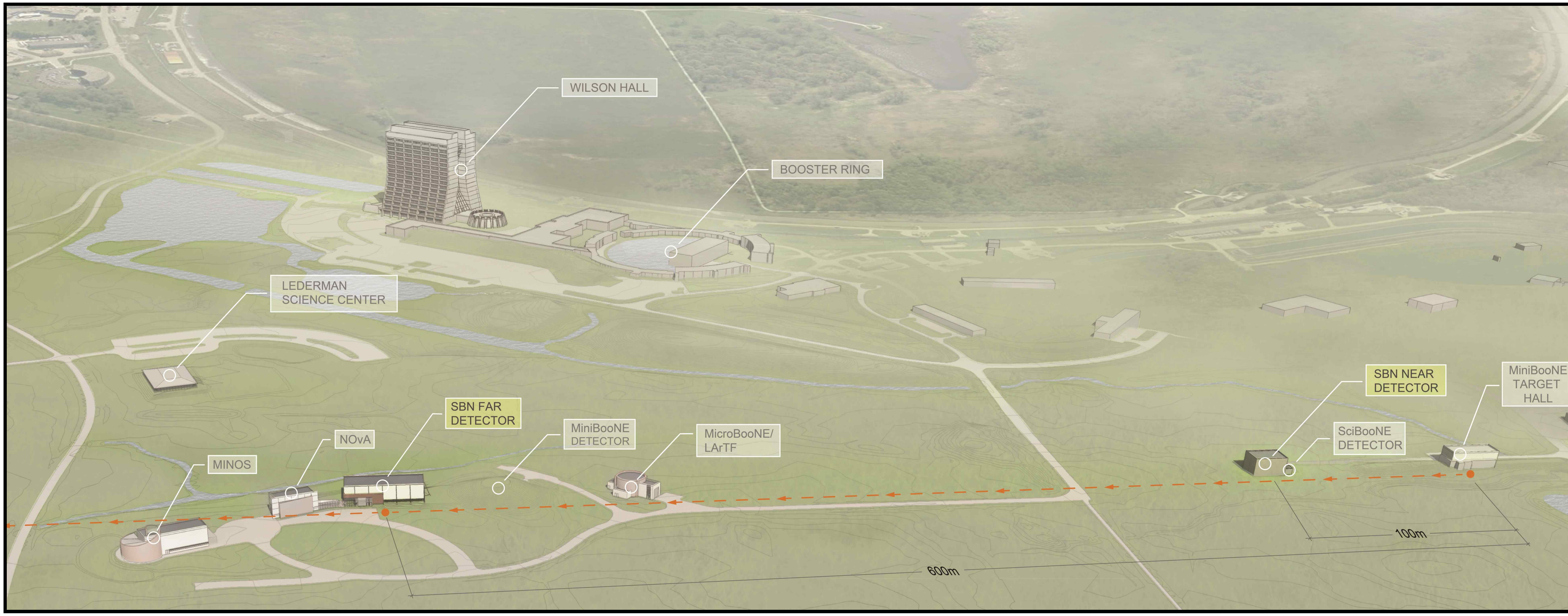
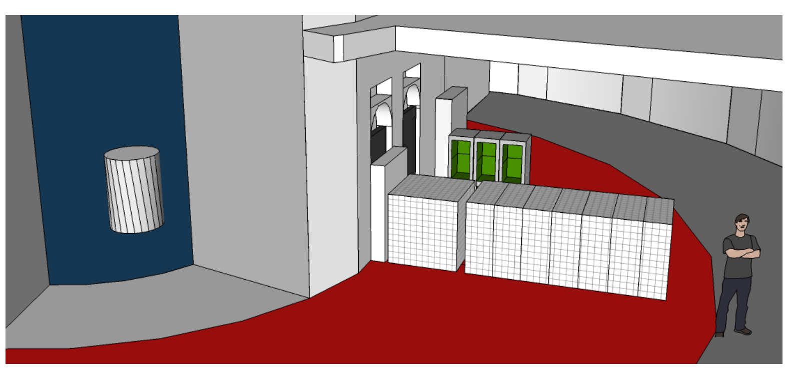


Short Baseline Neutrino Experiments



Roxanne Guenette
University of Oxford

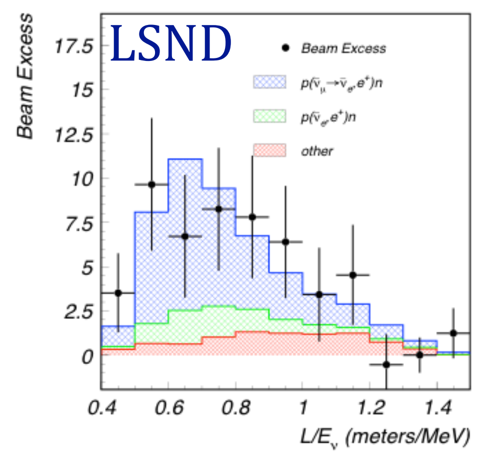
PPAP Meeting 24-25 September 2015

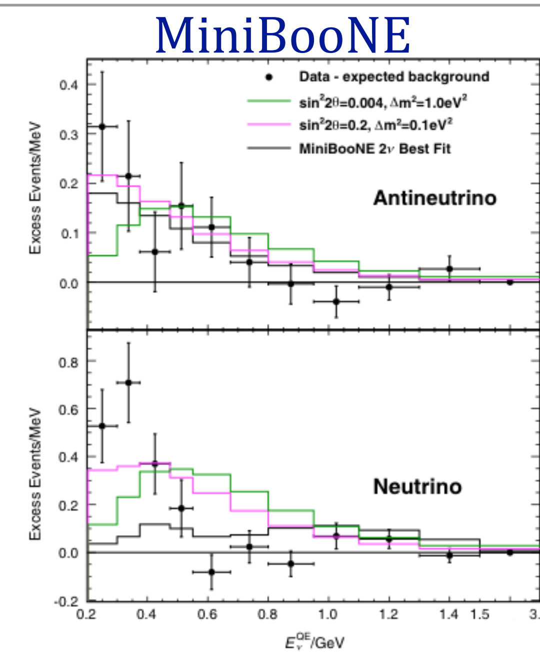
Outline

- Why a Short-Baseline Neutrino Programme?
- The SBN Programme at FNAL
  - MicroBooNE
  - SBND
- Summary

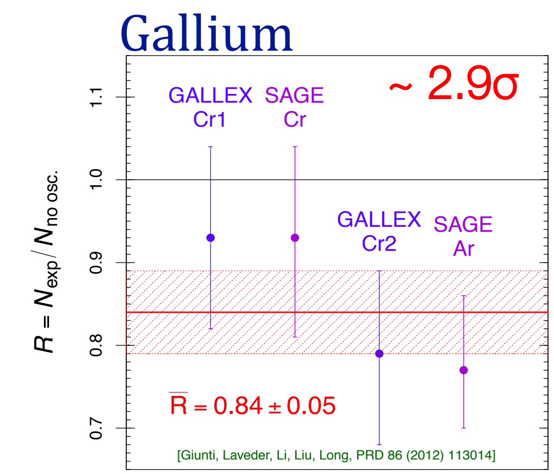
Why a Short baseline neutrino programme?

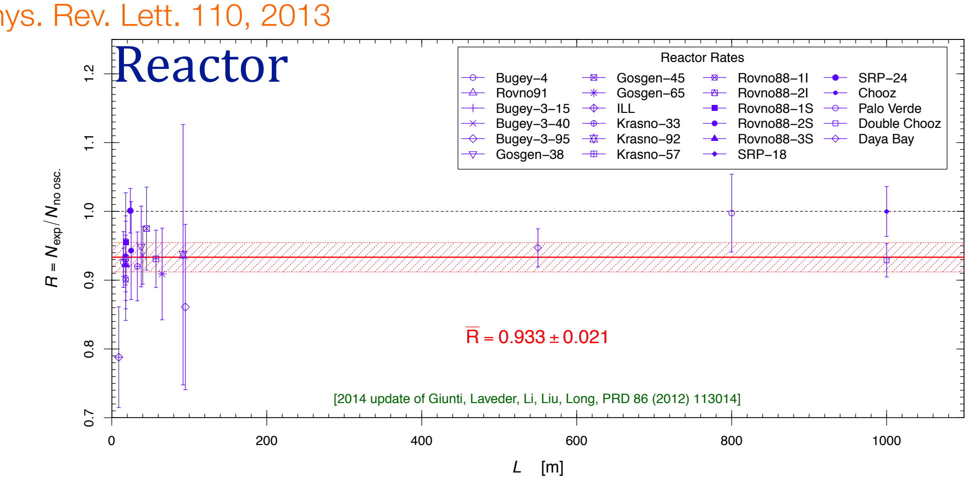
- Many SB anomalies
  - ➡ LSND anomaly (3.8σ)
  - ➡ MiniBooNE low-energy excess (~3σ)
  - ➡ Gallium anomaly (~3σ)
  - ➡ Reactor anomaly (~3σ)





Phys. Rev. Lett. 110, 2013





- **DUNE and CP violation measurement!**

Why a Short baseline neutrino programme?

- Many SB anomalies
  - ➡ LSND anomaly (3.8σ)
  - ➡ MiniBooNE low-energy excess (~3σ)
  - ➡ Gallium anomaly (~3σ)
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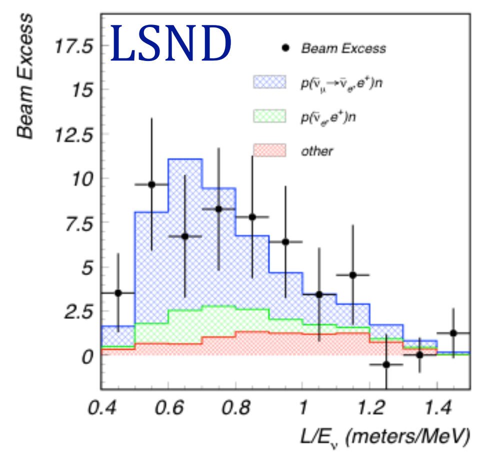
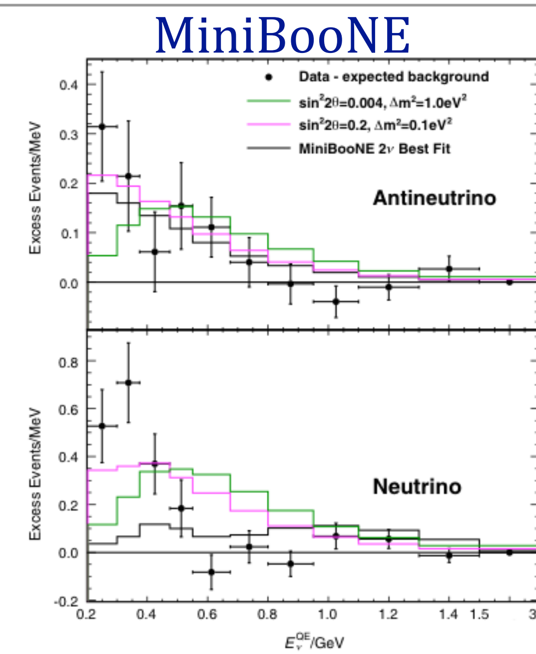
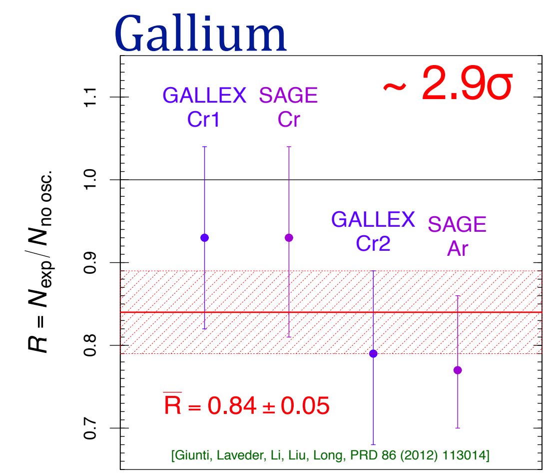
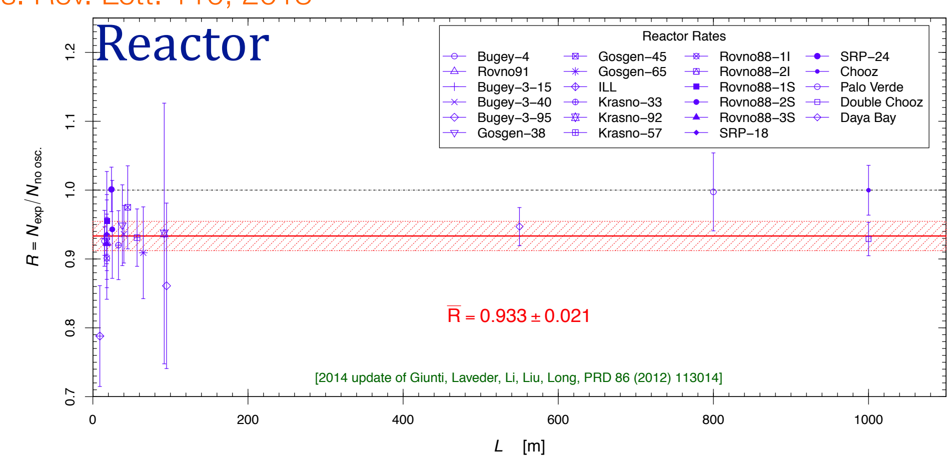




