IOP Institute of Physics
International Workshop on Next Generation Nucleon Decay and Neutrino Detectors (NNN17)
26–28 October 2017, University of Warwick, UK

WARWICK

Summary of parallel 1

Detectors

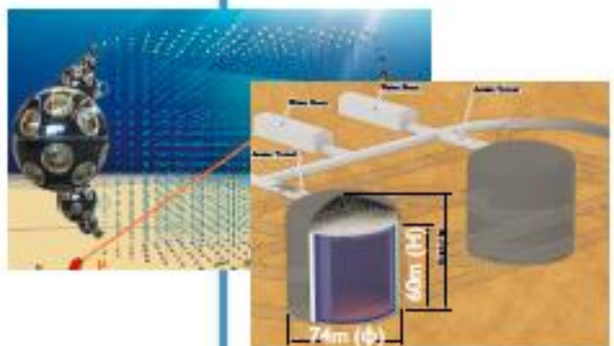
Yury Kudenko (INR, RU)
<u>Zhimin Wang (IHEP, CN)</u>
Jennifer L Raaf (FNAL, US)

NNN17, Warwick, October 28, 2017

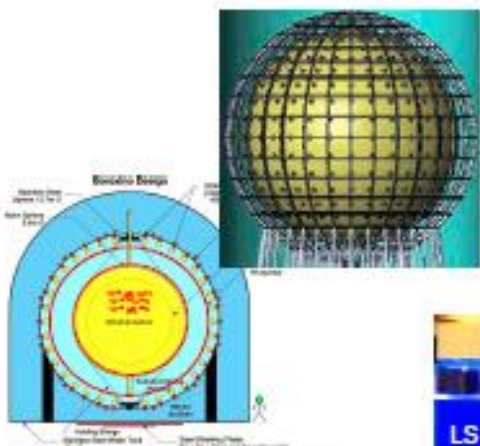
S. Moriyama
ICRR, University of Tokyo
2016/11/5
NNN16 @Beijing

Detector Target

Size/maturity



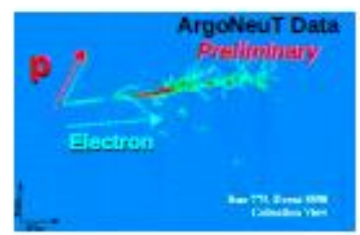
H_2O

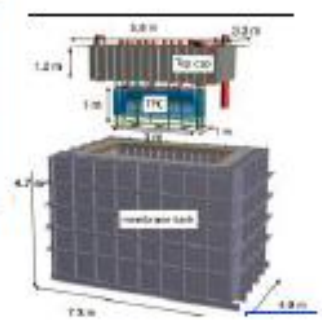


H_2O+LS

LS

LAr



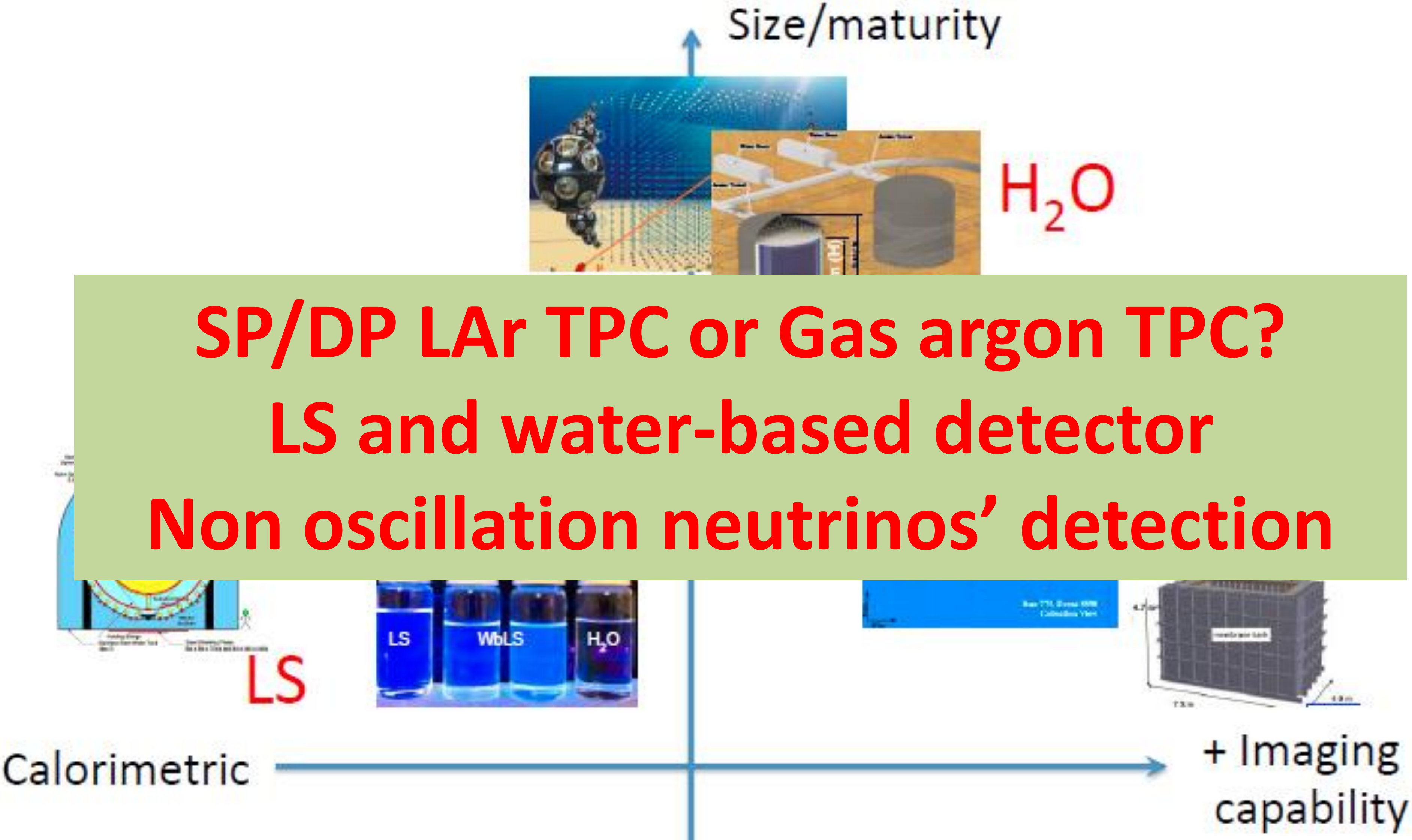


Calorimetric

+ Imaging capability

Detector Target

S. Moriyama
ICRR, University of Tokyo
2016/11/5
NNN16 @Beijing



SP/DP LAr TPC or Gas argon TPC?

LS and water-based detector

Non oscillation neutrinos' detection

Talk list

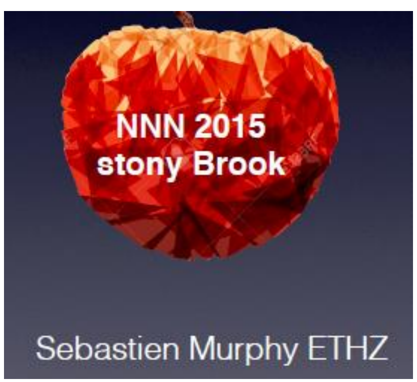
- 10 talks in ~240 minutes
- Apologize if the summary not highlight all your points.
- For more technical details, please refer to the parallel talks

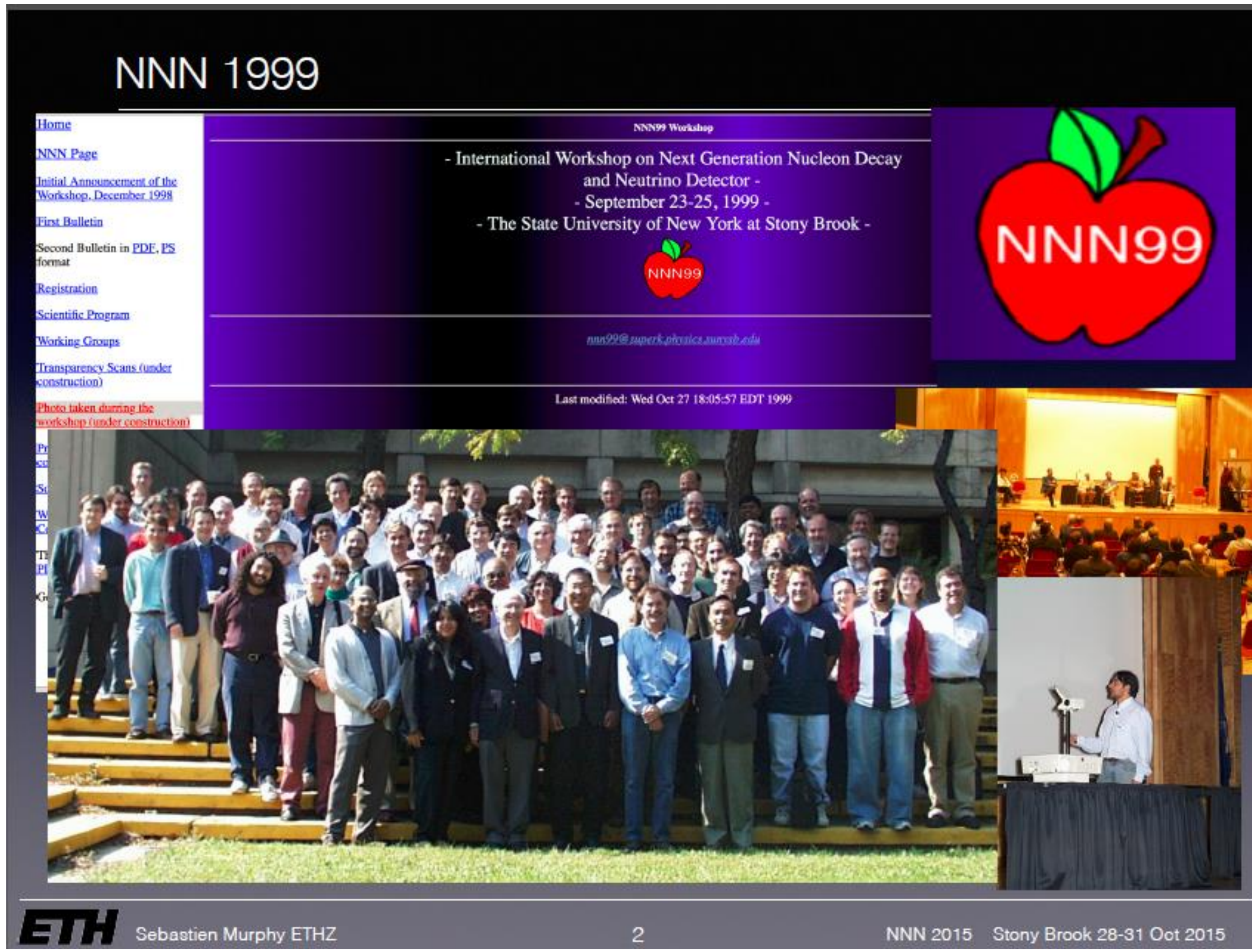
Thanks all the speakers and attendance of the detector session

14:00	**JUNO: Recent Progress in Detector R&D**	*Zhonghua Qin*	*Lecture Theatre, Scarman House*	14:00 - 14:21
	R&D for short baseline detectors (SBND) at FNAL	*Joleen Pater*		
	Status of the DUNE near detectors	*Jonathan Asaadi*	*Lecture Theatre, Scarman House*	14:42 - 15:03
15:00	**Status of Single Phase and Dual Phase DUNE protodectors at CERN**	*Laura Molina Bueno*		
	High Pressure TPC	*Morgan Wascko*	*Lecture Theatre, Scarman House*	15:24 - 15:45
	Tea/Coffee Break		*Other Institutes*	15:45 - 16:15
16:00	**Upgrade of the T2K near detector ND280**	*Benjamin Quilain*		
	Gd loaded SuperK: status and plan	*Yasuhiro Nakajima*	*Lecture Theatre, Scarman House*	16:36 - 16:57
17:00	**In search of sterile neutrinos: Status of the SoLid experiment**	*Simon Vercaemer*		
	The Ptolemy experiment: Towards cosmic neutrino background detection	*Alfredo Cocco*		
	Status of CONNIE	*Ben Kilminster*	*Lecture Theatre, Scarman House*	17:39 - 18:00

Argon-based detectors

- LAr TPC
  - Single phase
  - Dual phase
  - Which selected?
- High pressure Gas (Ar) TPC
- Other 3D sensitive technologies

