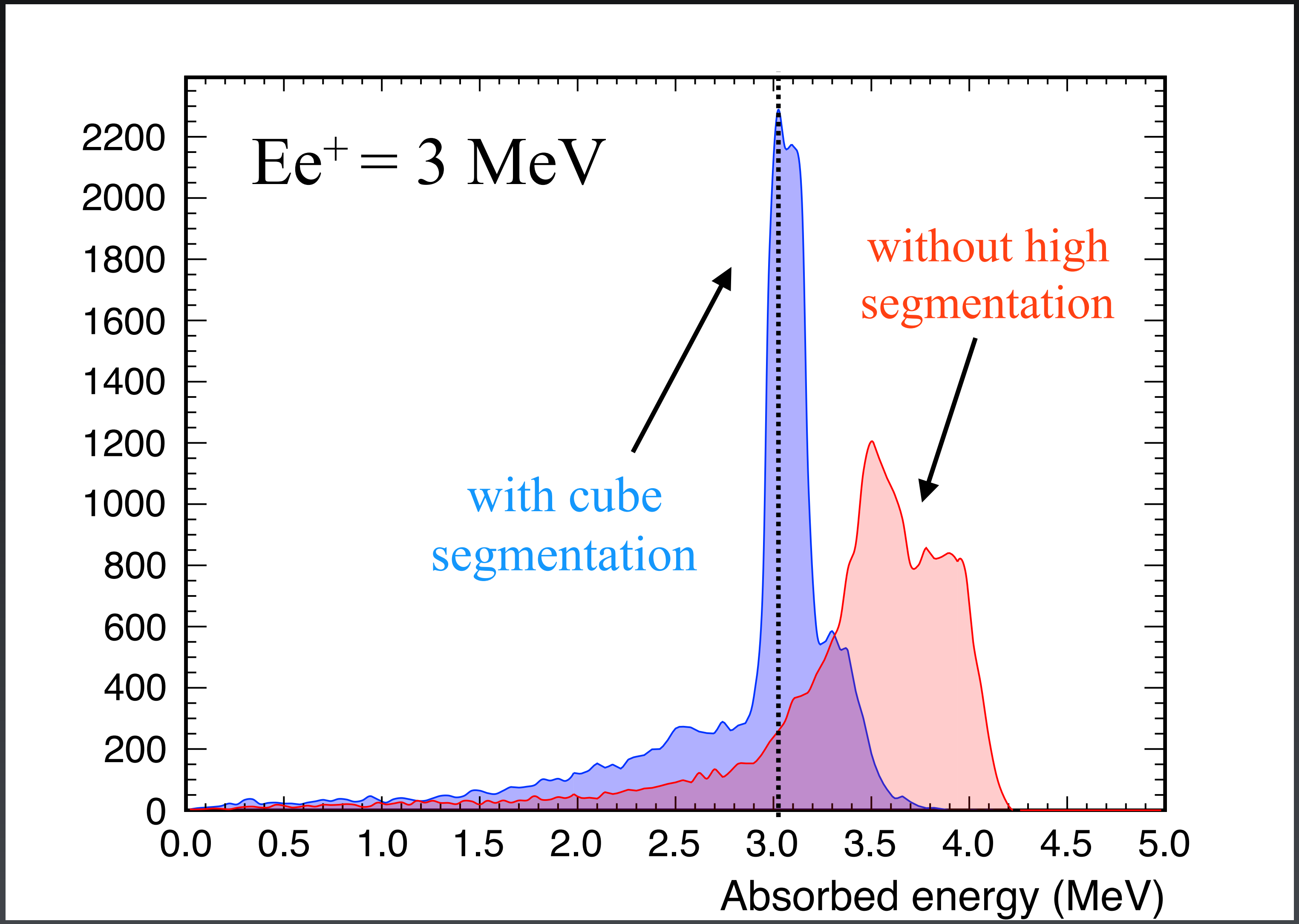




- high energy and robust signature insensitive to gamma-ray background

Precise Energy reconstruction

$$\bar{\nu_e} + p \rightarrow e^+ + n$$



- Precise energy measurement retained
- Doesn't affect energy resolution