Phys. Rev. Lett. 110, 2013





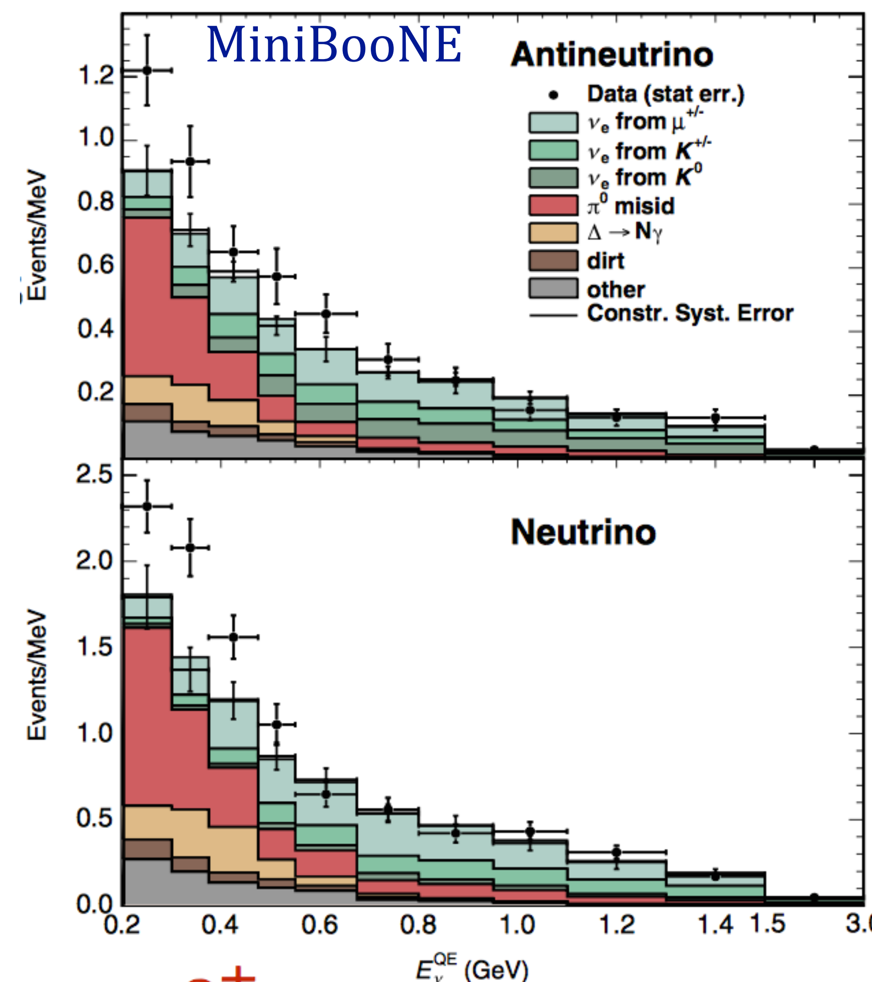
- **DUNE and CP violation measurement!**

"… any data indicating the violation of CP cannot be properly interpreted within the standard paradigm unless the presence of sterile states of mass O(1 eV) can be conclusively ruled out. "

Raj Gandhi, Boris Kayser, Mehedi Masud,Suprabh Prakash, (arXiv:1508.06275)

MicroBooNE

- Address the MiniBooNE low-energy excess
  - Look for excess
  - Identify signal (γ or e^- ?)
- Oscillation physics study (appearance/disappearance)
- Cross-section measurements
- Astroparticle and Exotic physics

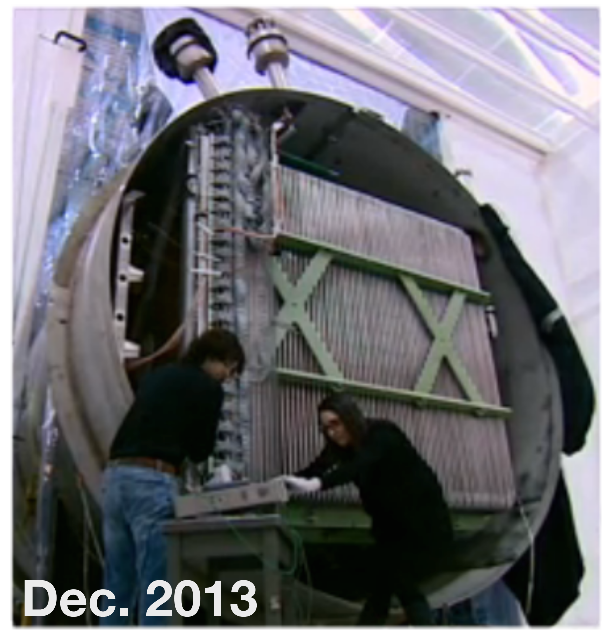


Phys. Rev. Lett. 110, 2013

courtesy of T. Miceli

MicroBooNE

- 170 tons Liquid Argon Time Projection Chamber



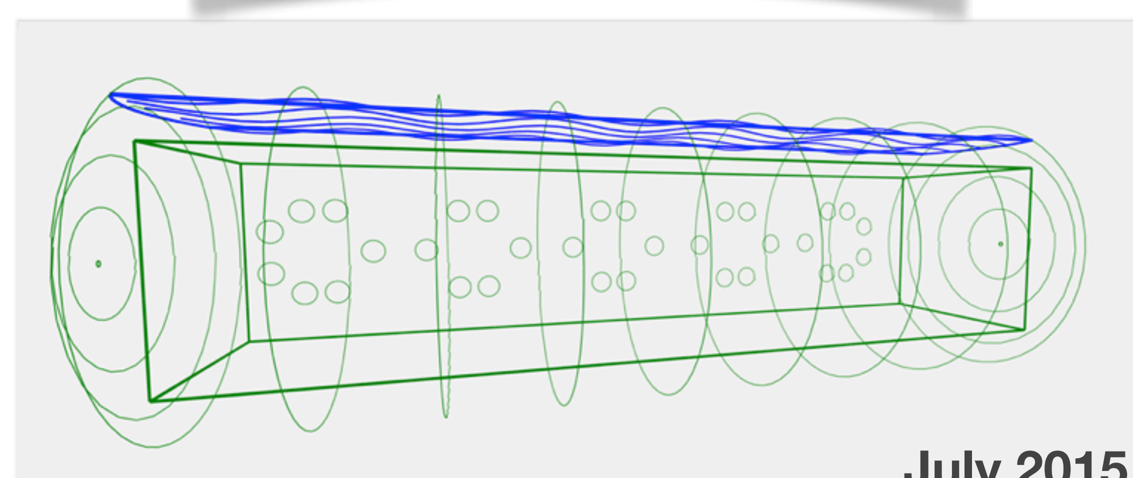
- ✓ Constructed
- ✓ Assembled
- ✓ Moved
- ✓ Installed

MicroBooNE

Aug. 2014

Oct. 2014

June 2015

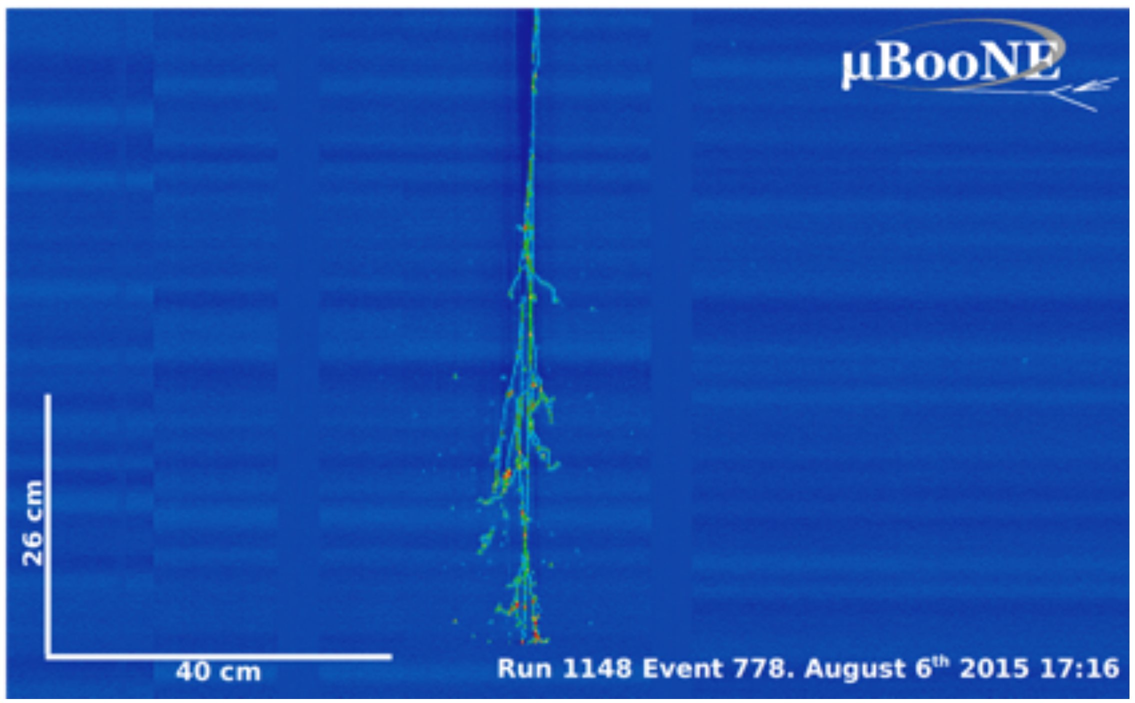


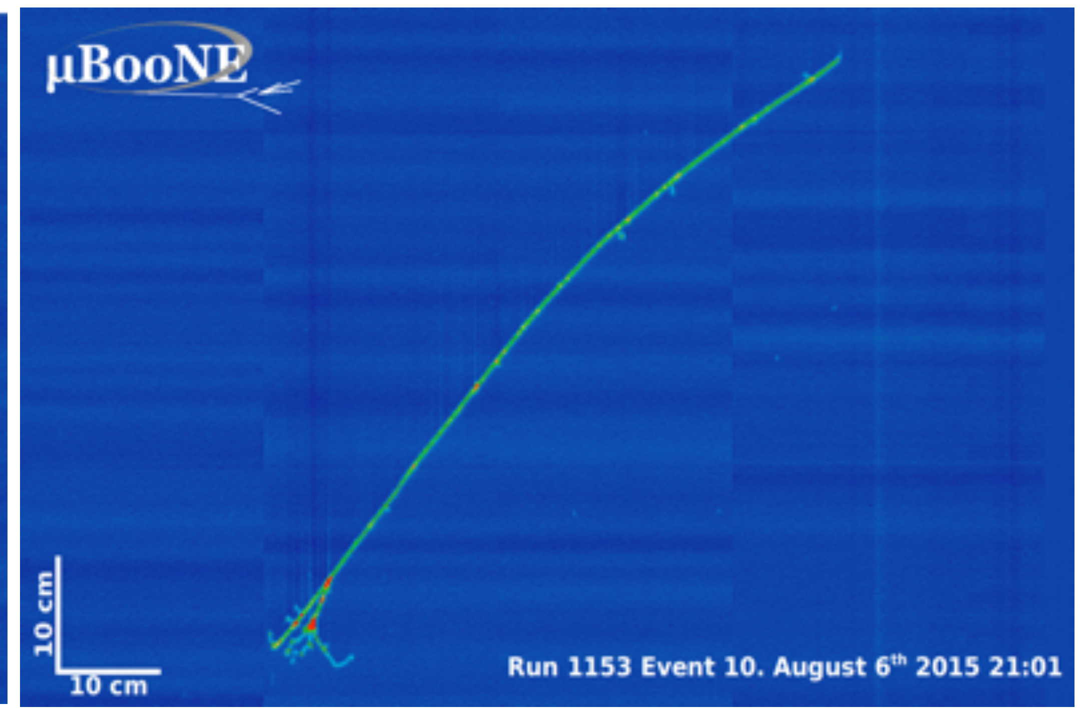
July 2015

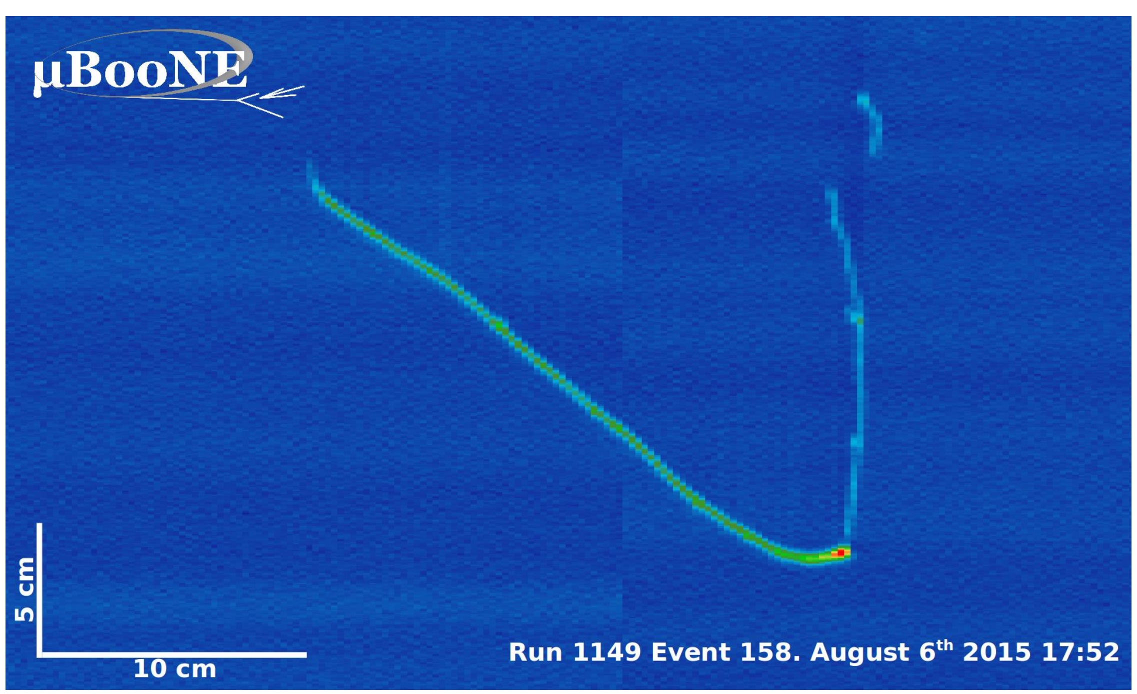
- ✓ Insulated
- ✓ Cabled
- ✓ Purged
- ✓ Filled

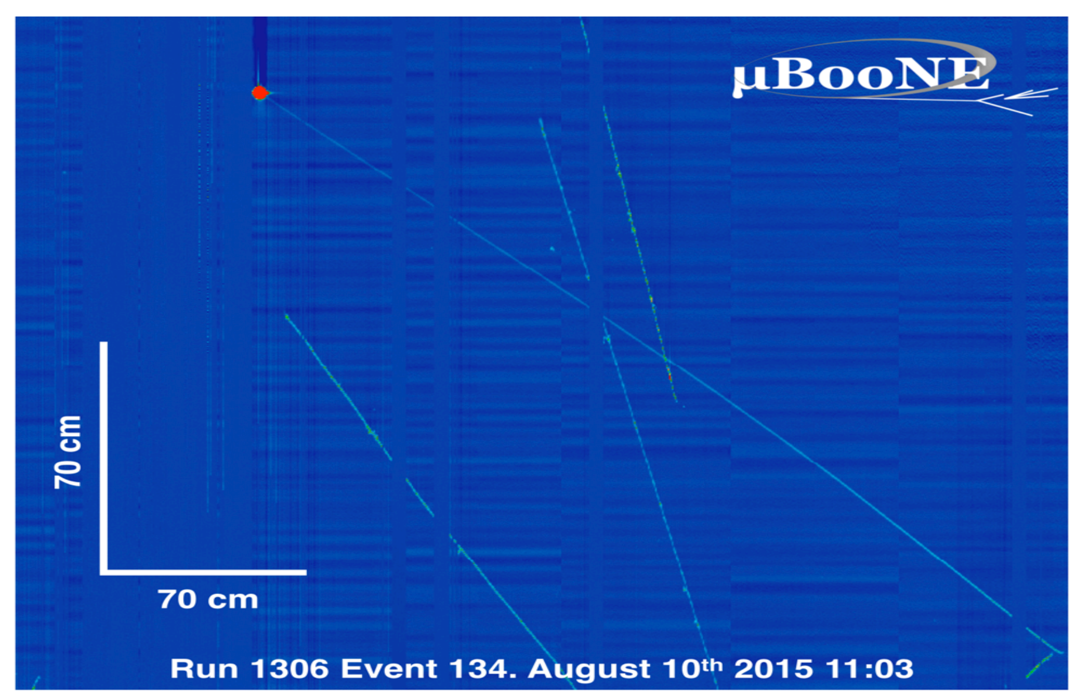
MicroBooNE Commissioning

- First tracks!