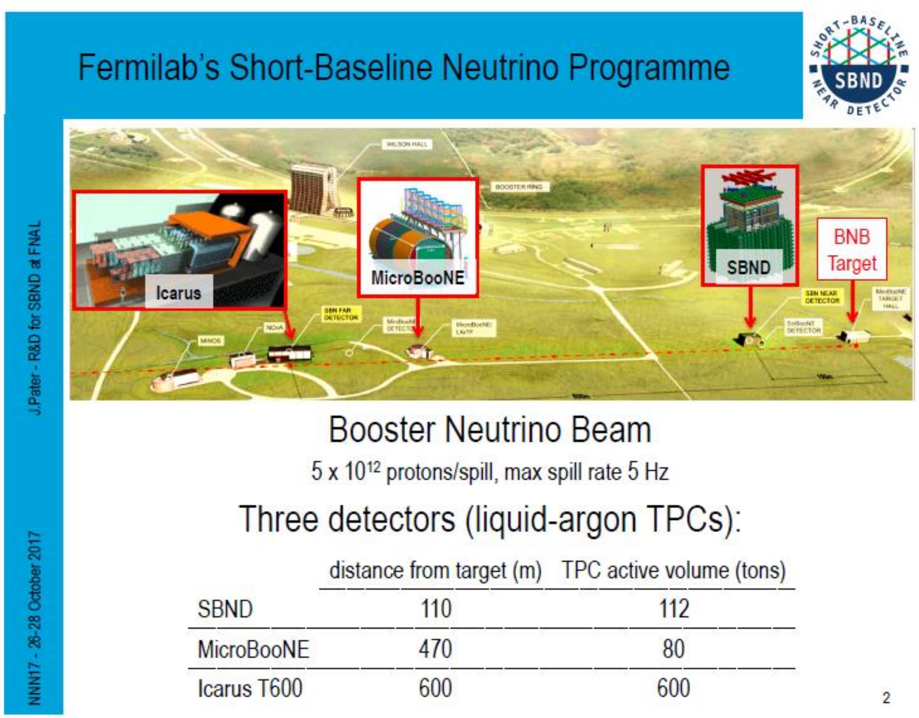


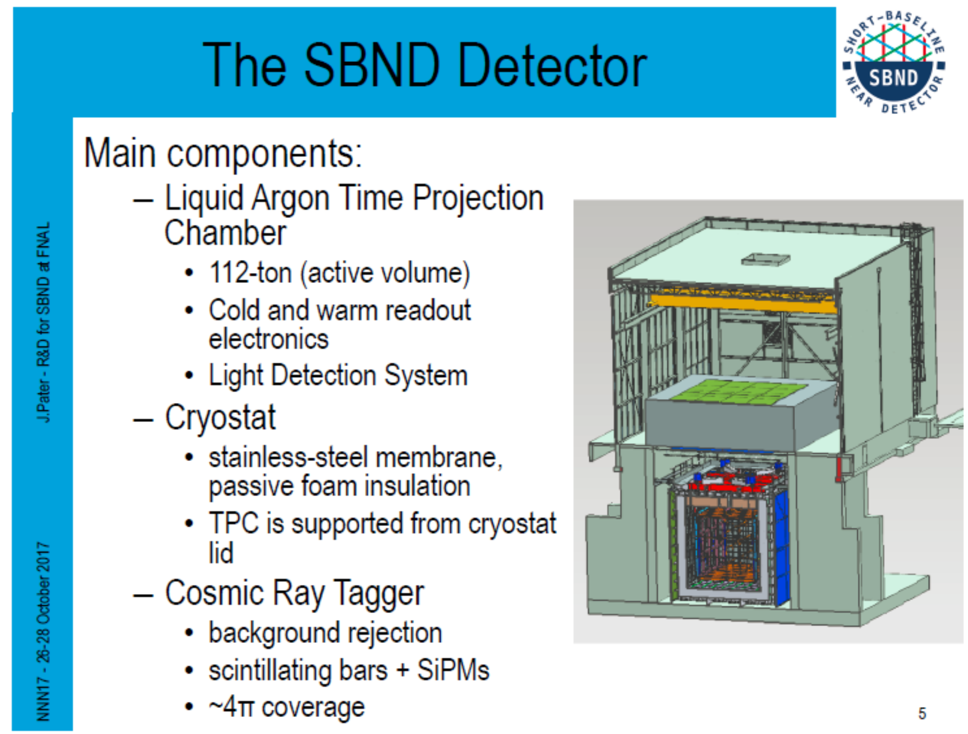


R&D for the Short-Baseline Near Detector (SBND) at FNAL

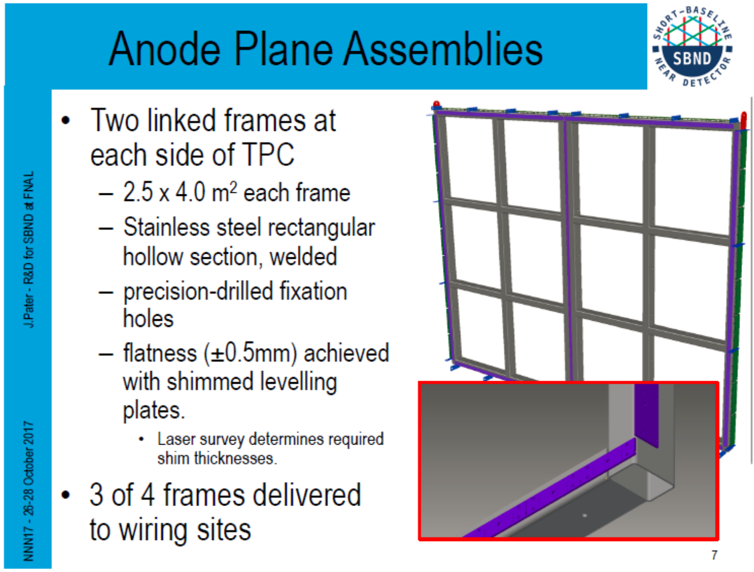
Jo Pater
The University of Manchester (UK)

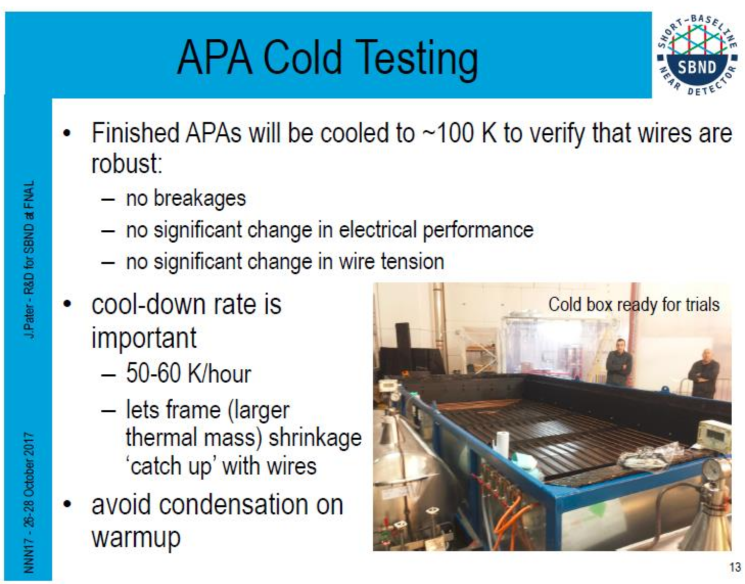
- SBND: Fermilab, baseline 110 m, target 112 ton
  - LAr TPC
  - With cosmic Ray tagger





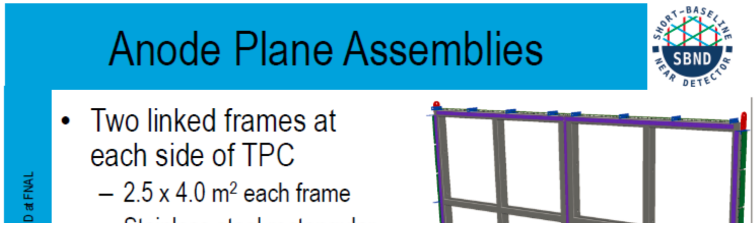
Assembly and testing





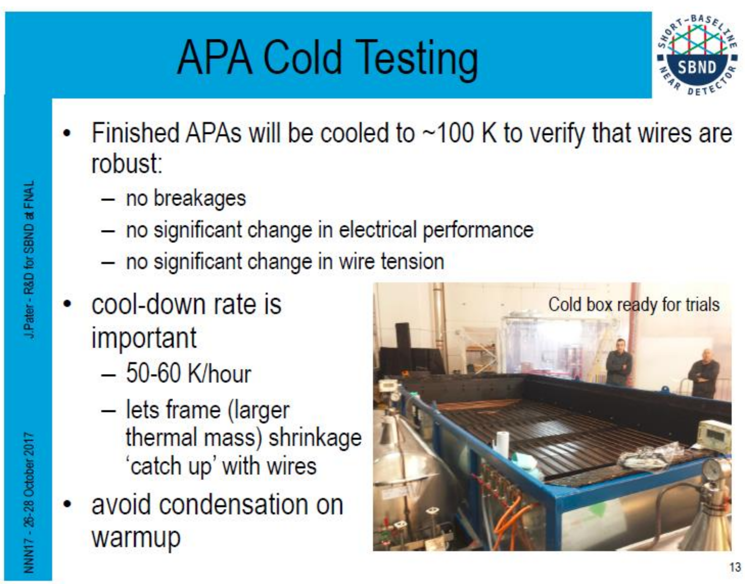
- APA wiring Techniques
- Cold testing
  - ~100 K
  - Rate 50~60 K/hour
  - Preparing for cold test early October 2017
- Cathode plane
  - ~100 kV
  - Construction nearing completion
- Light detection system
  - Scintillation light with WLS
  - Other possibilities in R&D phase
- Readout electronics
- Synergies SBND-DUNE

Assembly and testing



- APA wiring Techniques
  - Semi-automatic wiring
- Cold testing

On schedule for installation in 2018, commissioning in 2019



  - ~100 kV
  - Construction nearing completion
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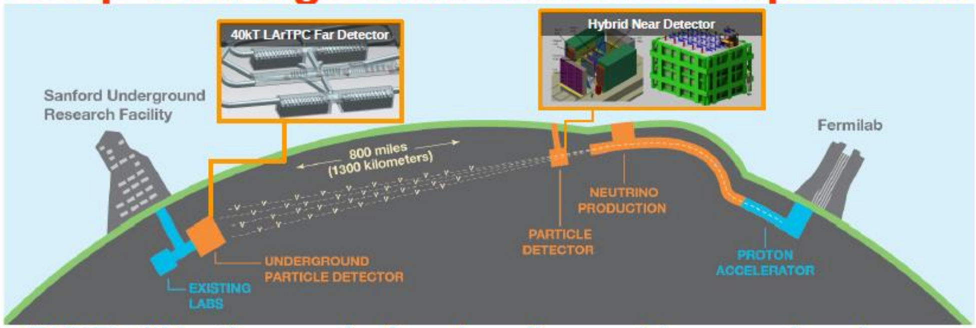
- Readout electronics
- Synergies SBND-DUNE

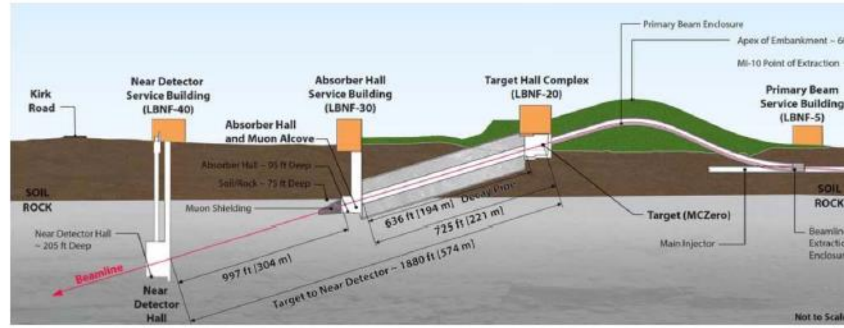
Jonathan Asaadi

University of Texas Arlington

Deep Underground Neutrino Experiment



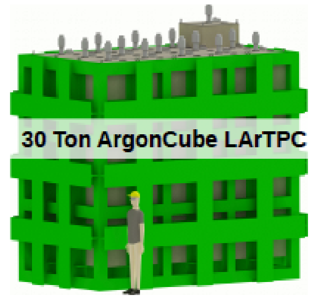
DUNE Near Detector

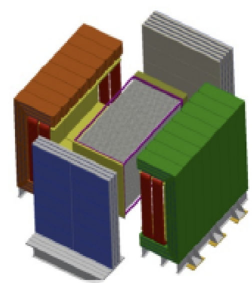


- Highly capable neutrino near detector
  - High statistics neutrino cross-section measurements and capability to fully characterize the spectrum and flavor composition of the beam
- Near detector hall will be located on Fermilab site ~200 ft underground (1880 ft baseline)