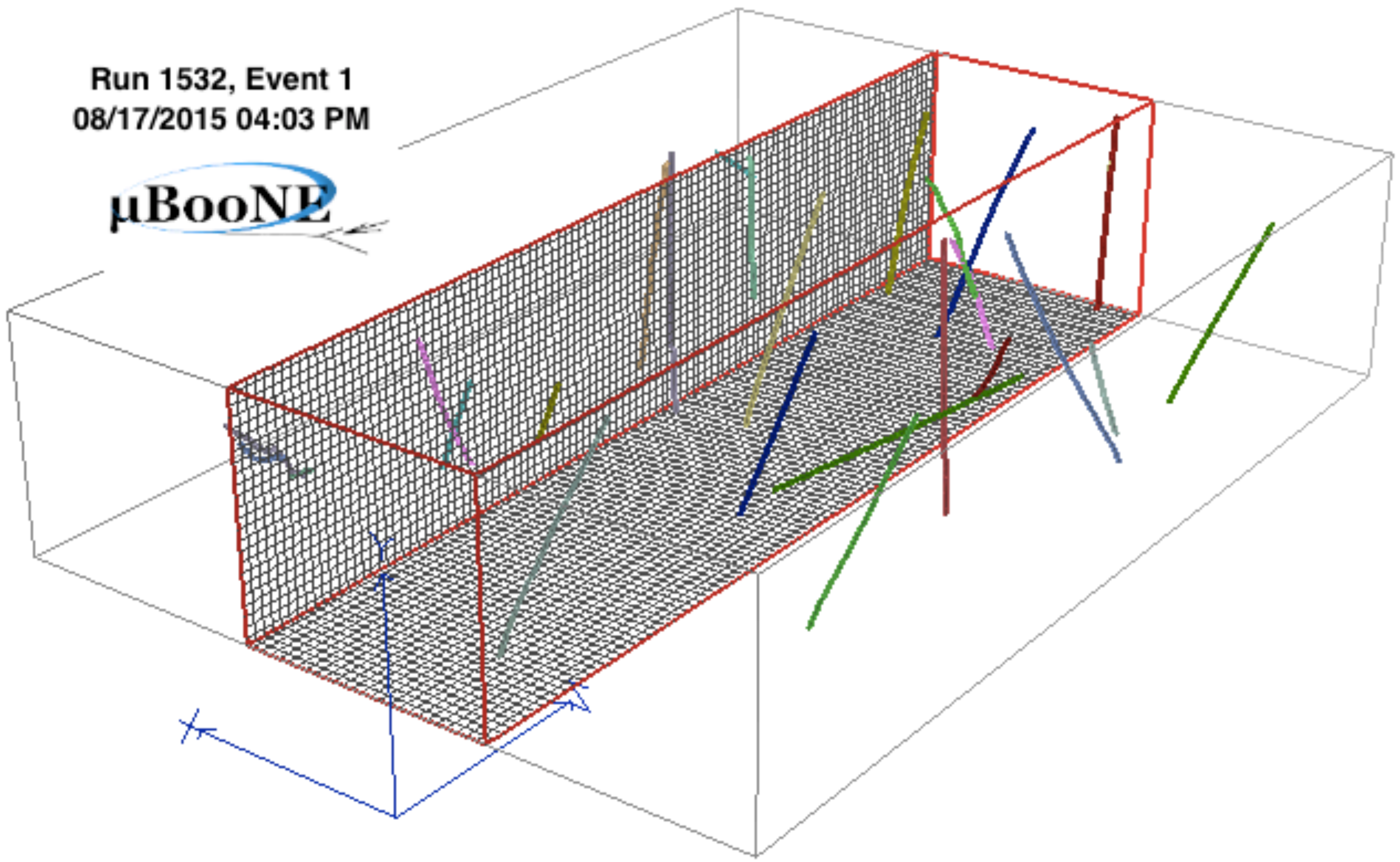






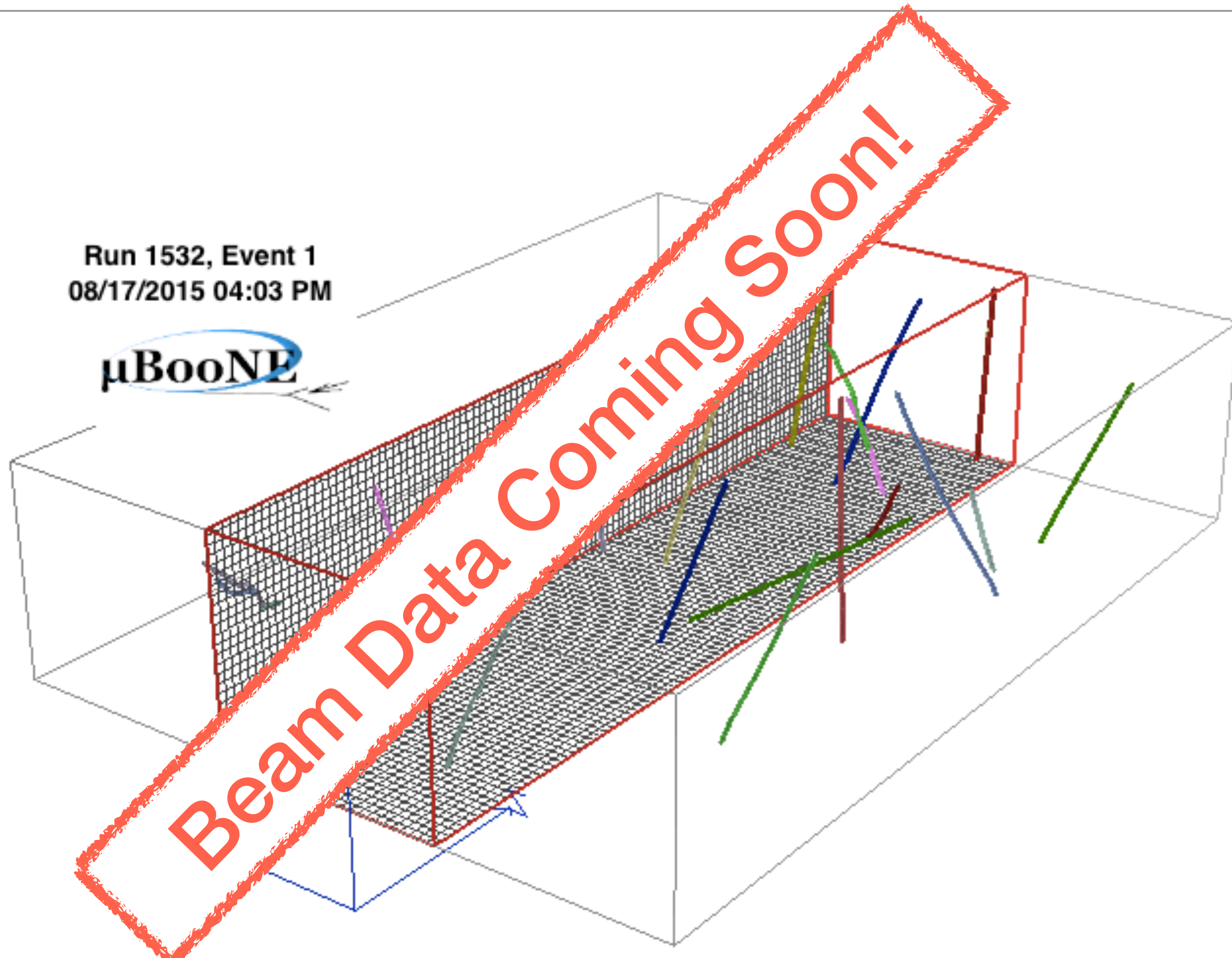


MicroBooNE automated reconstruction



4.8ms window (3 drift windows)

MicroBooNE automated reconstruction

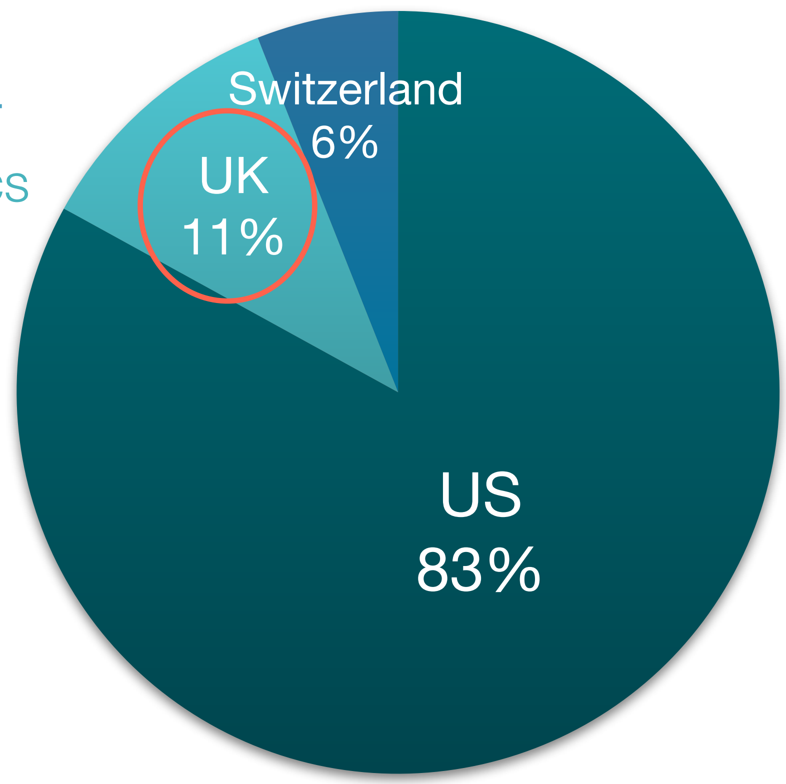


4.8ms window (3 drift windows)

MicroBooNE in the UK

People

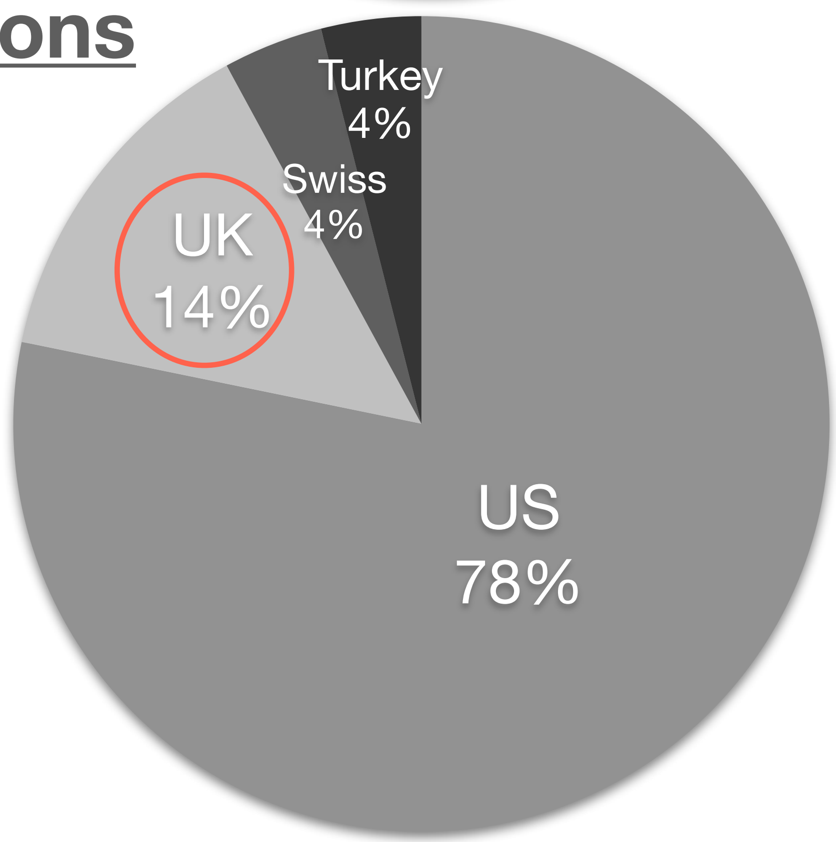
8 Academics
3 PDRAs
11 PhDs

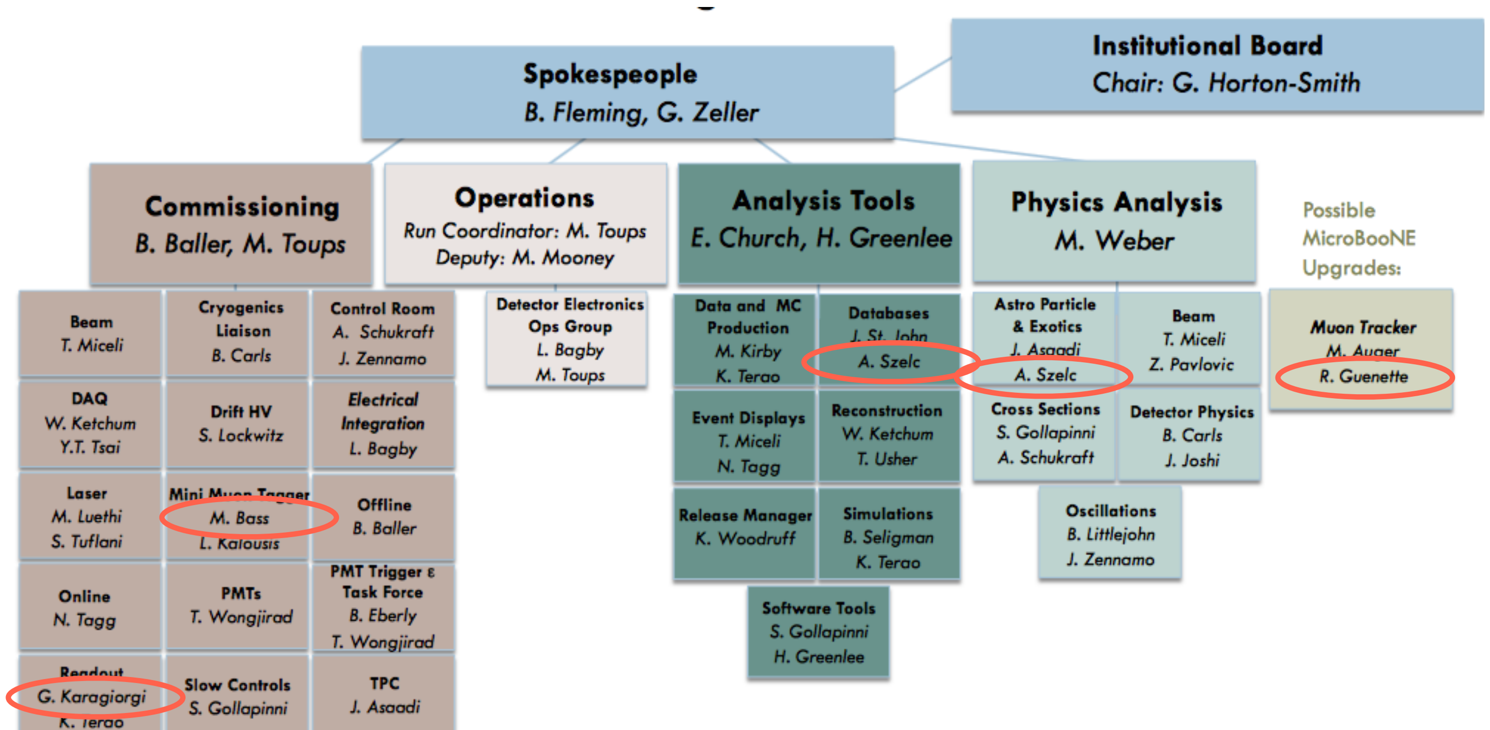


- Biggest International contribution
- Many leadership roles
- Significant impact on science
- Knowledge transfer for future LArTPCs

Institutions

Cambridge
Manchester
Lancaster
Oxford





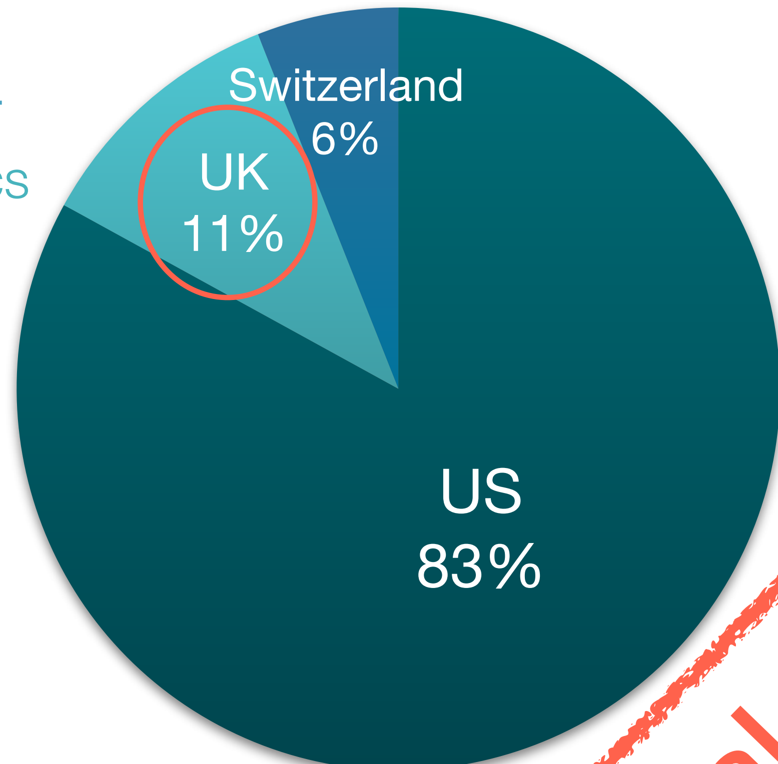
MicroBooNE in the UK

µBooNE

LArTPC

People

8 Academics
3 PDRAs
11 PhDs



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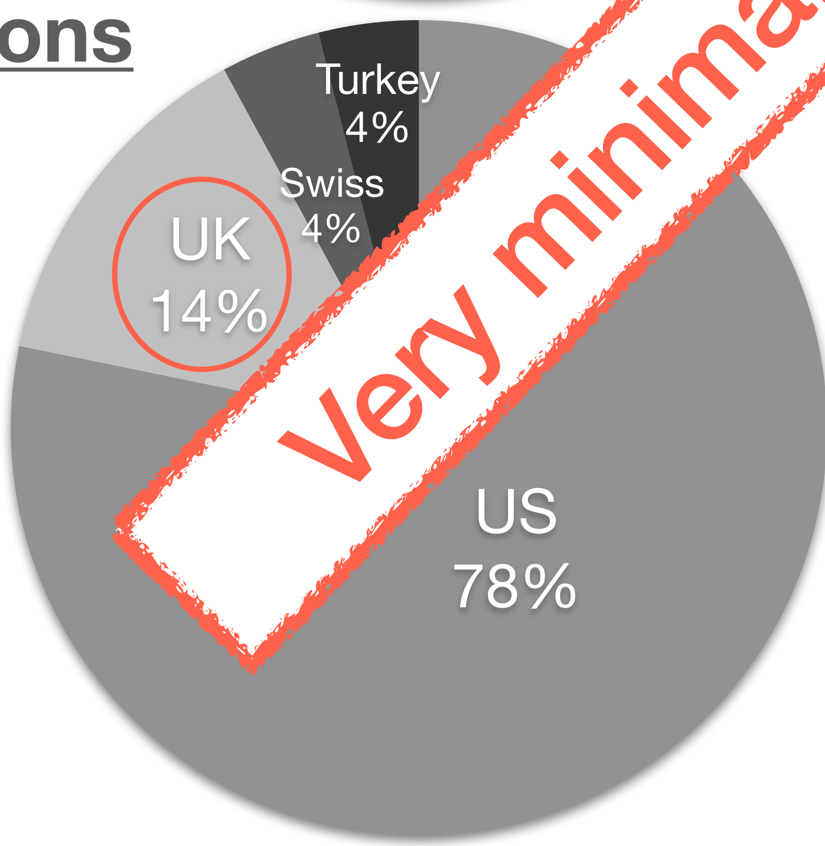
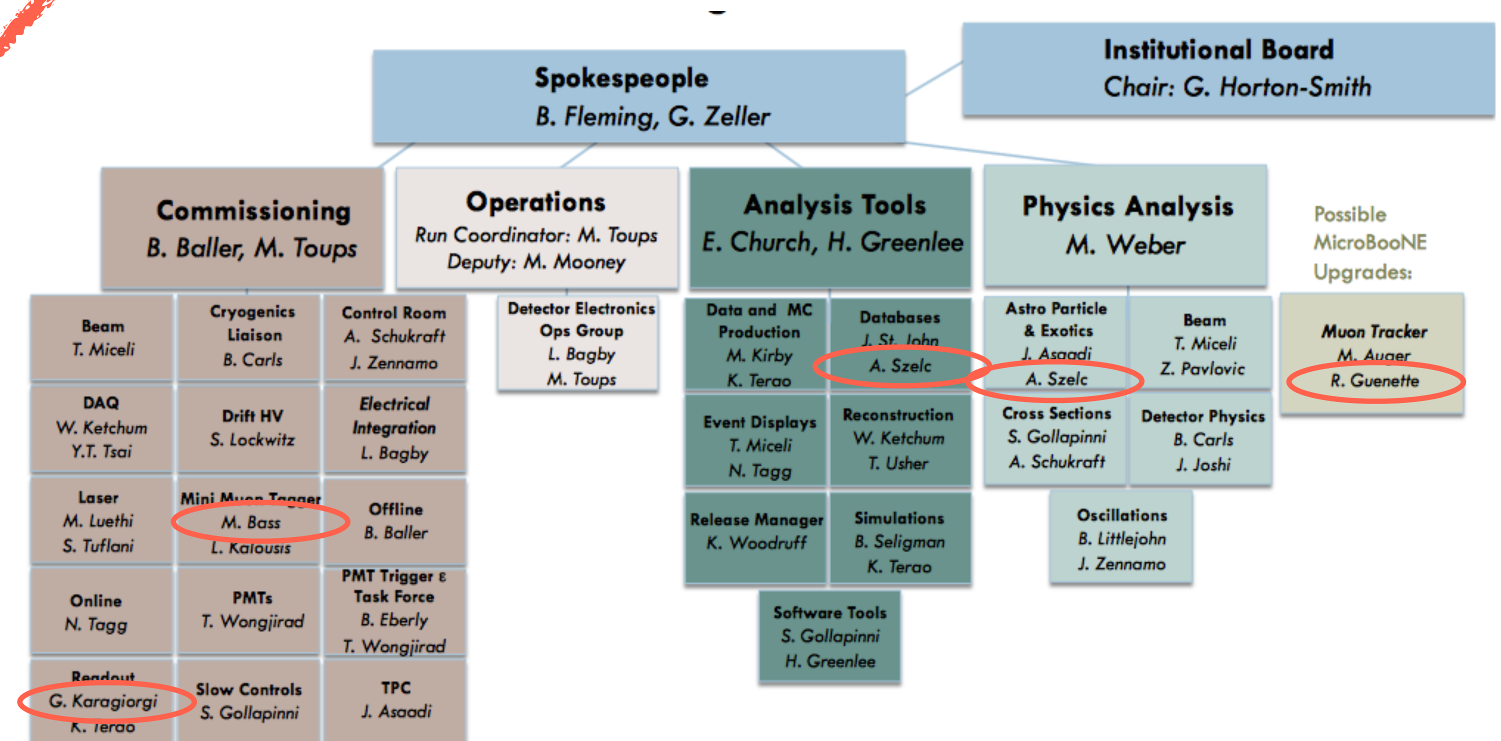
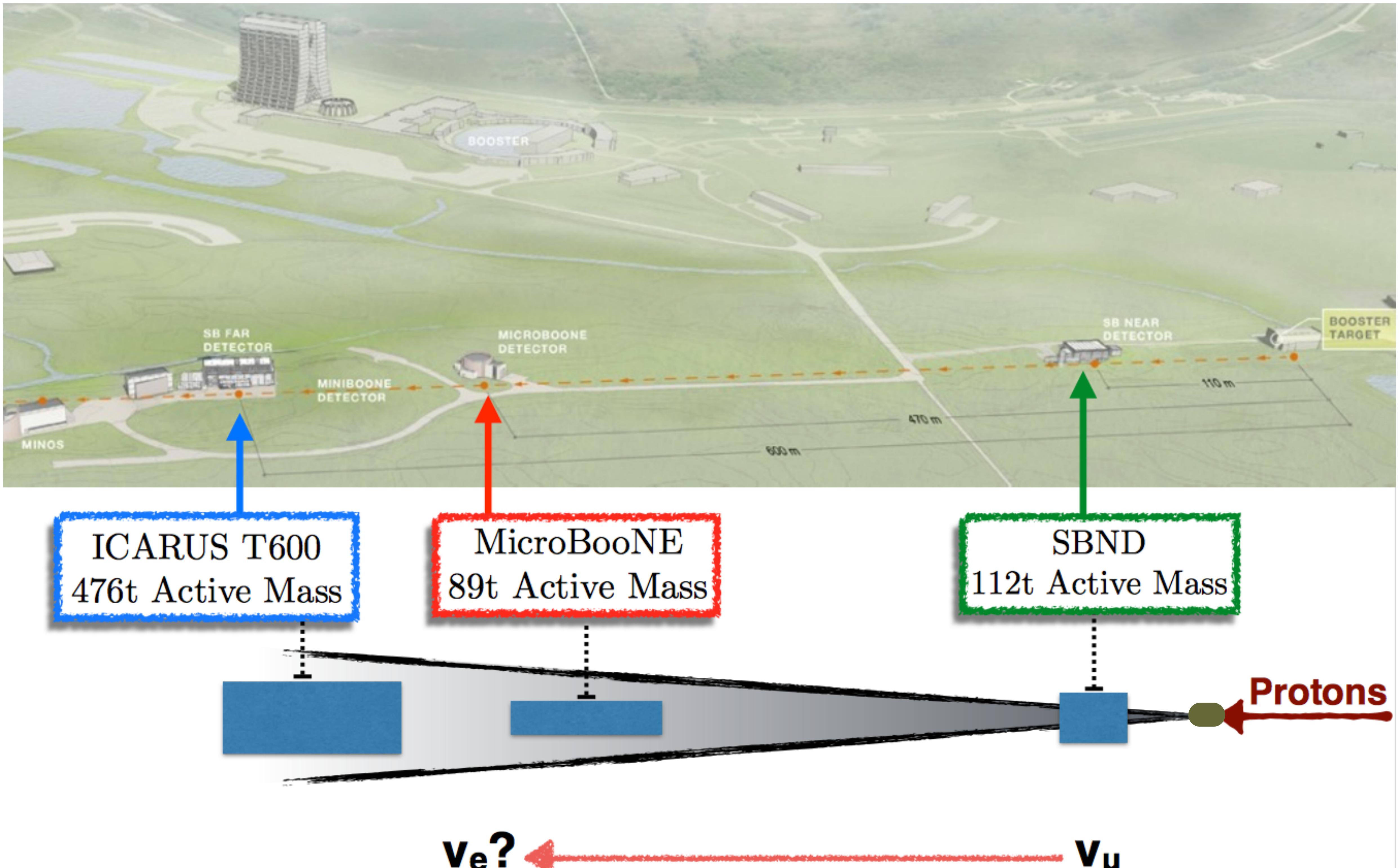


- Biggest Int… nal contribution
- Man… ship roles
- … cant impact on science
- Knowledge transfer for future LArTPCs