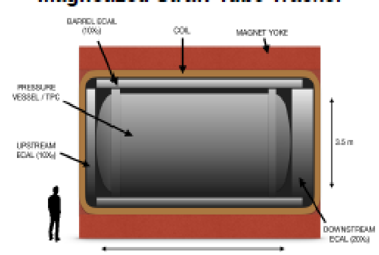
Detector technologies

- **Liquid Argon TPC**
  - Modular liquid argon design (ArgonCube) to provide identical near/far target
  - Short drifts and pixel readout to deal with high occupancy environment
- **Straw Tube Tracker**
  - NOMAD-inspired type fine grain tracker
  - Magnetized detector for sign discrimination
- **High Pressure Gas Argon TPC**
  - High pressure TPC keeps neutrino yield high while providing excellent 3d vertex information
  - Argon nuclear target allows for straightforward near/far extrapolation
- **Other technologies**
  - Scintillating Plastic Tracker
  - "DUNE-PRISM"



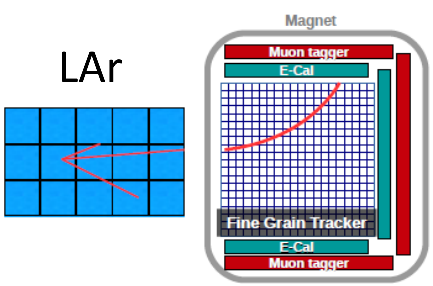


Magnetized Straw Tube Tracker



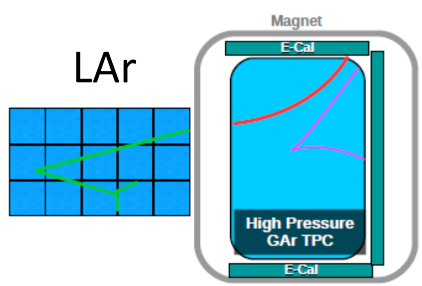
- Hybrid approach: combine a non-magnetized liquid argon detector along with a fine grain tracker to maximize the physics potential of the near detector
  - LAr TPC detector provides the same nuclear target as the far detector
  - Fine Grain Tracker (FGT) will be capable of measuring neutrino interactions within its own volume (lower thresholds and high resolution)

LAr



FGT

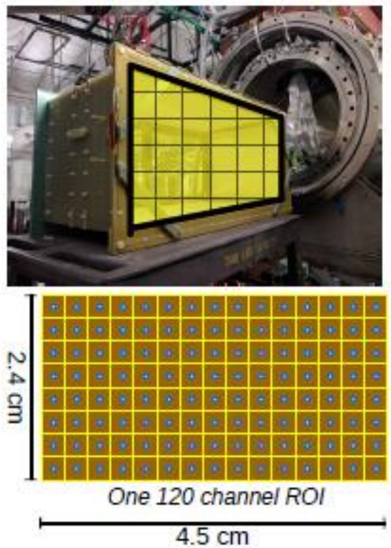
LAr



HP GAr TPC

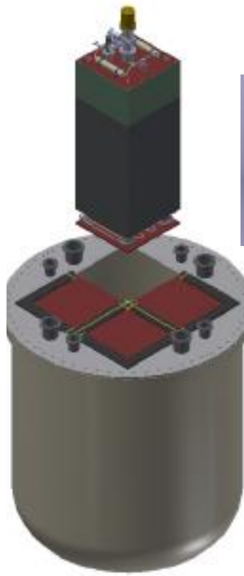
R&D

Taking data Nov-Dec 2017



Highly-multiplexed Pixel LArTPC in a Testbeam
(28,800 pixels readout with 480 channels)

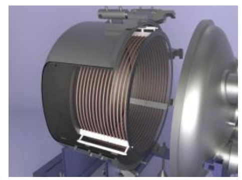
ArgonCube



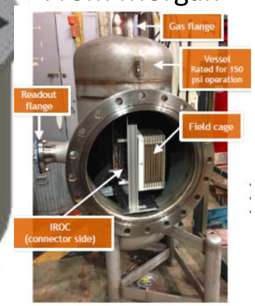
2 x 2 demonstrator module

HP Gas TPC

UK efforts



From Morgan



US efforts

- Pixel LAr TPC R&D
  - to demonstrate viability for use in DUNE ND
- ArgonCube 2x2 demonstrator
  - to test functional modularity
- PixLAr test beam run
  - to test readout in high rate environment
- High Pressure Gaseous Argon R&D for possible use in long-baseline near detectors
  - UK efforts: 1m^3 HPTPC
  - US efforts: Operate ALICE readout chambers at high pressure
- Straw Tube Tracker
  - under consideration as part of the DUNE near detector complex.
- Other Technologies

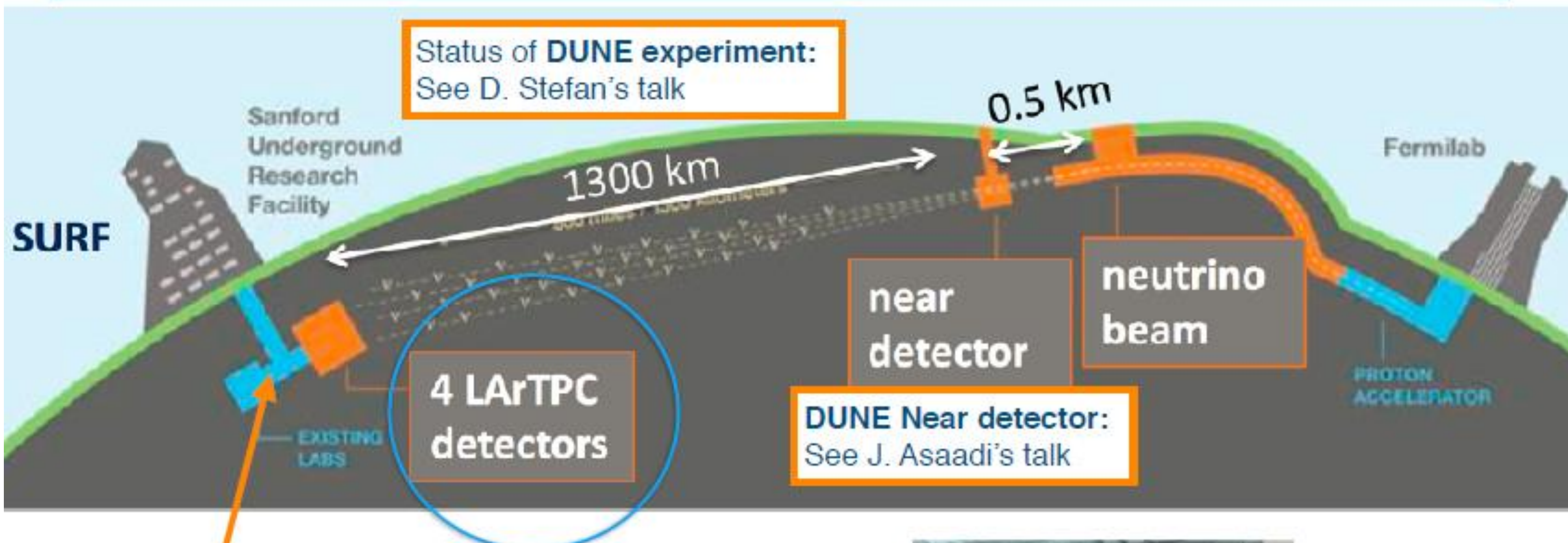
- **Timeline**
  - Upcoming DUNE near detector workshop where lots of discussion and planning will take place
  - Working for a CDR in 2019
  - TDR to be in place by 2020 to plan for construction

Status of single phase and dual phase protodetectors at CERN

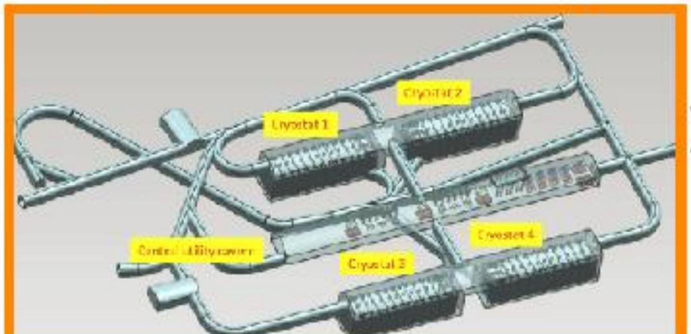
L.Molina Bueno on behalf of **WA105**

The DUNE experiment

DUNE WA105



DUNE Far detector:
4modules of 10kton detectors

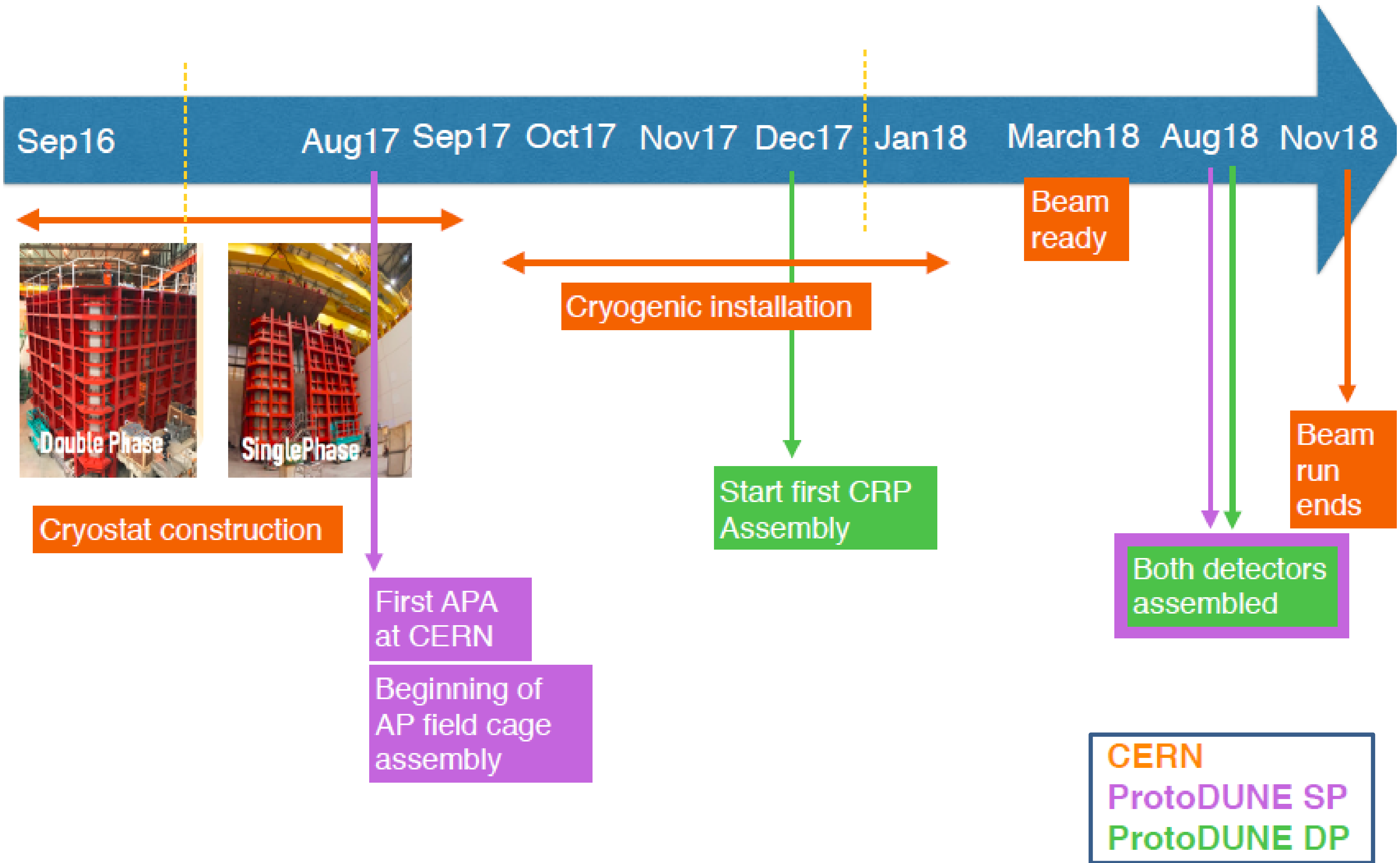


ProtoDUNEs project

- **Engineering the technology through the 10 kton detector.**
- **Test two different technologies: *single phase* and *dual phase***
- **Develop the construction and QA processes**