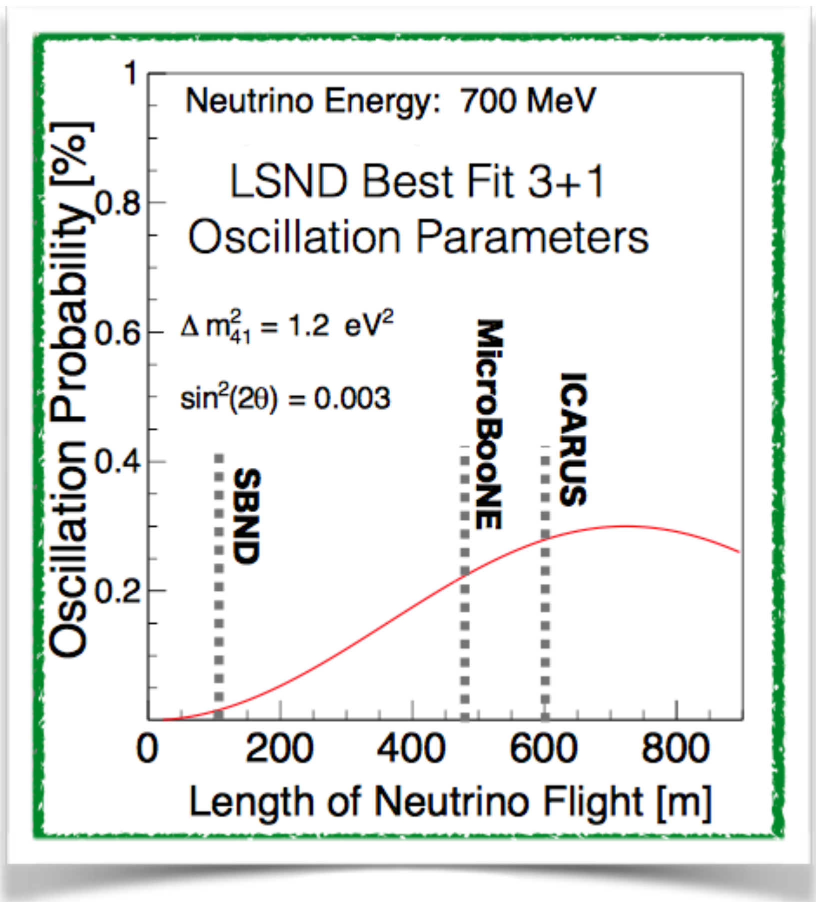
Very minimal funding support

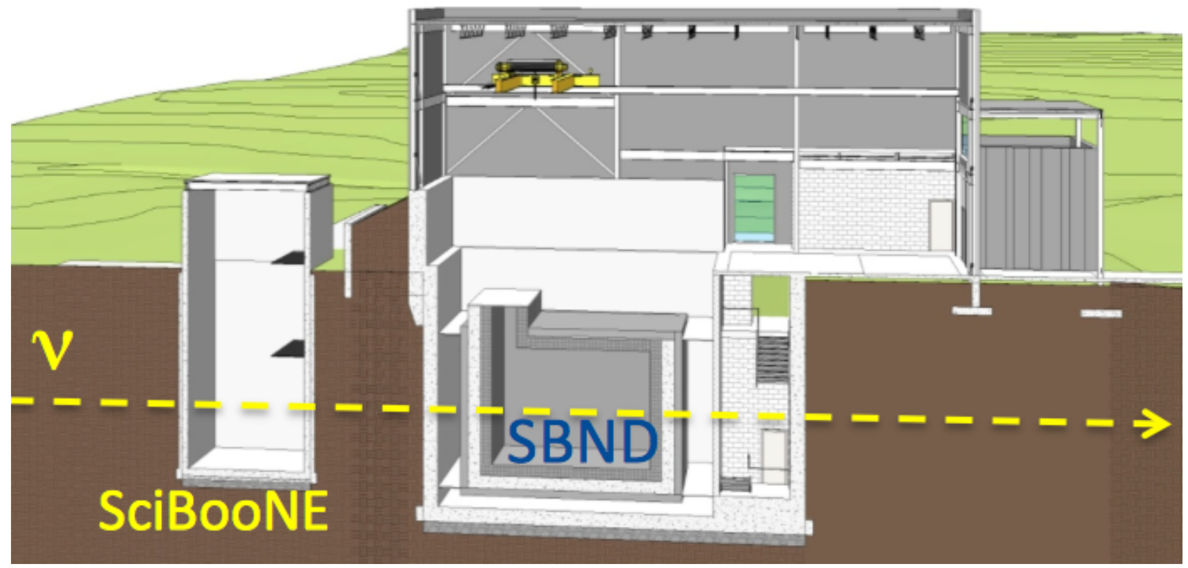


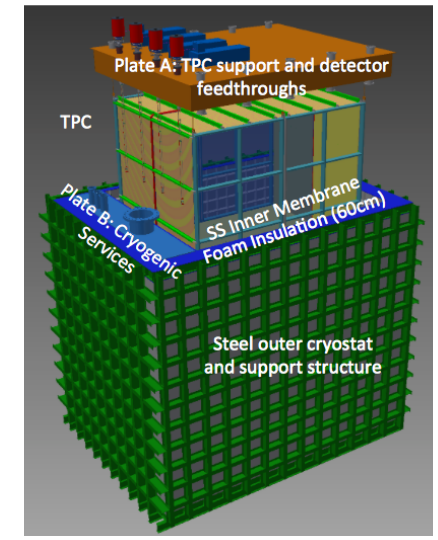
The SBN Programme

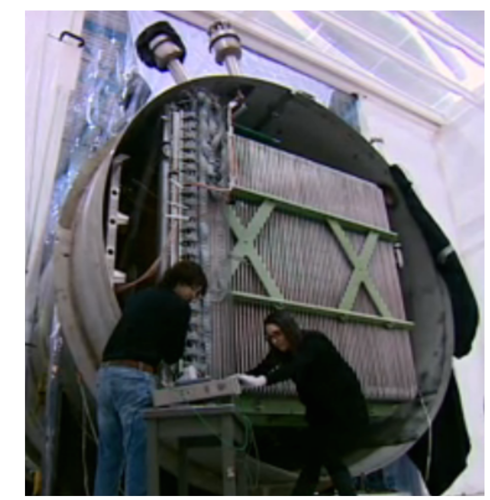


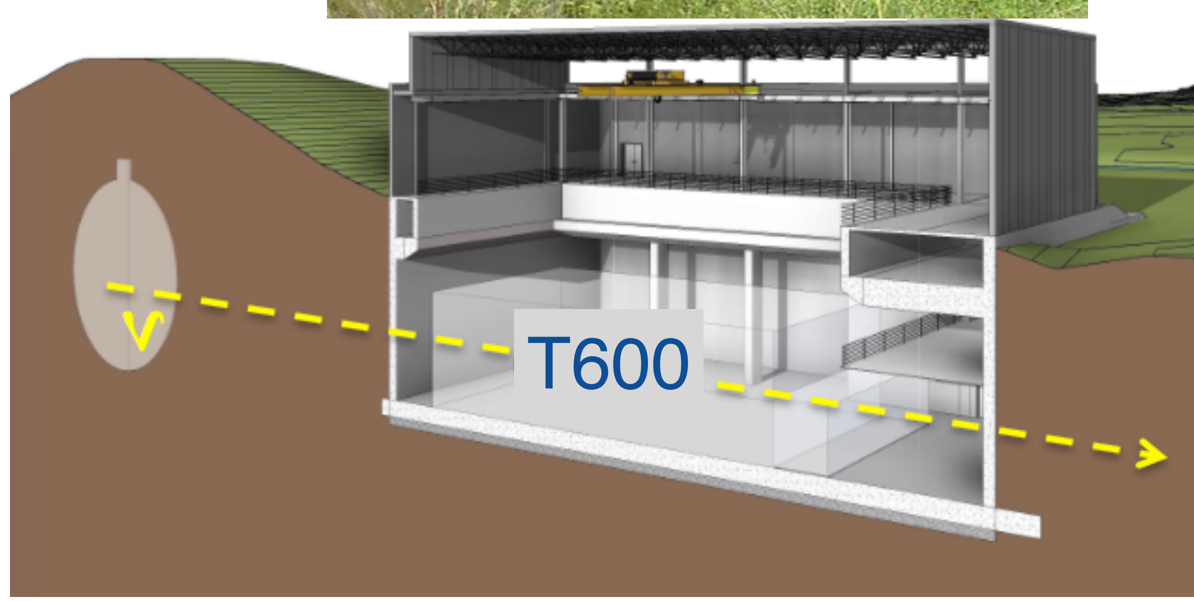
The SBN Programme



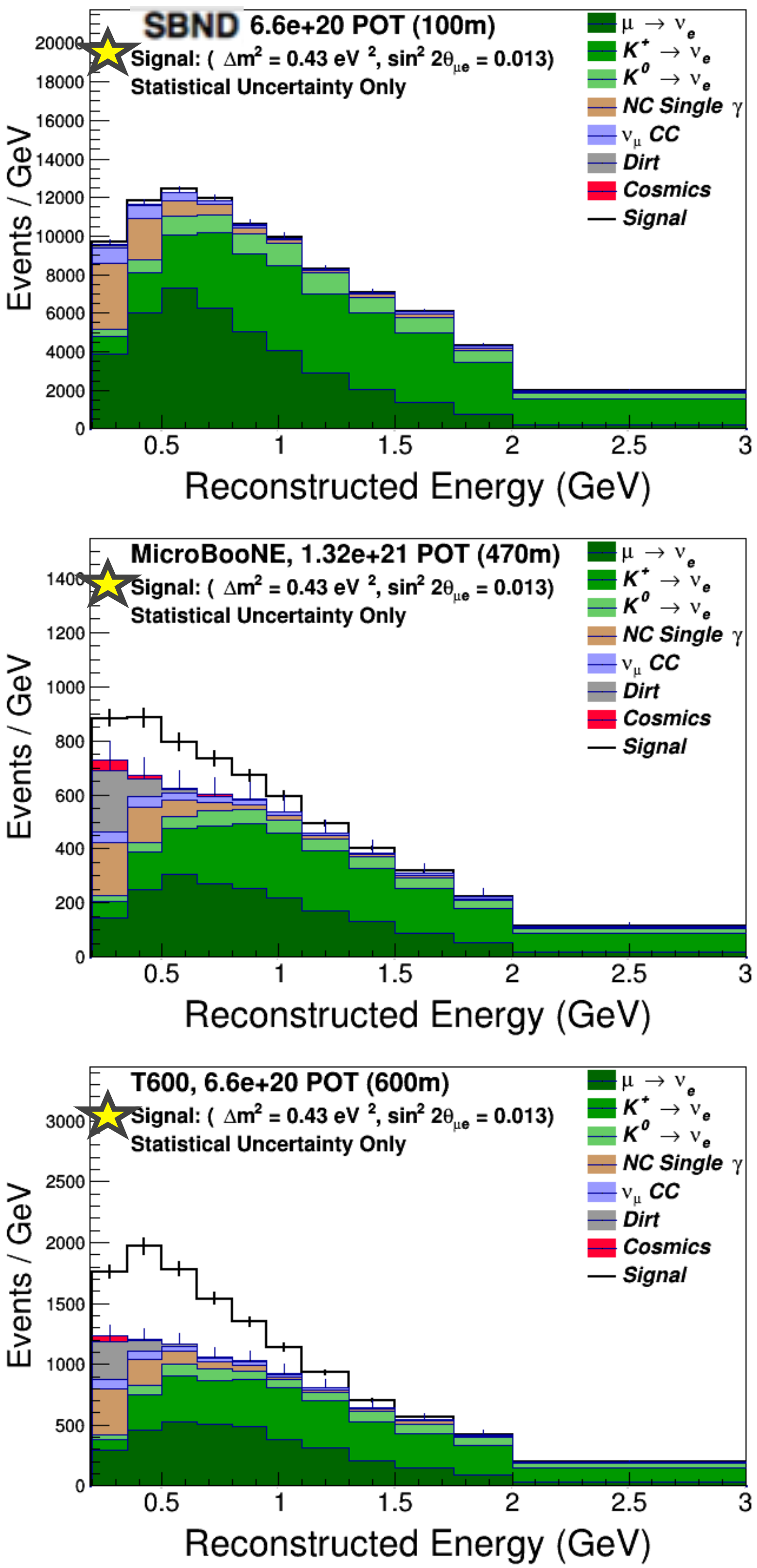


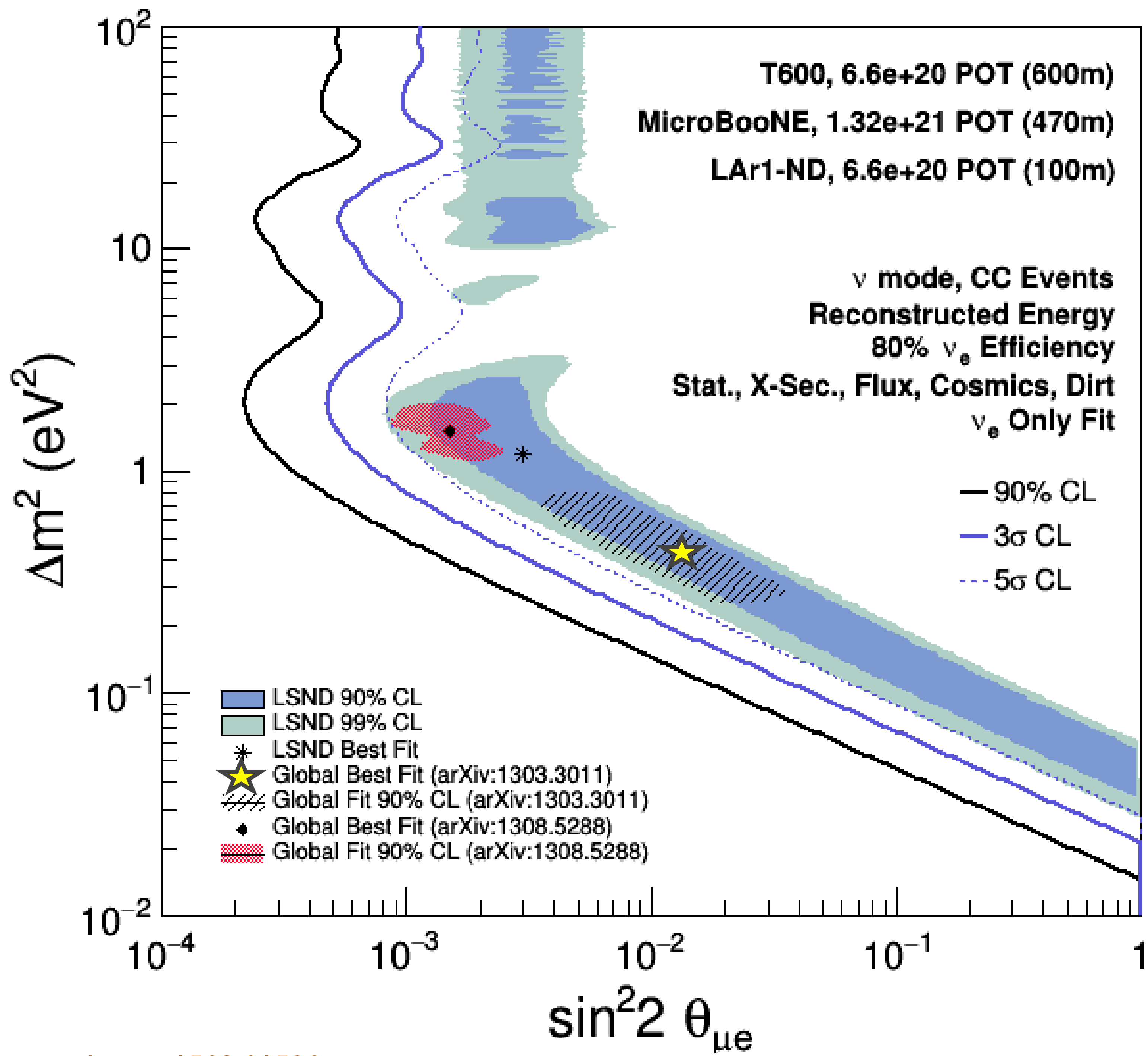






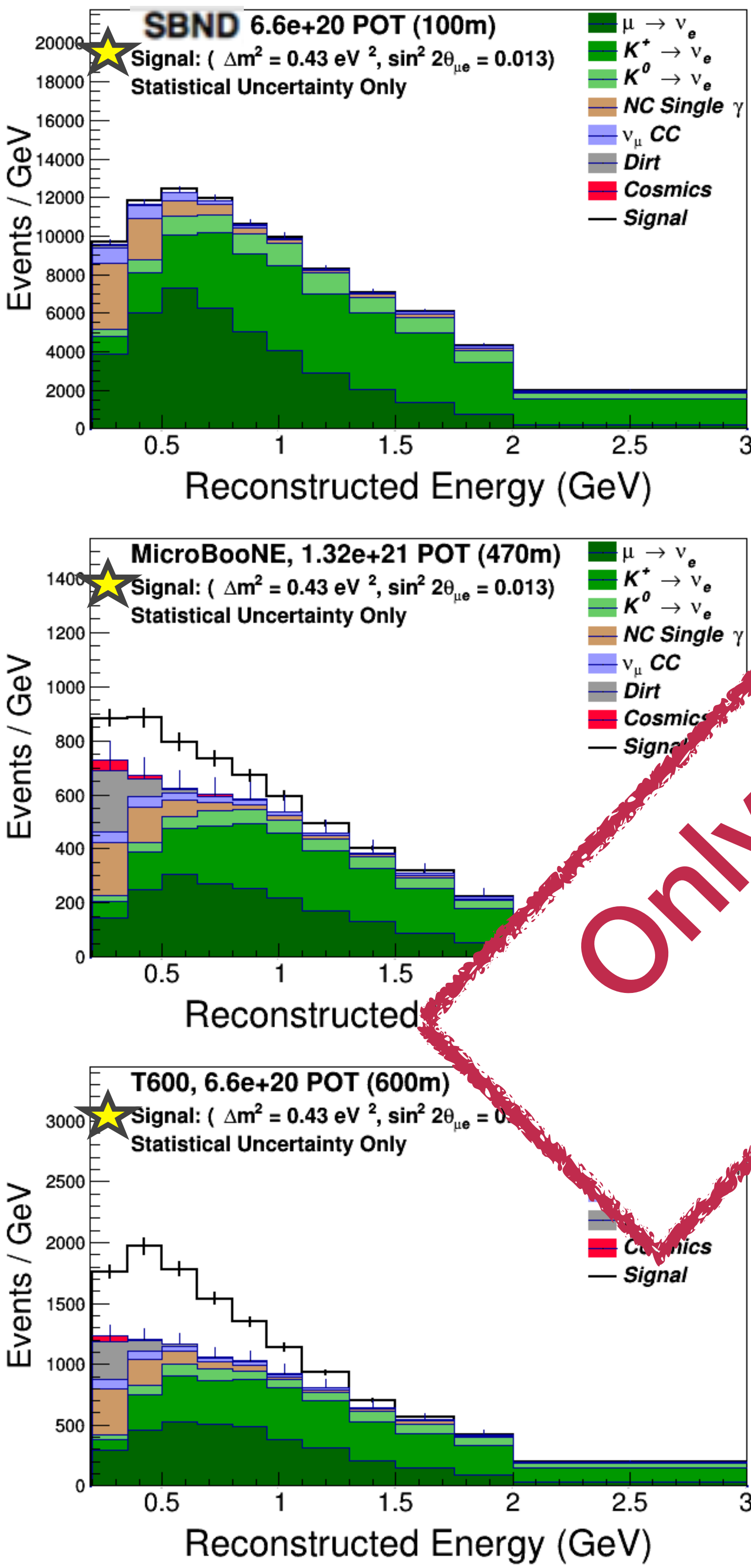
The SBN Programme



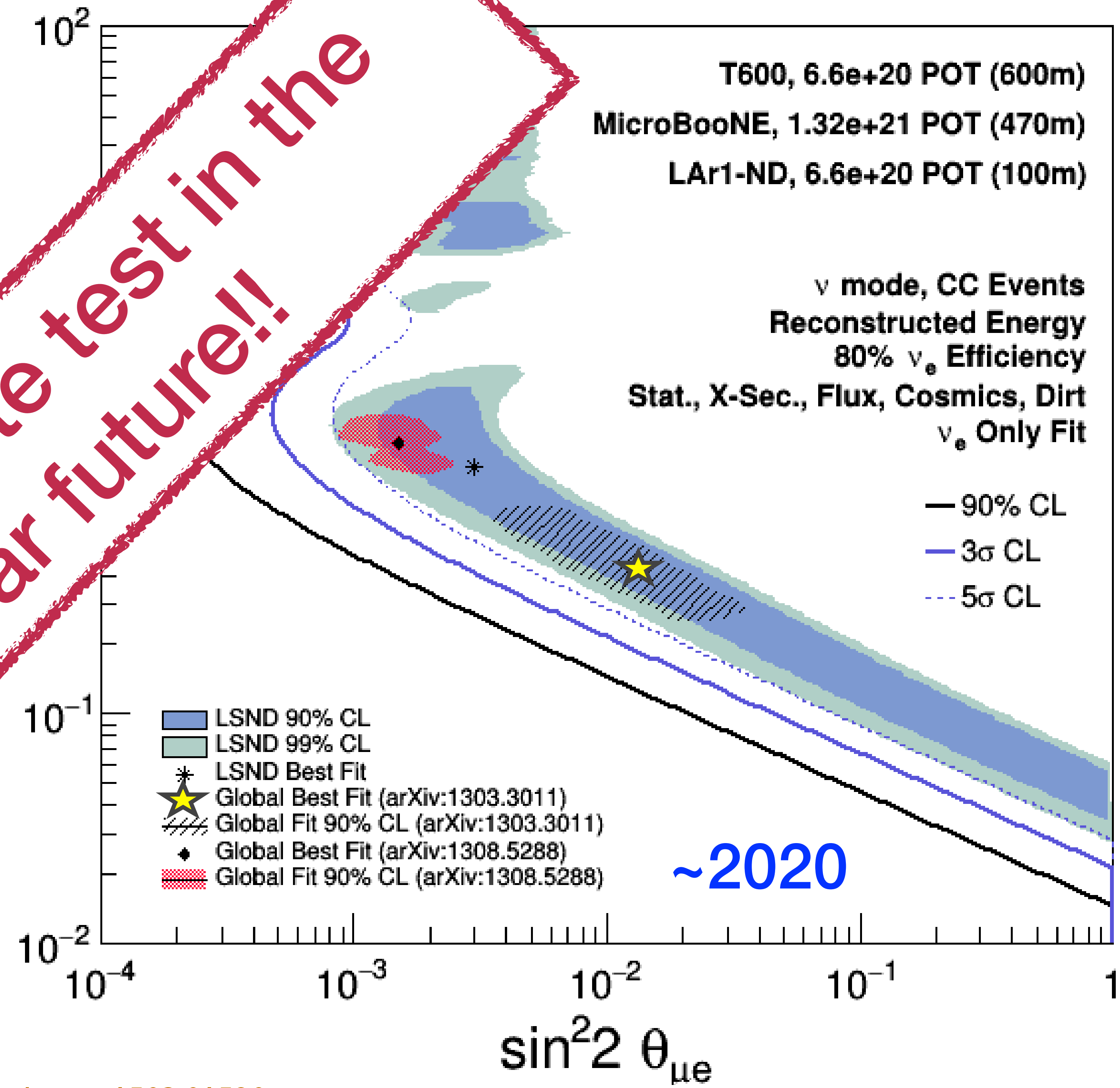


SBN proposal arxiv:1503.01520

The SBN Programme



Only definite test in the near future!!



SBN proposal arxiv:1503.01520

SBND

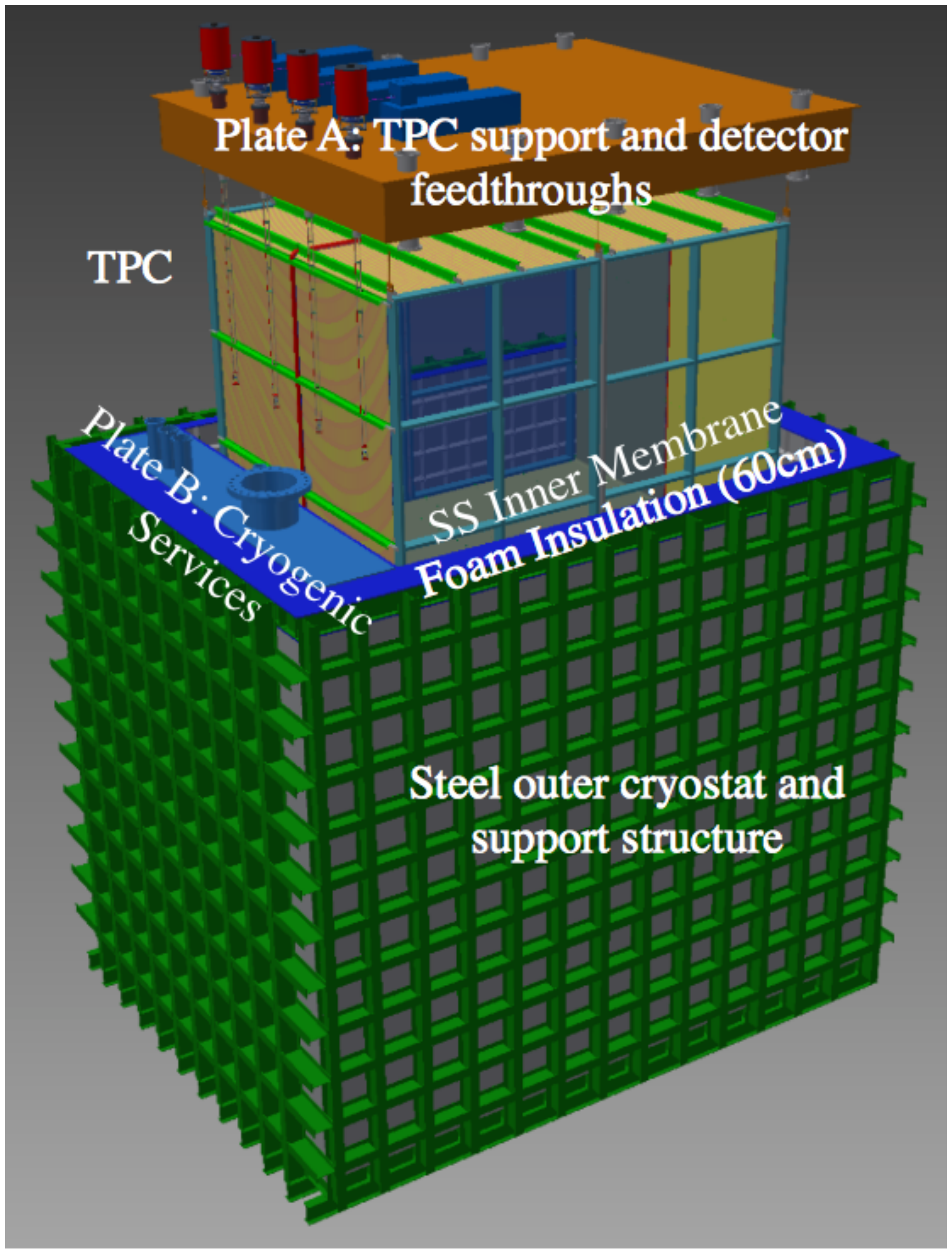
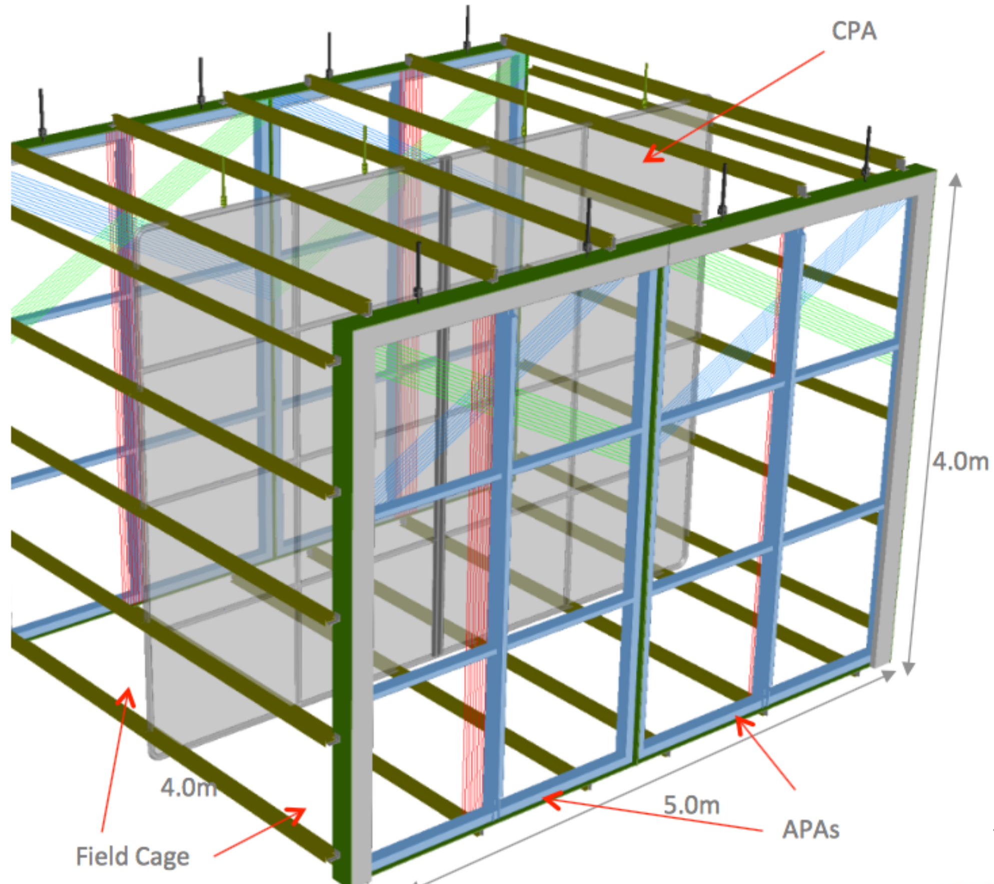
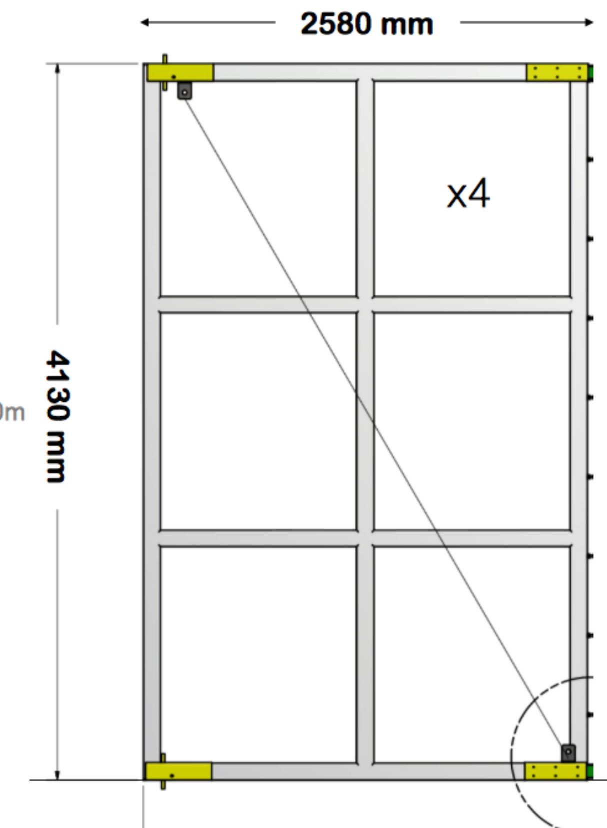
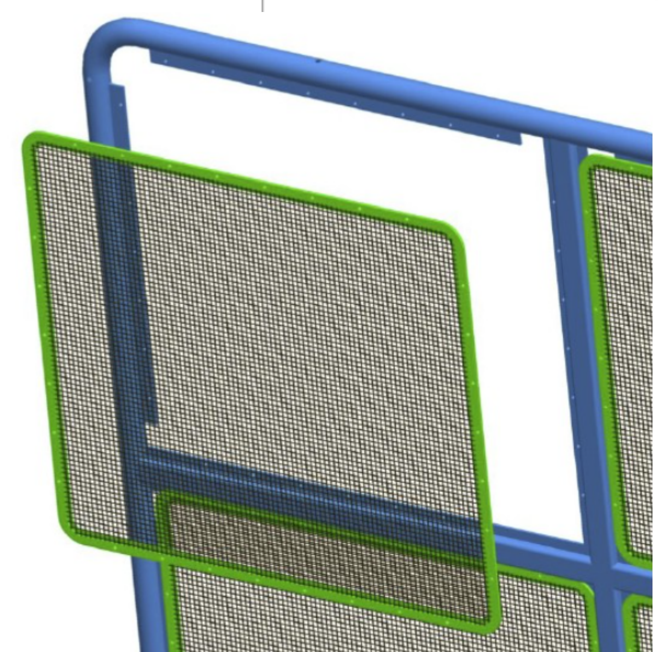