R&D@CERN for SP/DP

ProtoDUNEs timescale

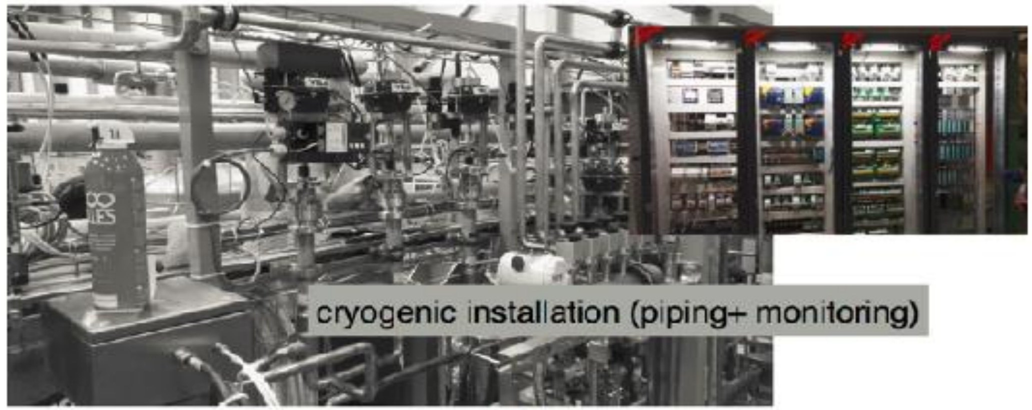


- SP and DP
- Cryogenic:
  - Purity compatible with ms electron lifetime

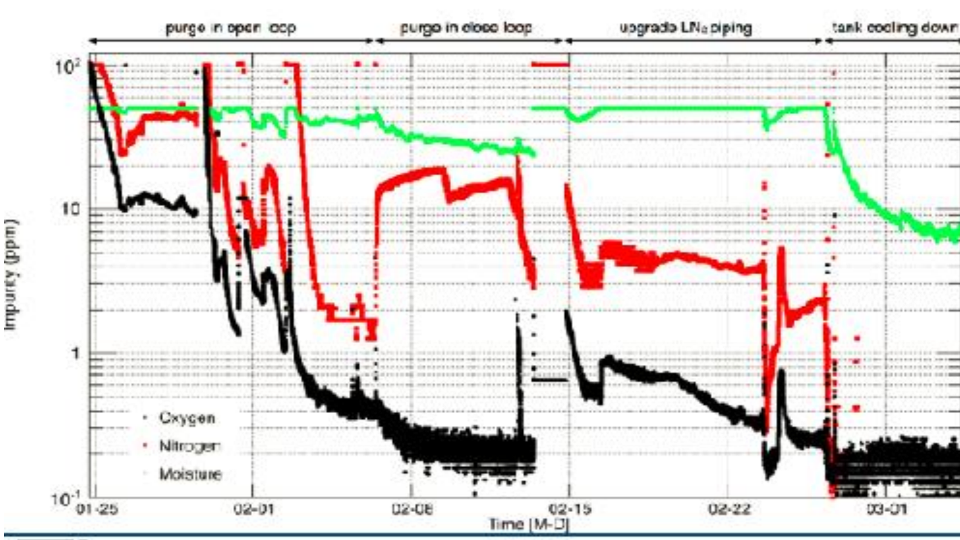
Cryogenic performance

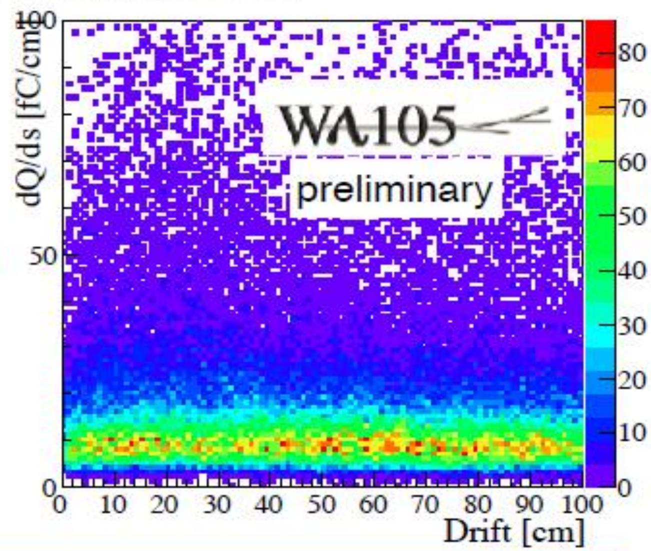
DUNE WA105

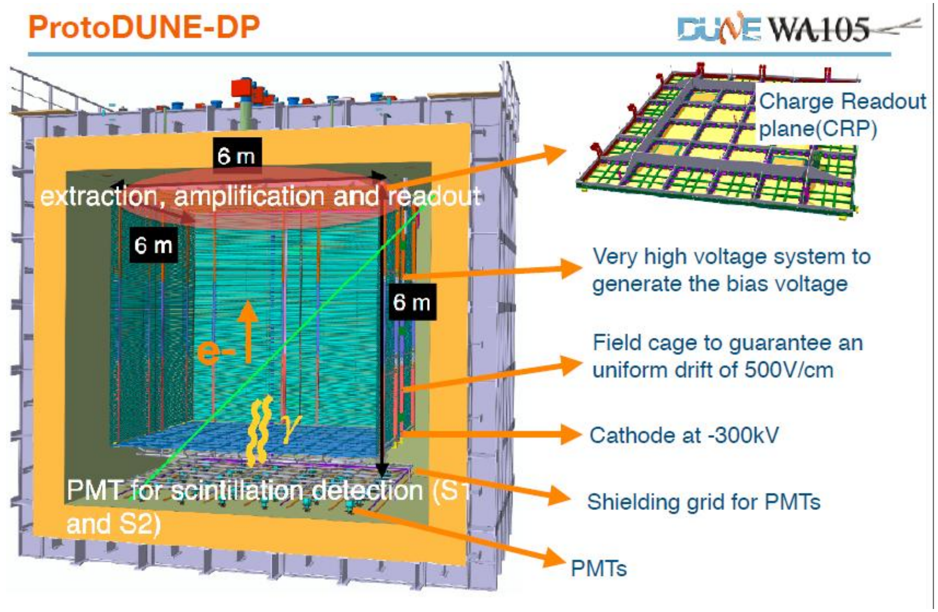
- ProtoDUNE cryogenic system will be designed and operated by CERN cryogenic group
- **Successful test of the performance on the 3x1x1 prototype where a purity compatible with ms electron lifetime has been achieved.**

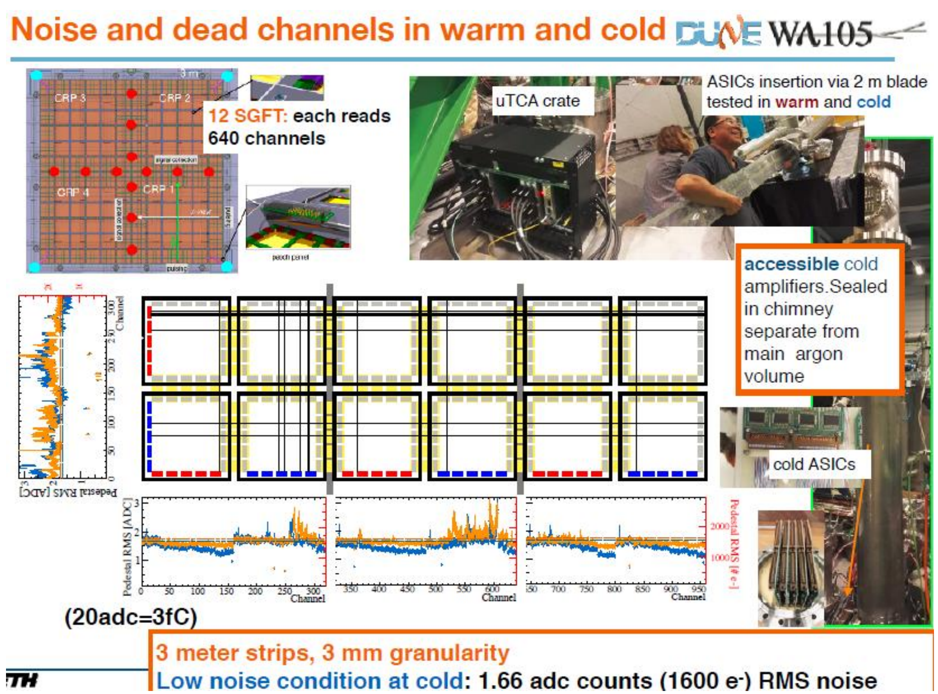


cryogenic installation (piping+ monitoring)