Plate A: TPC support and detector feedthroughs
TPC
Plate B: Cryogenic Services
SS Inner Membrane
Foam Insulation (60cm)
Steel outer cryostat and support structure

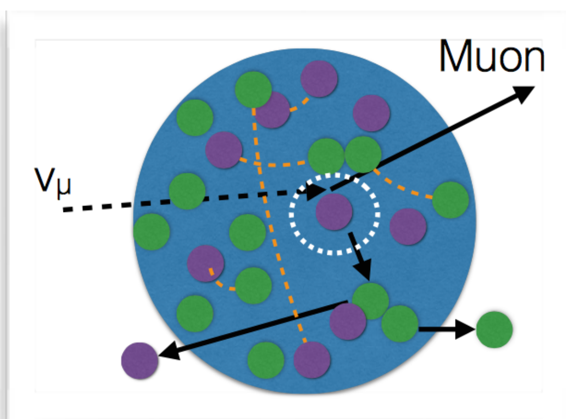

CPA
4.0m
4.0m
5.0m
Field Cage
APAs

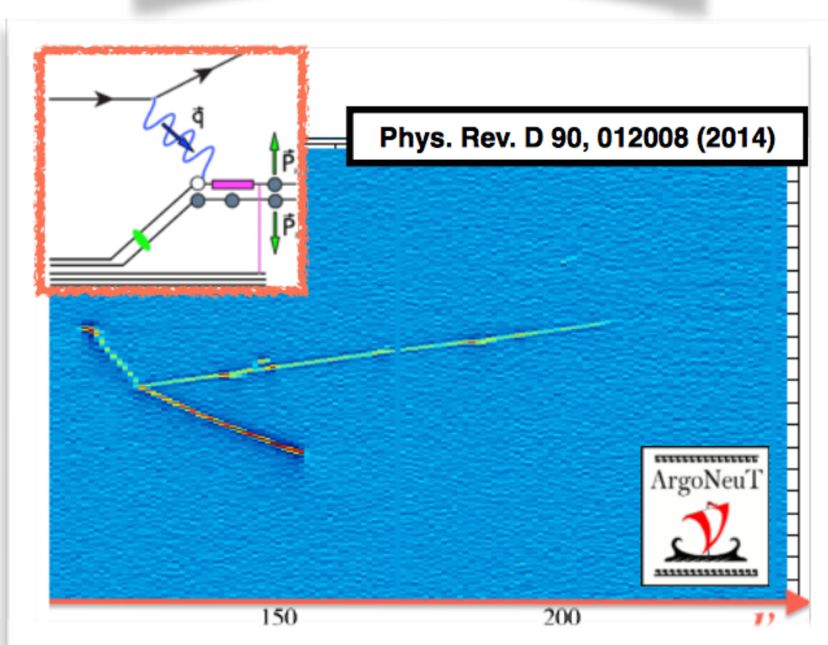

2580 mm
4130 mm
x4



SBND Physics

- Crucial to identify the source of potential excess in MicroBooNE
- Essential to understand beam contamination (ν_e, $\bar{\nu}_e$)
- Cross-sections measurements





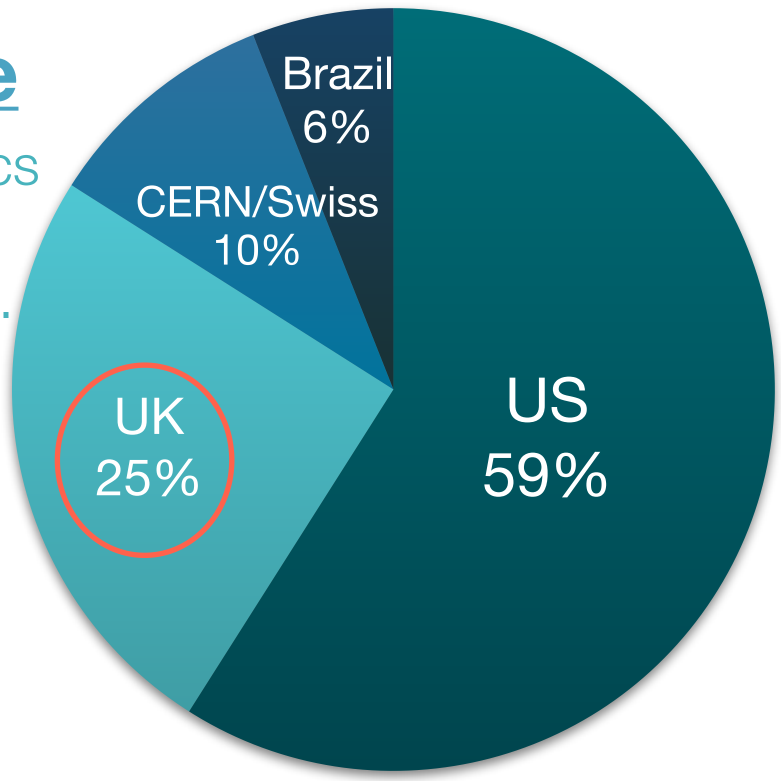
Process		No. Events	Events/ ton	Stat. Uncert.
	ν_μ *Events (By Final State Topology)*			
CC Inclusive		5,212,690	46,542	0.04%
CC 0 π	$\nu_\mu N \to \mu + Np$	3,551,830	31,713	0.05%
	· $\nu_\mu N \to \mu + 0p$	793,153	7,082	0.11%
	· $\nu_\mu N \to \mu + 1p$	2,027,830	18,106	0.07%
	· $\nu_\mu N \to \mu + 2p$	359,496	3,210	0.17%
	· $\nu_\mu N \to \mu + \geq 3p$	371,347	3,316	0.16%
CC 1 $\pi^\pm$	$\nu_\mu N \to \mu +$ nucleons $+ 1\pi^\pm$	1,161,610	10,372	0.09%
CC $\geq 2\pi^\pm$	$\nu_\mu N \to \mu +$ nucleons $+ \geq 2\pi^\pm$	97,929	874	0.32%
CC $\geq 1\pi^0$	$\nu_\mu N \to \mu +$ nucleons $+ \geq 1\pi^0$	497,963	4,446	0.14%
NC Inclusive		1,988,110	17,751	0.07%
NC 0 π	$\nu_\mu N \to$ nucleons	1,371,070	12,242	0.09%
NC 1 $\pi^\pm$	$\nu_\mu N \to$ nucleons $+ 1\pi^\pm$	260,924	2,330	0.20%
NC $\geq 2\pi^\pm$	$\nu_\mu N \to$ nucleons $+ \geq 2\pi^\pm$	31,940	285	0.56%
NC $\geq 1\pi^0$	$\nu_\mu N \to$ nucleons $+ \geq 1\pi^0$	358,443	3,200	0.17%
	ν_e *Events*			
CC Inclusive		36798	329	0.52%
NC Inclusive		14351	128	0.83%
Total ν_μ and ν_e Events		7,251,948	64,750	
	ν_μ *Events (By Physical Process)*			
CC QE	$\nu_\mu n \to \mu^- p$	3,122,600	27,880	
CC RES	$\nu_\mu N \to \mu^- \pi N$	1,450,410	12,950	
CC DIS	$\nu_\mu N \to \mu^- X$	542,516	4,844	
CC Coherent	$\nu_\mu Ar \to \mu Ar + \pi$	18,881	169	

Millions of events!

SBND in the UK

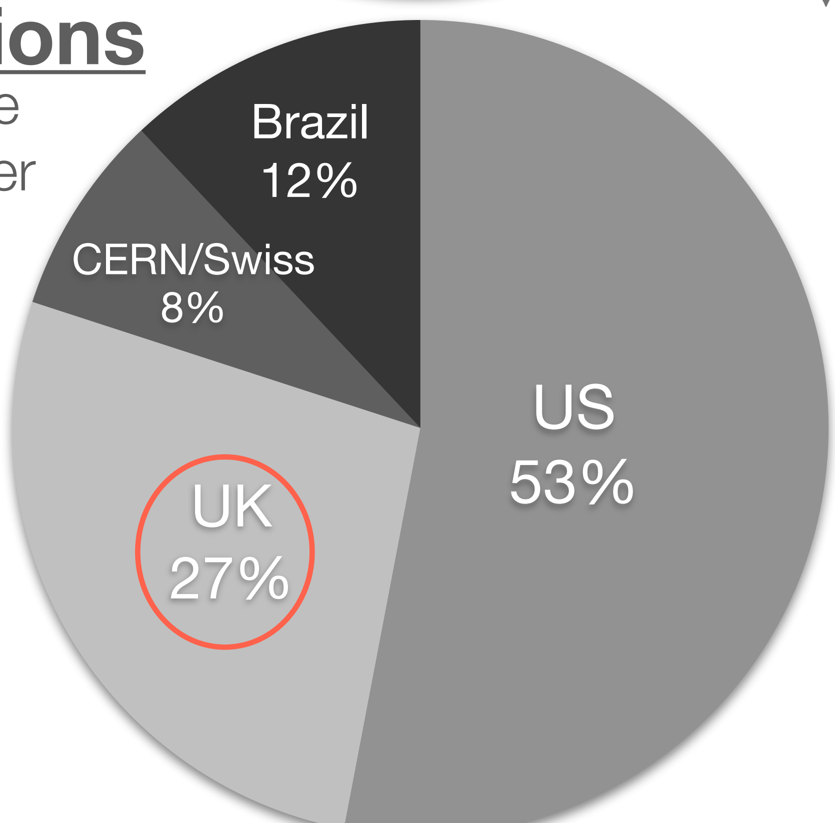
People

13 Academics
5 PDRAs
6 Eng./Tech.
6 PhDs



Institutions

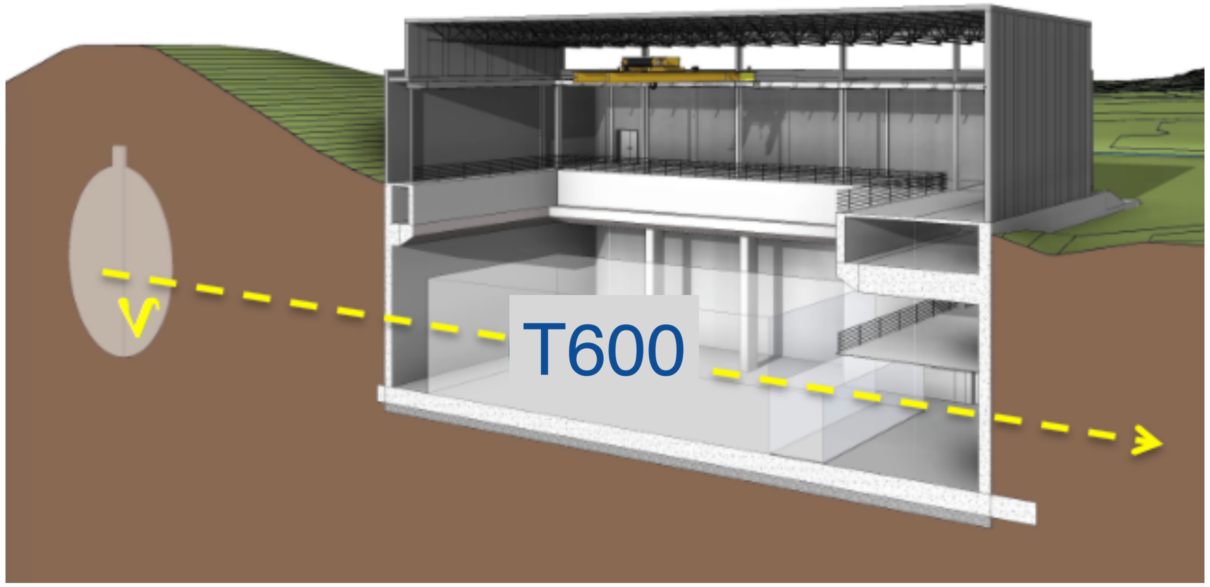
Cambridge
Manchester
Lancaster
Liverpool
Oxford
Sheffield
UCL