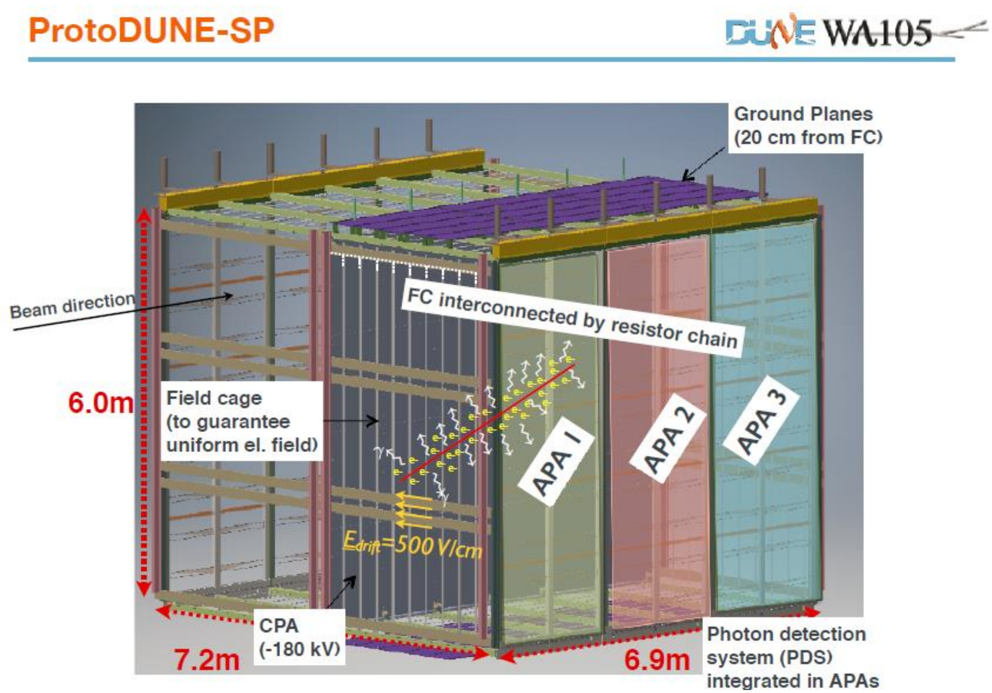


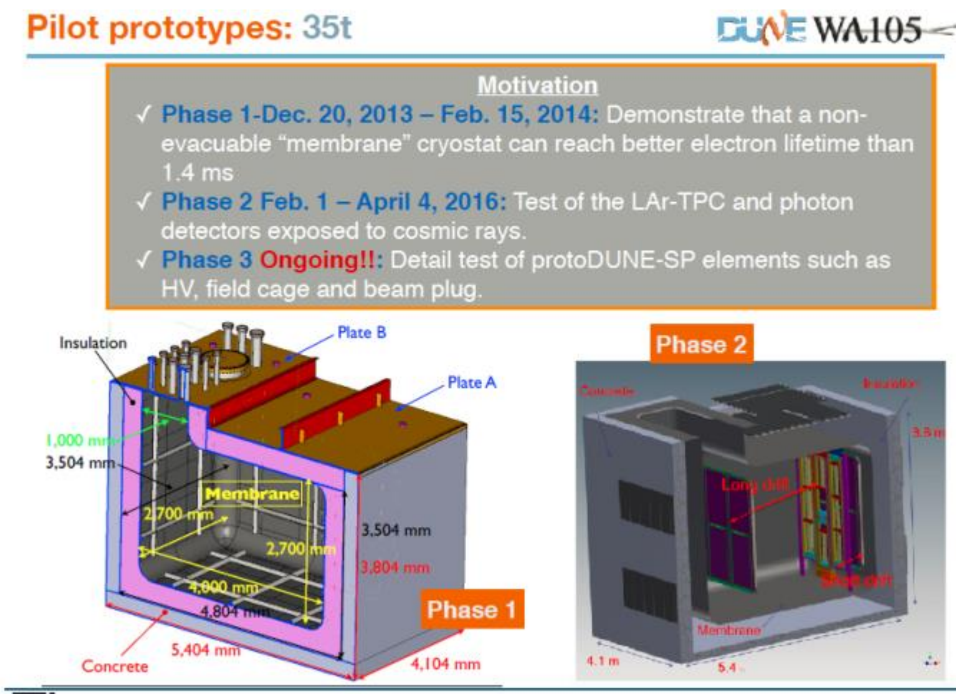






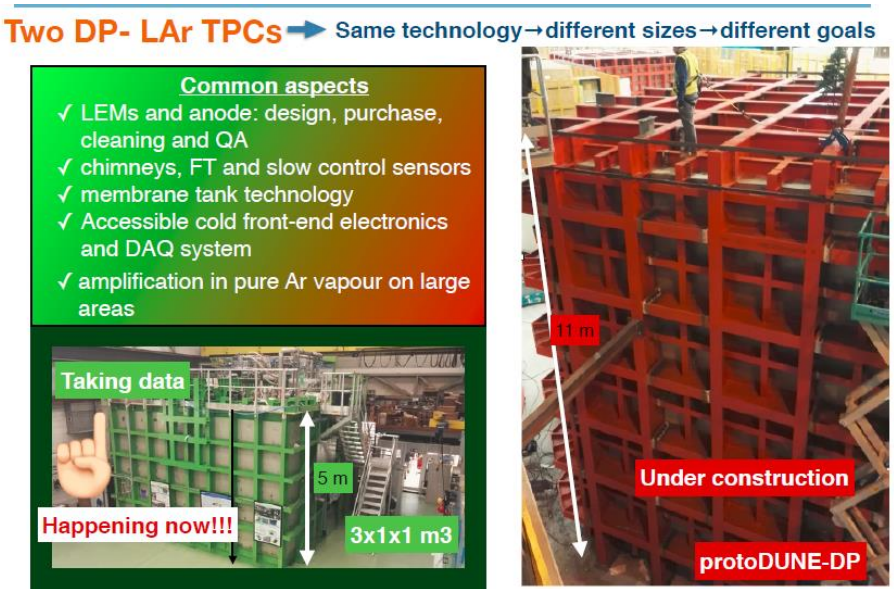
- DP: All are in good shape
- Field cage
  - Joint effort between WA105 and CERN
  - sub-module fully assembled
- Charge readout plane
  - Ordered 80 LEMs and 80 anodes last May/June. The first 36 to be assembled in CRP 1 already at testing and cleaning in CEA Saclay
  - The assembly of the first CRP module will start in November.
- Light detection system
  - 40 PMTs delivered, testing ongoing.
  - TPB coating ongoing at CERN September/October
- Noise in cold
  - Low noise condition at cold: 1.66 adc counts (1600 e_-) RMS noise

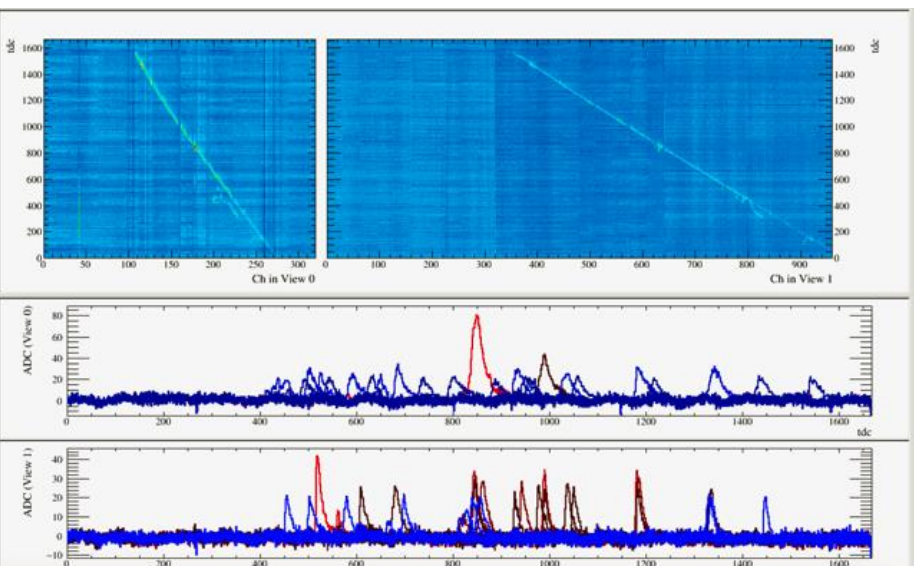




- Field cage
- Cathode
  - Cathode bias voltage -180 kV
- Anode plane assembly (APA)
  - First APA in EHN1 cleanroom since August 2017
- The first 10 photon detectors installed in APA1
  - All channels tested and responding successfully
  - Assembly on APA2 ongoing.
- Very high voltage (VHV) system
  - Common DP/SP effort
  - new 300 kV in EHN1.
  - Organizing test ~November

Pilot prototypes





- 3x1x1 m3 Taking data
  - More than 350K events collected!!!
  - Full Hardware test
  - Test of neutrino reconstruction algorithms
- protoDUNE-DP
  - Under construction

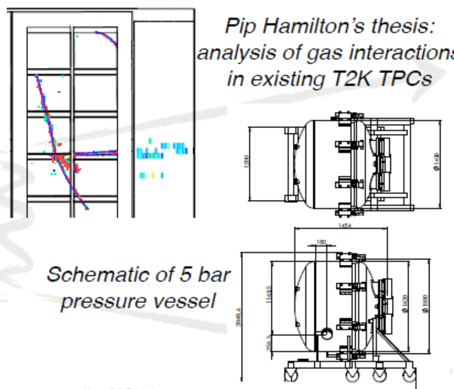
- **Following the schedule, next year will be crucial for the technologies**

R&D Towards an HPTPC Neutrino Detector

M O Wascko
<m.wascko@imperial.ac.uk>
Imperial College London

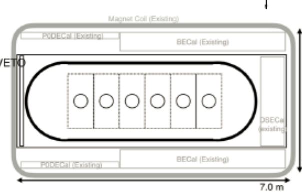
HPTPC overview

- Neutrino detector wish list:
  - ~4π coverage
  - Magnetisation
  - 3D reconstruction
  - Excellent PID
  - Nuclear target flexibility
  - Low momentum particle detection threshold
  - Technology synergy with other areas/fields
- ➡HPTPC has it all!



Pip Hamilton's thesis: analysis of gas interactions in existing T2K TPCs

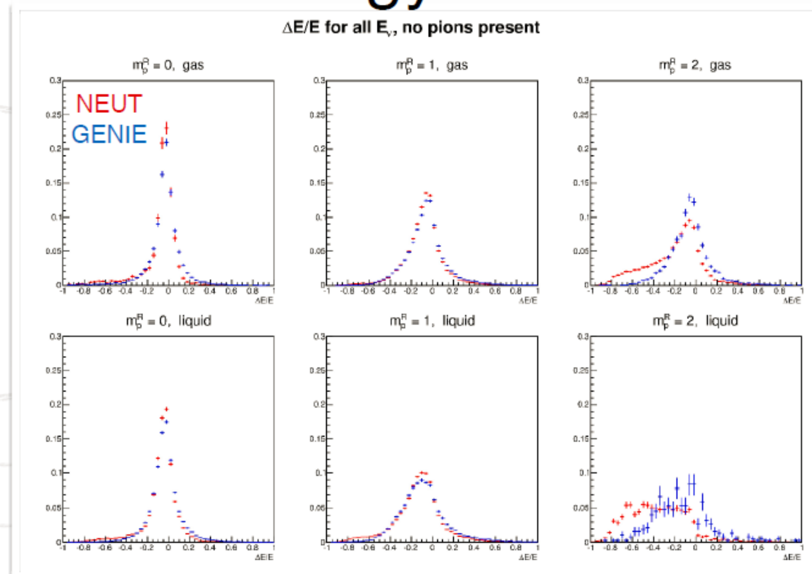
Schematic of 5 bar pressure vessel



Cartoon of HPTPC in ND280
(0th order design: simples pressure vessel possible)

Neutrino Energy Reconstruction

G. Sanjana



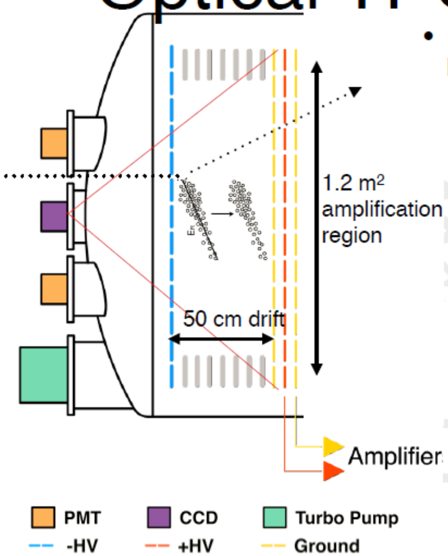
Generator-level studies of neutrino energy bias (kinematic recon)

@UK

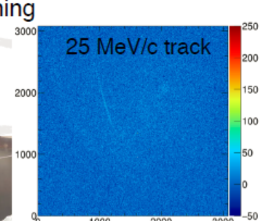
1m3 HPTPC R&D

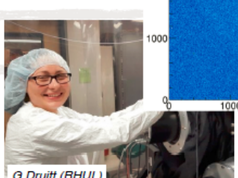
- Optical TPC Readout
  - Image electroluminescent scintillation produced in amplification region
- Commissioning TPC & readout in low pressure vessel
- Readout commissioning
  - CCD noise stable to ~1 ADC across device
  - good baseline stability
  - Initial measured gas gain ~3.2x10^4

Optical TPC Readout



- Image electroluminescent scintillation produced in amplification region
  - Digital camera + lens outside vessel
    - Currently using CCDs
  - Commission: CF_4, physics: Ar-CF_4
  - ~1 m object distance
  - results in 1 mm readout pitch with 4x4 readout binning

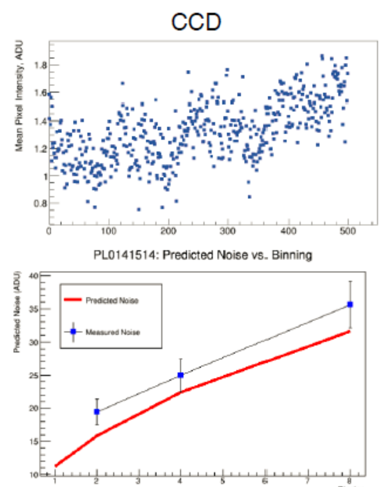




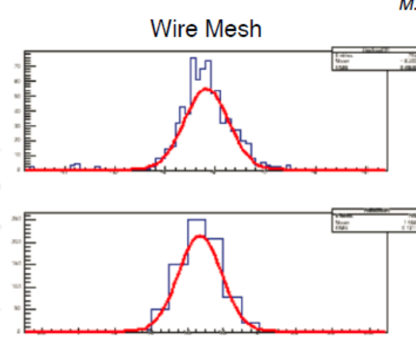
Imperial College London 2017 / 10 / 26 NNN17, Warwick, UK Morgan

Readout commissioning

M. Ward



- CCD noise stable to ~1 ADC across device, and rms in line with manufacturer specs



- good baseline stability, with RMS of whole readout chain consistent with digitizer-only noise rms of <1 ADC (=0.5 mV).
  - top: anode preamplifiers, bottom: ground mesh fast amplifiers
- Initial measured gas gain ~3.2×10^4

High Pressure Vessel

- Rated to 7.5 atm,
- 1 beam window (2 mm Al), 6 optical ports + 12 flanges for gas, HV, controls, calibration, etc.

Pressure vessel arrived at RHUL yesterday!