- Biggest International contribution
- Many leadership roles (L2-manager for TPC, Conveners of Simulation & Software Group, Speaker Committee Leader)
- Significant impact on science and DUNE roadmap
- Knowledge transfer for DUNE:
    - APA construction
    - APA wire winding
    - HV feedthrough
    - light collection systems
    - installation and integration of TPC
    - Event Reconstruction Software

ICARUS

- Refurbishment of T600
- Building construction
- First T300 module ready end 2015
- Second T300 module ready end of 2016
- Italy + Poland + Russia + US Institutions

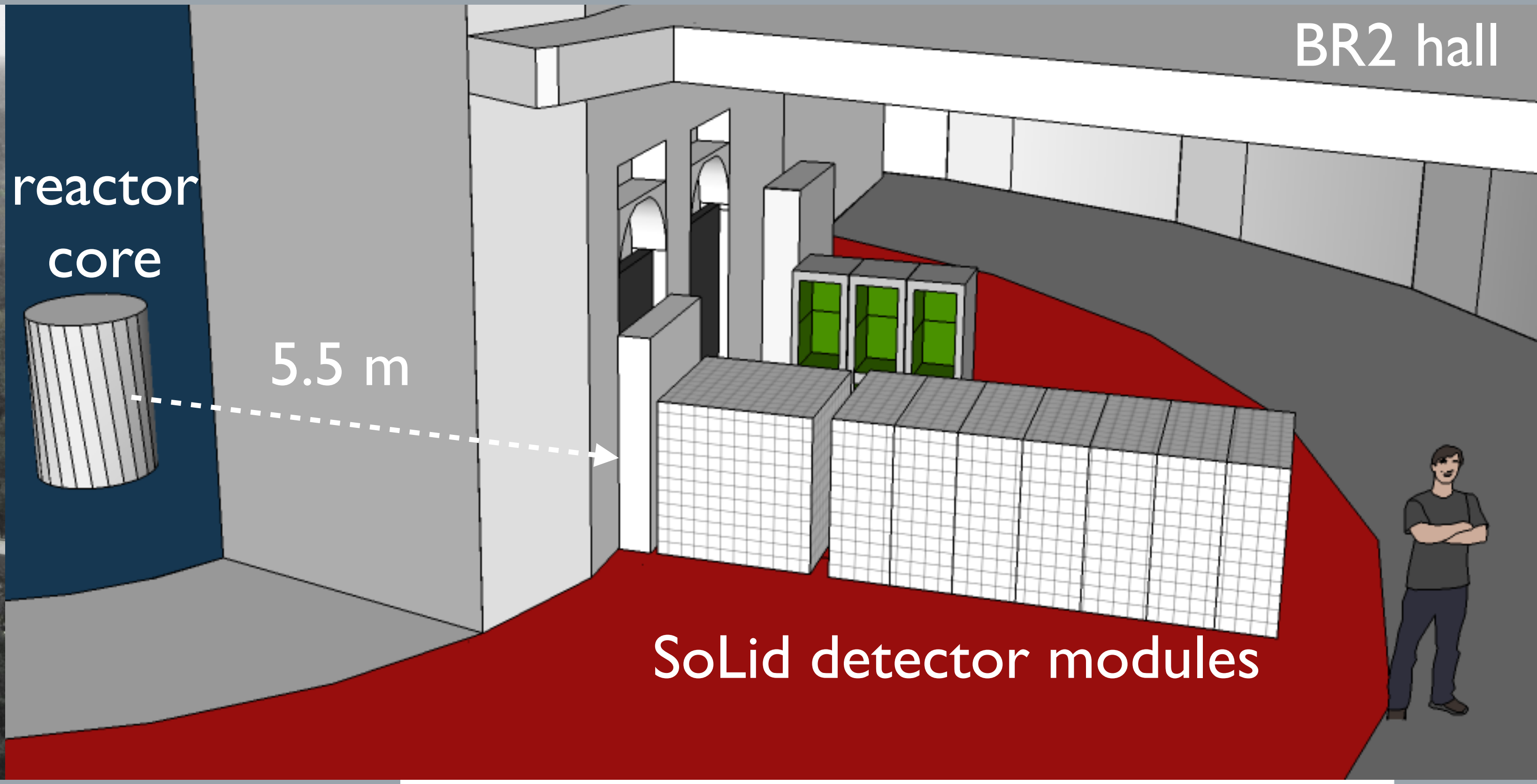


Conclusions on SBN

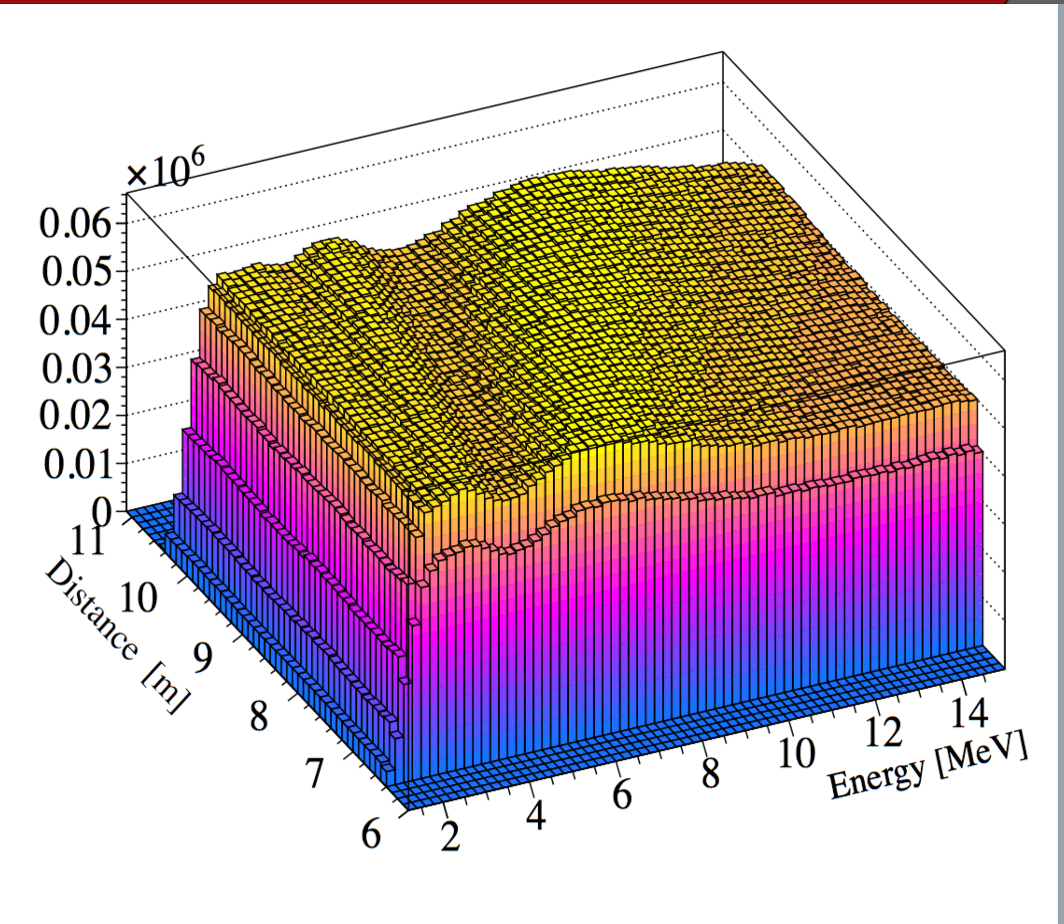
- MicroBooNE is turning on (beam neutrino data in less than 2 weeks!)
  → ONLY RUNNING LArTPC in the next years
- MicroBooNE will answer the MiniBooNE low-energy excess
- SBND will address the source of a MicroBooNE excess (if any)
- SBN will give a definitive answer to LSND/MiniBooNE anomaly
- Sterile neutrino question is critical for DUNE (perfect timescale)
- Cross-section measurements in MicroBooNE and SBND will have a great impact
- UK is driving many parts of the SBN Programme
- SBN programme is the only way to participate in LAr experiments before DUNE

The SoLid experiment

personal communication. By courtesy of SCK•CEN

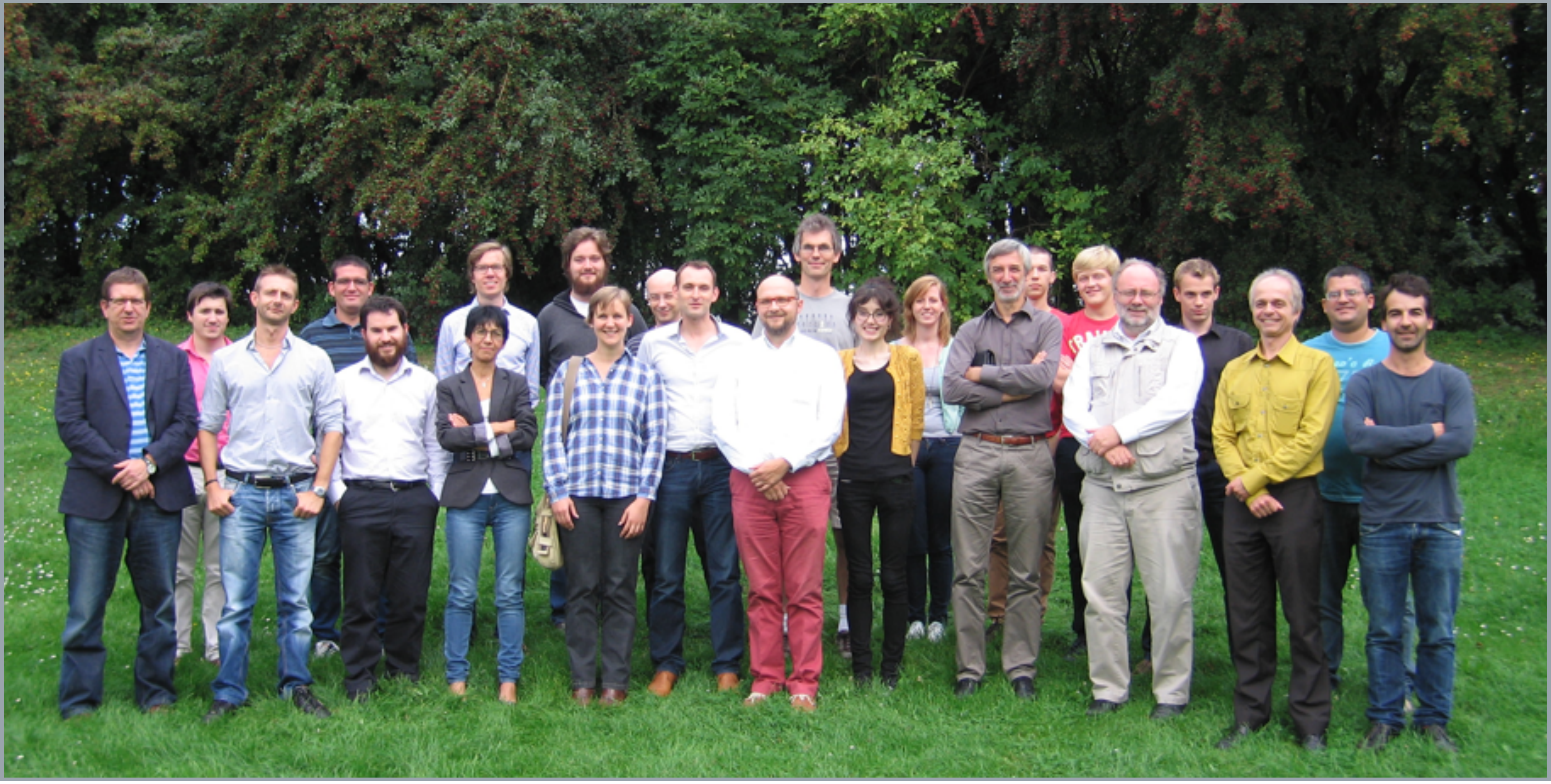


- BR2 reactor at SCK•CEN, Mol, Belgium
  - High Power BR2 research reactor with low background
  - 2. Composite scintillator detector technology



SoLi∂ collaboration

- 4 countries, 10 institutes, ~ 50 people



SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Universiteit Antwerpen

Vrije Universiteit Brussel

UNIVERSITEIT GENT

LAL LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

lpc caen

Subatech

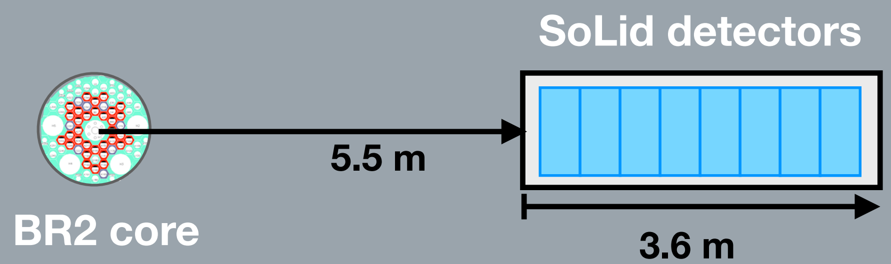
UNIVERSITY OF OXFORD

University of BRISTOL

VirginiaTech Invent the Future

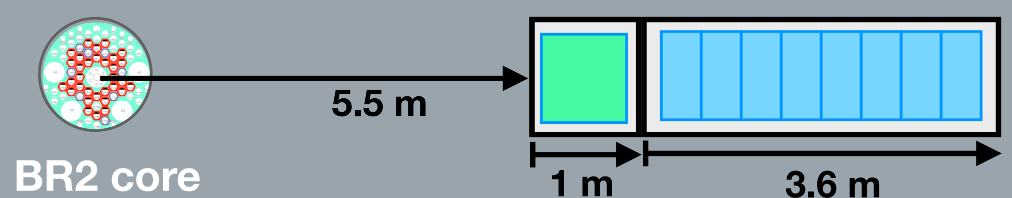
Sensitivity to 3+1 neutrinos

Phase I



8x MARS modules
PVT cubes + WLS fibres
2 tonnes fiducial

Phase II



CHANDLER HiRes module
WLS PVT cubes + PMTs
1 tonne fiducial