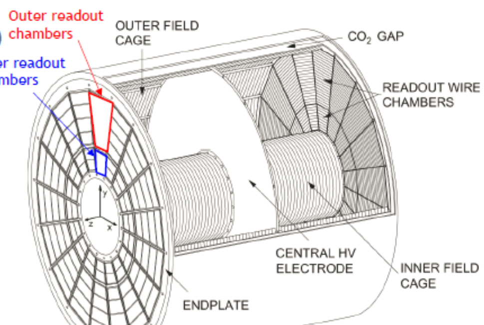
3D design rendering *Vessel on crane at RHUL* *Vessel in clean tent at RHUL*

- *Pressure vessel arrived at RHUL*
- Fermilab HPTPC R&D: Attractive possibility for HP-GArTPC:
  - **recycle ALICE TPC readout chambers**
  - gas gain ~2x10^4
  - Readout chamber and field cage constructed
  - Preparing interface from IROC to LArIAT DAQ
  - Gas system under construction

High Pressure GArTPC R&D at Fermilab

- DUNE Near Detector design options are under study now
  - LArTPC + downstream magnetized fine-grained tracker (e.g., HP-GArTPC)
- Attractive possibility for HP-GArTPC: **recycle ALICE TPC readout chambers**
  - ALICE chambers will be replaced during upcoming upgrade
  - Demonstrated excellent reconstruction capabilities in high-rate environment
  - Will provide excellent vertex visualization for neutrino interactions
  - Raw 3D data (pad plane readout)
    - Readout area ~32 m², ~557k channels
  - ALICE operation was at 1 atm
    - Need to demonstrate capability at 10 atm for use in DUNE ND complex

ALICE TPC



NIM A 622:1 (2010) 316-367

Status and Future Plans

@US

- Readout chamber and field cage constructed
- Preparing interface from IROC to LArIAT DAQ
- Gas system under construction
  - Test at 1 atm by the end of the year
    - 90:10 Ar:CO_2 and/or Ar:CH_4 to start
    - Test other gas mixtures, e.g. Xe-doped Ar
  - Tests at higher pressure after successful completion of 1 atm
- Future
  - Operation in charged particle test beam
  - Larger vessel and readout chambers (~1 m³) in NuMI neutrino beam

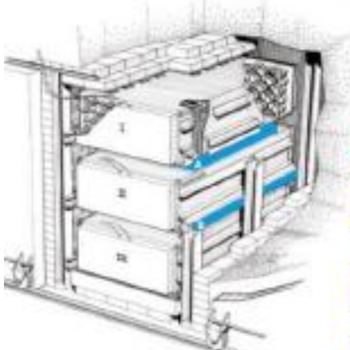
D. Grant, M. He, H. Tanaka, R. Wendell

NNN15
October 28-31, 2015, Stony Brook University

WC and LS detectors

well known technology straightforward

Reines-Cowan



Mixture of water and liquid scintillator, first detection of neutrinos

Kamiokande

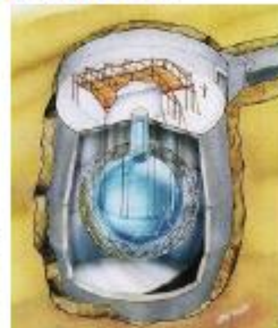
Supernova neutrinos

SuperK

Atmospheric neutrinos' oscillation

SNO

Solar neutrinos' oscillation



IceCube

PeV neutrinos

KamLAND

Reactor neutrinos and θ_{12}, Geoneutrinos

Borexino

Solar neutrinos, Geoneutrinos

Double Chooz

RENO

Daya Bay

Reactor neutrinos and θ_{13}

Recent progress in detector R&D for JUNO

Zhonghua Qin
(IHEP, Beijing)

the JUNO experiment

JUNO (Jiangmen Underground Neutrino Observatory) will be located in Jiangmen city, Guangdong province in South China:

- ~ 53km from the Yangjiang and Taishan NPP
- ~700m under ground

NPP	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW

JUNO detector

- JUNO is composed of a central detector and a VETO detector

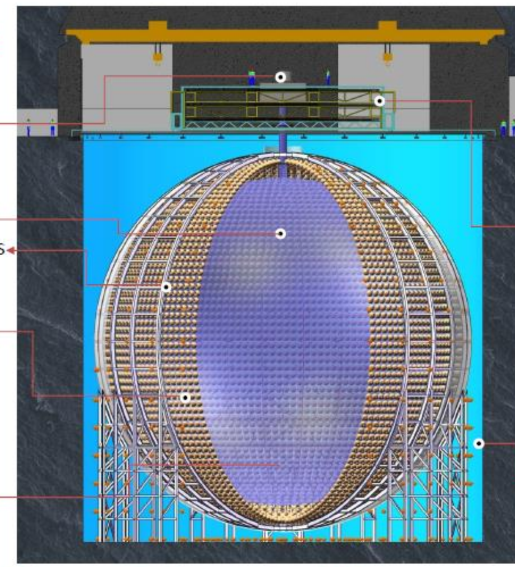
Central detector

Calibration
-ACU, ROV, etc.

Acrylic sphere
Stainless-steel truss

PMT
-18,000 20" PMTs
-25,000 3" PMTs

Liquid scintillator
-20 kton LS



VETO detector

Top Tracker
-62 Plastic scintillator walls

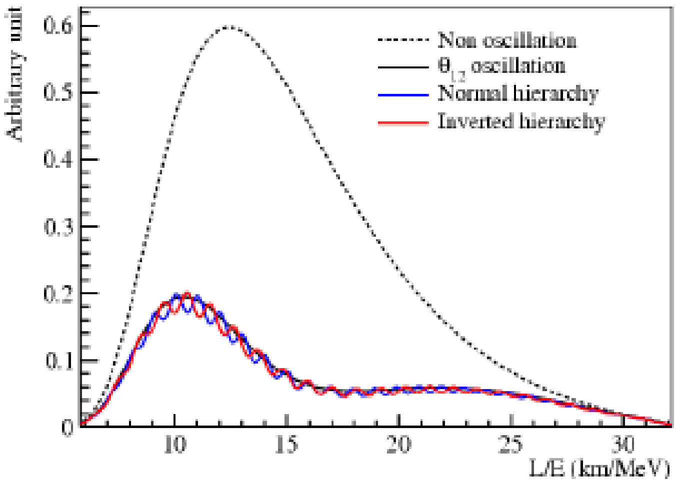
Water Cherenkov detector
-35 kt high-purity water
-2000 20" PMTs

- Acrylic sphere: Φ35.4m
- Stainless-steel struss: Φ40.1m
- Water pool: Φ43.5m

- Start of the detector on-site construction is expected in the beginning of 2019.
- JUNO plans to start operation in 2020.

Energy resolution of JUNO

- JUNO physics goal: measure the mass hierarchy(MH) with 3-4 σ precision in 6 years.
  - Precision measurement of energy spectrum is needed.
  - Sensitivity heavily depends on the energy resolution:

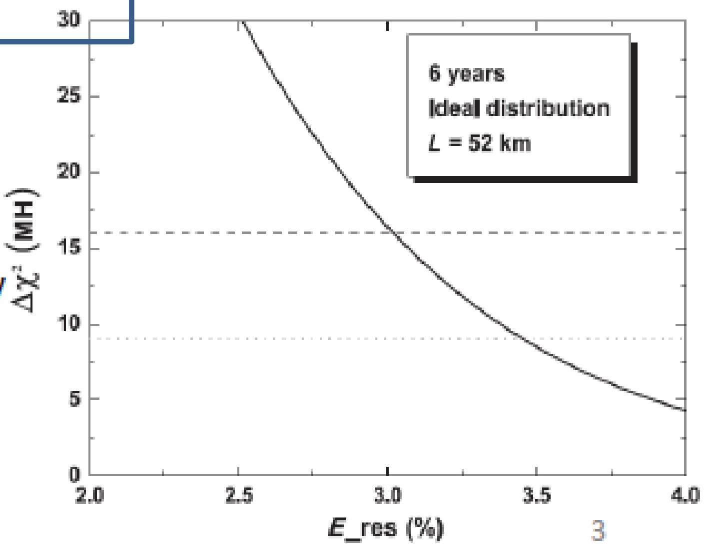


$$\frac{\sigma(E)}{E} = \sqrt{\frac{\sigma^2{}_{stoch}}{E} + \sigma^2{}_{nonstoch}}$$

-$\sigma_{stoch.}$:stochastic term, depends on photostatistics;

-$\sigma_{non\_stoch.}$:non-stochastic term, issues of stability, uniformity, linearity;

- JUNO energy resolution requirement: $\frac{\sigma(E)}{E}$ ~3% @1MeV.
  - as many as possible p.e. (>1200 p.e./MeV)
    - → more than 75% PMT coverage
    - → ~30% QE of PMT
    - → High light-yield Liquid scintillator: > 10^4 ph./MeV
    - → High-purity Liquid scintillator : att. Len. > 20m
  - low systematics: <1%;



Calibration

- **Goal: keep the energy scale uncertainty <1%; calibrate the detector non-uniformity;**
- Four complementary calibration systems under R&D
  - 1-D: Automatic Calibration Unit (ACU)
    → for central axis scan;
  - 2-D:
    Cable Loop System (CLS)
    → scan vertical planes;
    Guide Tube Calibration System (GTCS)
    → CD outer surface scan;
  - 3-D: Remotely Operated under-LS Vehicle (ROV)
    → whole detector scan
- Radioactive sources
  - γ: ^{40}K, ^{54}Mn, ^{60}Co, ^{137}Cs
  - e^+: ^{22}Na, ^{68}Ge
  - n: ^{241}Am-Be, ^{241}Am- ^{13}C or ^{241}Pu- ^{13}C, ^{252}Cf
- Status
  - ACU promising to reach sub-cm positioning
  - CLS test reaches to 10cm precision
  - Full-size GTCS tested
  - First version of ROV designed and tested

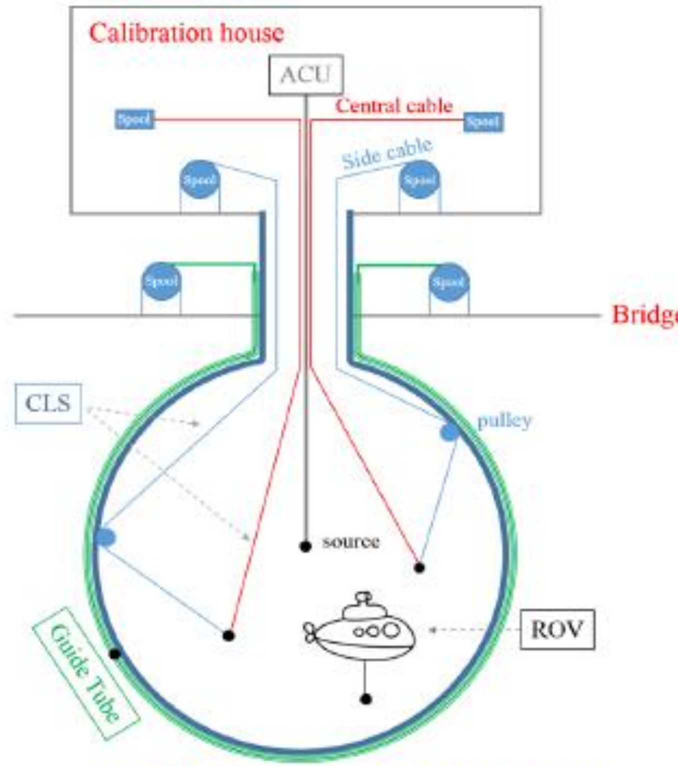
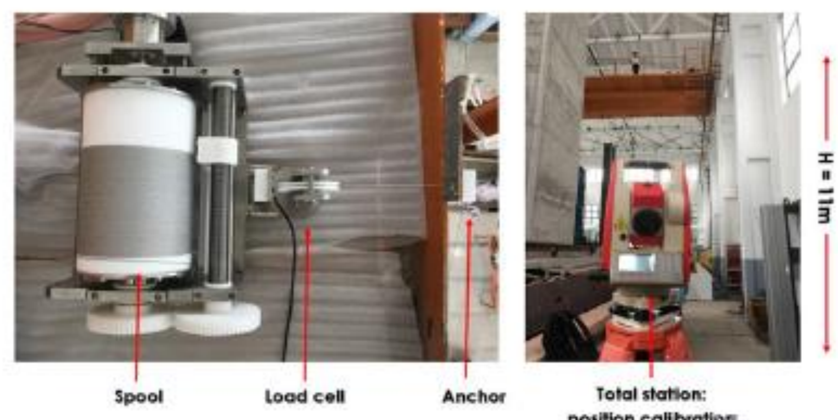


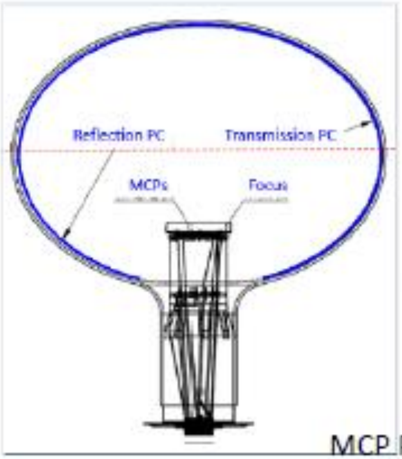
Diagram of calibration system



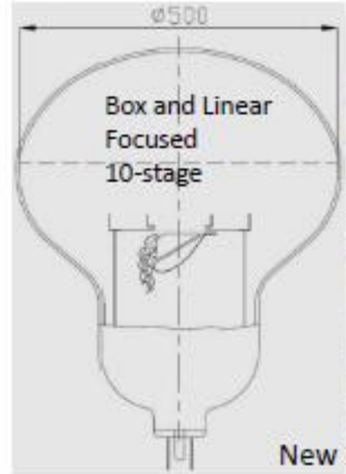
ACU test

Production of 20” PMT

- 15000 MCP-PMTs are from NNVT (North Night Vision of Technology CO., LTD).
- 5000 dynode-PMTs are from Hamamatsu company.



MCP PMT

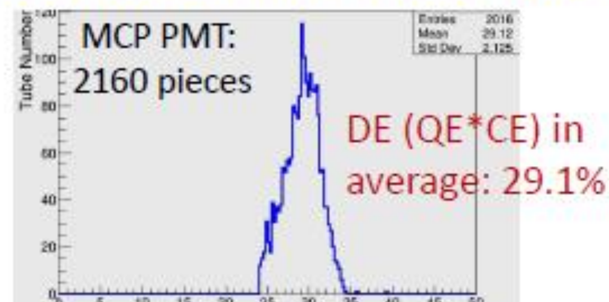


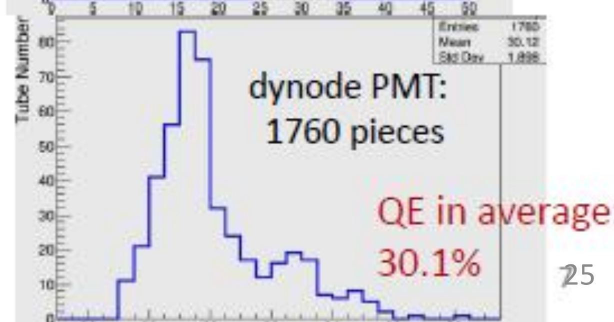
New 20-inch PMT R12860

- the key parameters

Characteristics	unit	MCP-PMT (NNVT)	R12860 (Hamamatsu)
Detection Efficiency (QE*CE)	%	27%	27%
P/V of SPE		3.5, > 2.8	3, > 2.5
TTS on the top point	ns	~12, < 15	2.7, < 3.5
Rise time/ Fall time	ns	R~2, F~12	R~5,F~9
Anode Dark Count	Hz	20K, < 30K	10K, < 50K
After Pulse Rate	%	1, <2	10, < 15
Radioactivity of glass	ppb	238U:50 232Th:50 40K: 20	238U:400 232Th:400 40K: 40

- Measurement from the vendors





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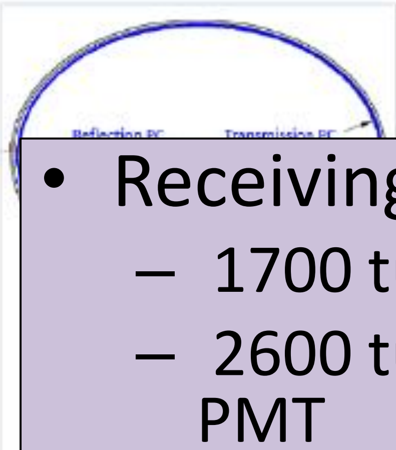
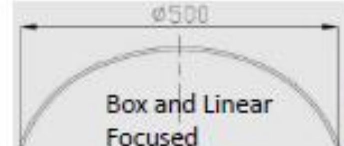
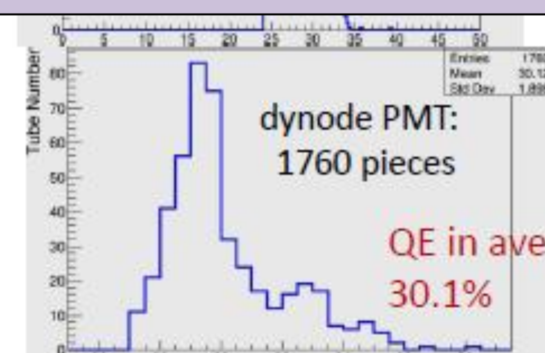




- Receiving the 20" PMTs from vender
  - 1700 tubes from Hamamatsu
  - 2600 tubes from NNVT with the newly developed MCP PMT

- For the 34 m acrylic sphere: Engineer Design finished and signed the bidding
- Signed bidding with HZC for 25000 3" tubes

TTS on the top point	ns	~12, < 15	2.7, < 3.5
Rise time/ Fall time	ns	R~2, F~12	R~5,F~9
Anode Dark Count	Hz	20K, < 30K	10K, < 50K
After Pulse Rate	%	1, <2	10, < 15
Radioactivity of glass	ppb	238U:50 232Th:50 40K: 20	238U:400 232Th:400 40K: 40



Upgrade of the near detectors towards CP violation search in T2K/T2K-II

Benjamin Quilain (Kavli IPMU, The University of Tokyo)
on behalf of the ND280-upgrade taskforce and WAGASCI collaboration

List of current systematic uncertainties

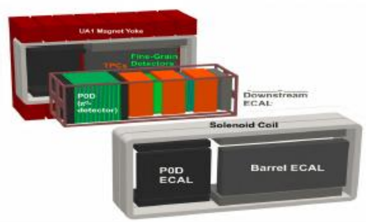
2016 analysis error table	$\delta_{N_{SK}}/N_{SK}$ (%)				
	1-Ring μ		1-Ring e		
Error Type	ν mode	$\bar{\nu}$ mode	ν mode	$\bar{\nu}$ mode	$\nu/\bar{\nu}$
SK Detector	3.9	3.3	2.5	3.1	1.6
SK Final State & Secondary Interactions	1.5	2.1	2.5	2.5	3.5
ND280 Constrained Flux & Cross-section	2.8	3.3	3.0	3.3	2.2
$\sigma_{\nu_e}/\sigma_{\nu_\mu}$, $\sigma_{\bar{\nu}_e}/\sigma_{\bar{\nu}_\mu}$	0.0	0.0	2.6	1.5	3.1
NC 1γ Cross-section	0.0	0.0	1.5	3.0	1.5
NC Other Cross-section	0.8	0.8	0.2	0.3	0.2
Total Systematic Error	5.1	5.2	5.5	6.8	5.9
External Constraint on θ_{12}, θ_{13}, Δm^2_{21}	0.0	0.0	4.1	4.0	0.8

- Uncertainty on extrapolation of ND280 constraints to SK
  Same flux, target, acceptance between near and far.

Far detector | Near detector

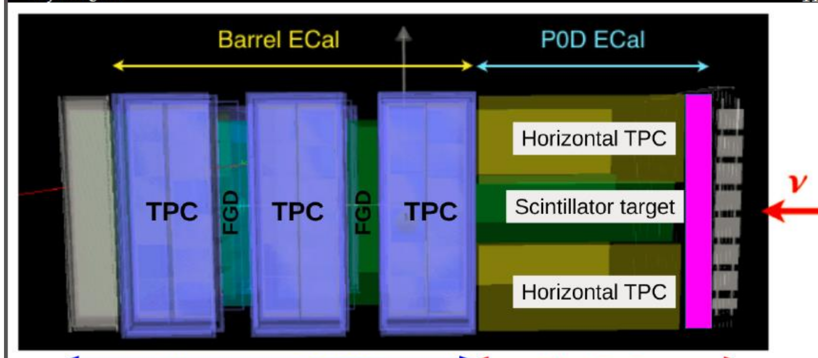
Target : 100 % H_2O vs 80 % CH + 20% H_2O

Acceptance : 4π vs Foward



Reducing the uncertainties

Proposal for the ND280 upgrade



1. Existing two FGD targets : H_2O + CH ~ 1.8 T each

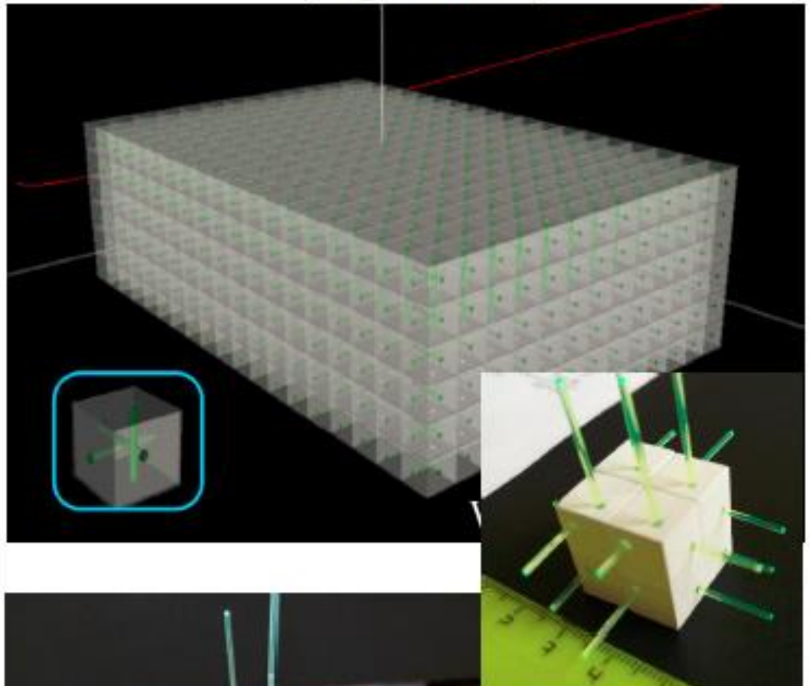
2. One new fully active plastic target embedded in 4π tracker ~ 1.5 T

3. Use 3 ND280 TPC + build 2 new TPCs & support structure
→ particle momenta can be measured in all direction (SK 4π angular acceptance)

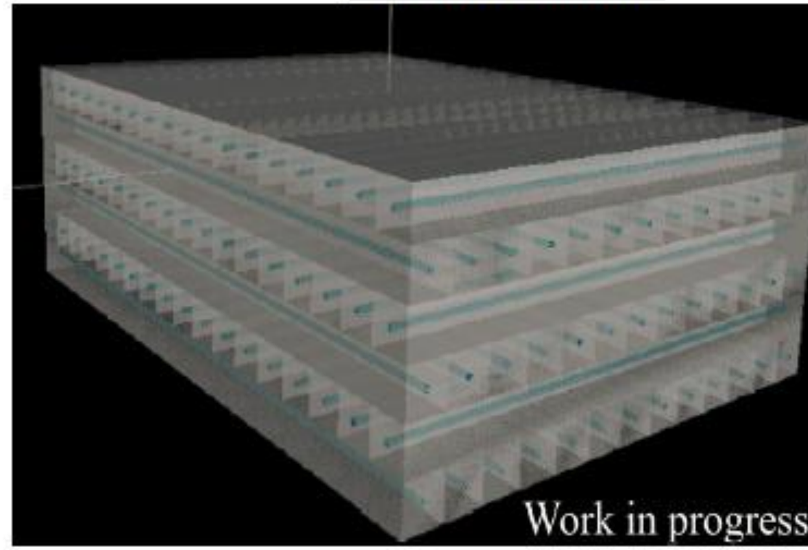
Maximal acceptance coverage

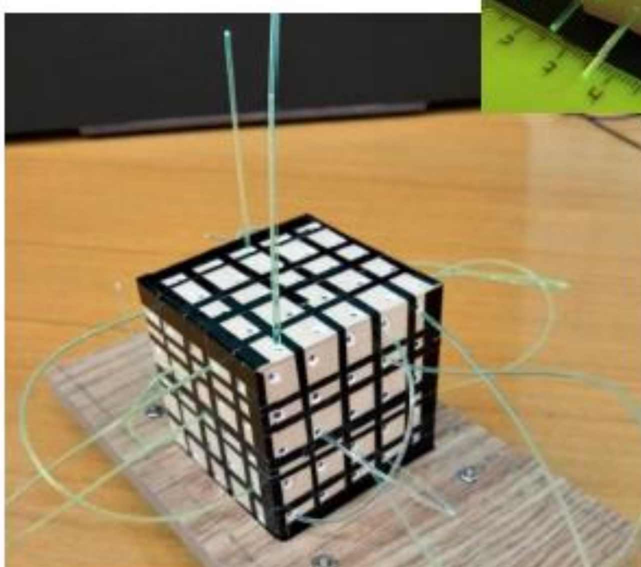
Candidates for the new target

Super-FGD



Horizontal FGD





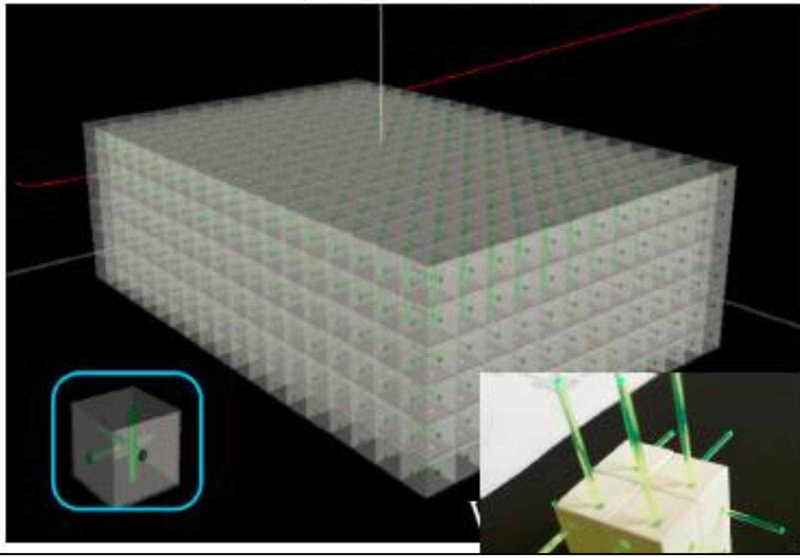
	Super-FGD	Horizontal FGD
Pros	4π High resolution for low momenta hadrons	Well known, easy assembly Low cost
Cons	Challenging assembly Large costs	Not 4π

Main candidate : R&D already started at INR

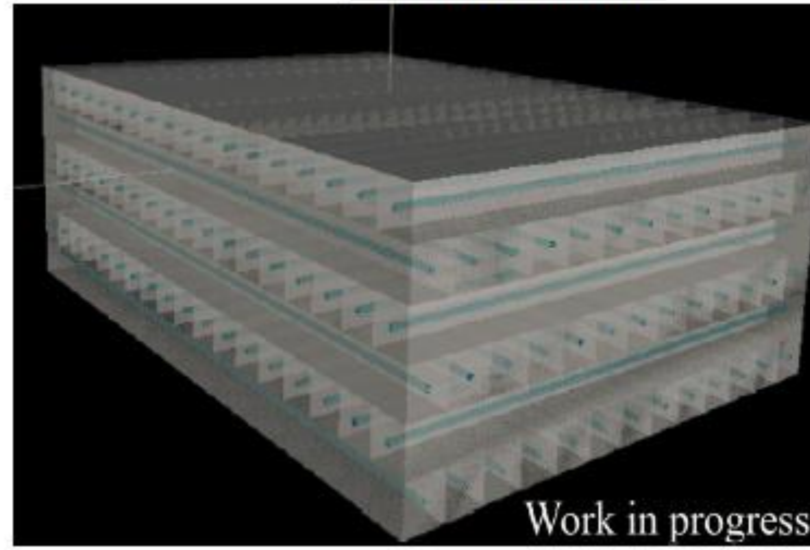
→ Now prototype @CERN for test beam

Candidates for the new target

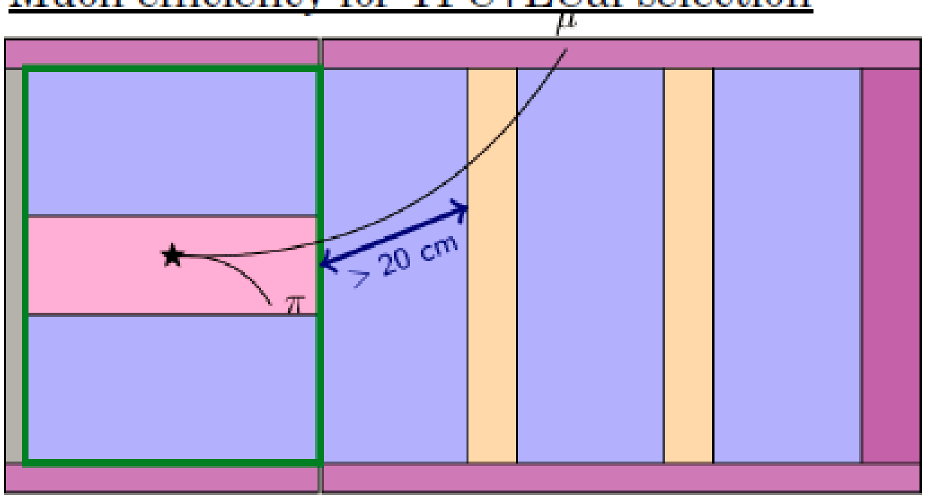
Super-FGD

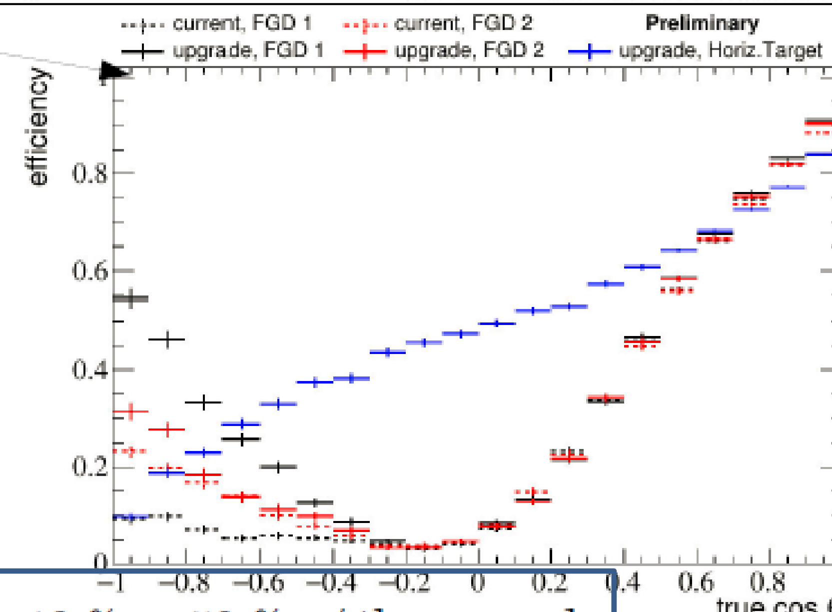


Horizontal FGD



Muon efficiency for TPC+ECal selection





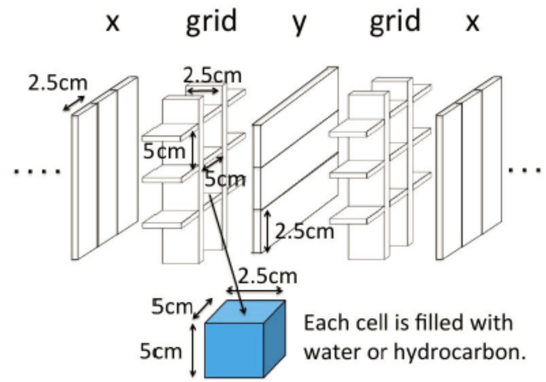
Muon reconstruction @large angle : Increase from 10 % → 50 % w/ the upgrade

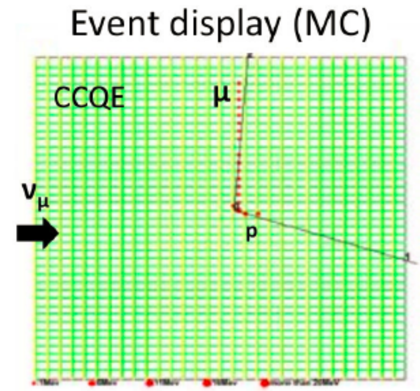
A new water-based detector : WAGASCI

1. 4π angle acceptance as SK (4π) for lepton kinematics
2. High granularity to identify interaction final states
3. Similar nucleus target as Super-K

WAGASCI tracker: Alternance of XY planes & 3D grid scintillators.

4π angular acceptance
Good vertex resolution (even for large angle tracks)





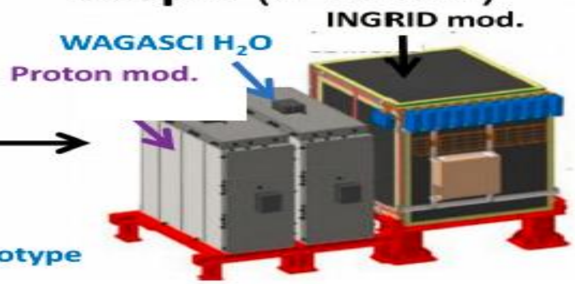
Goal : Cross-section measurement on water (& H_2O/CH ratio) with high angle acceptance.

Module ID card :

Step 0 (JFY2016)

Oct. 2016

Step 1 (JFY2017)

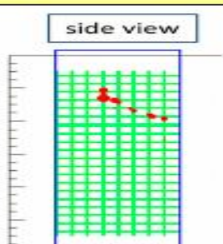


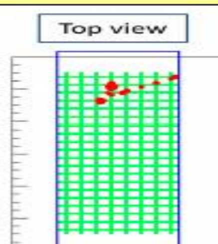
Oct. 2017

Step 2 (JFY2018)

Apr. 2018

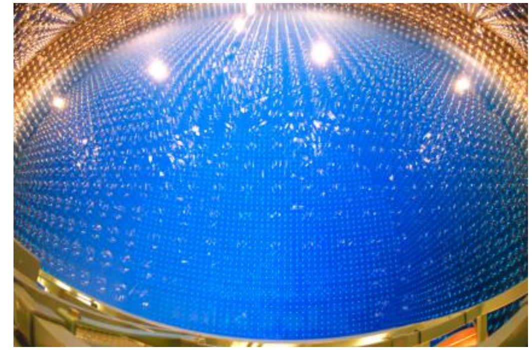
On-axis : Prototype module ν measurement	On-axis : Prototype module $\bar{\nu}$ measurement	
	1.5° off-axis : H_2O module $\bar{\nu}$ measurement	
		1.5° off-axis : H_2O + prototype modules + Side-MRD + Baby-MIND





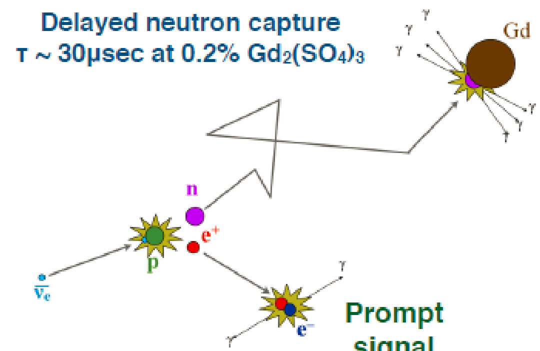
Gd loaded Super-K: status and plan

Yasuhiro Nakajima (ICRR, The University of Tokyo),
for the Super-Kamiokande Collaboration



Supernova & DSNB

- Dissolving Gd to Super-Kamiokande to significantly enhance detection capability of neutrons from ν interactions
- Idea first proposed in:
  J. F. Beacom and M. R. Vagins, Phys. Rev. Lett. 93 (2004) 17110

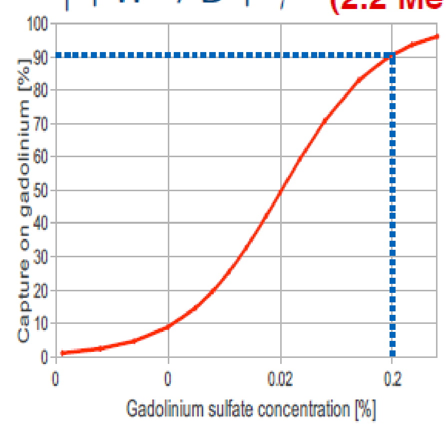


$$\overline{\nu}_e + p \rightarrow e^+ + n$$
$$| + {}^{x}Gd \rightarrow {}^{x+1}Gd + \gamma(s)$$ **(8 MeV)**
$$| + H \rightarrow D + \gamma$$ **(2.2 MeV)**

Advantage of Gd:

- Large n-capture cross section:
  - 90% of Gd capture efficiency at 0.2% loading of $Gd_2(SO_4)_3$ (corresponds to 100 ton/SK)
- Large released energy of ~8MeV
  - Well above most of natural radioactivity and the SK trigger threshold

Strongly tag electron antineutrinos by prompt (e^+) and delayed (n-Gd) coincidences



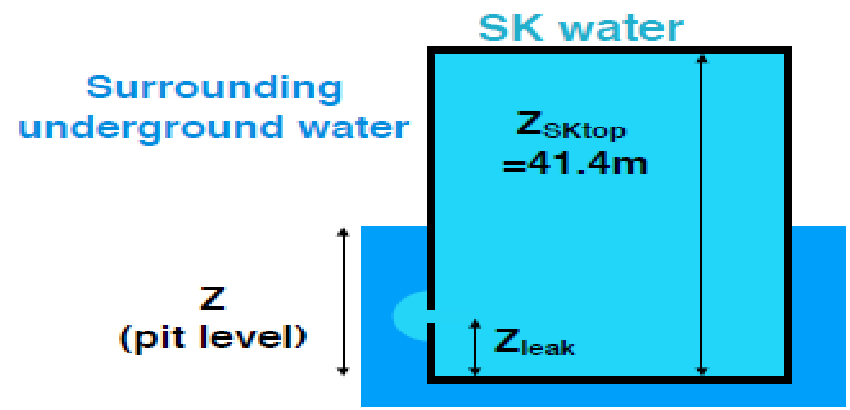
Overview of R&D and preparation

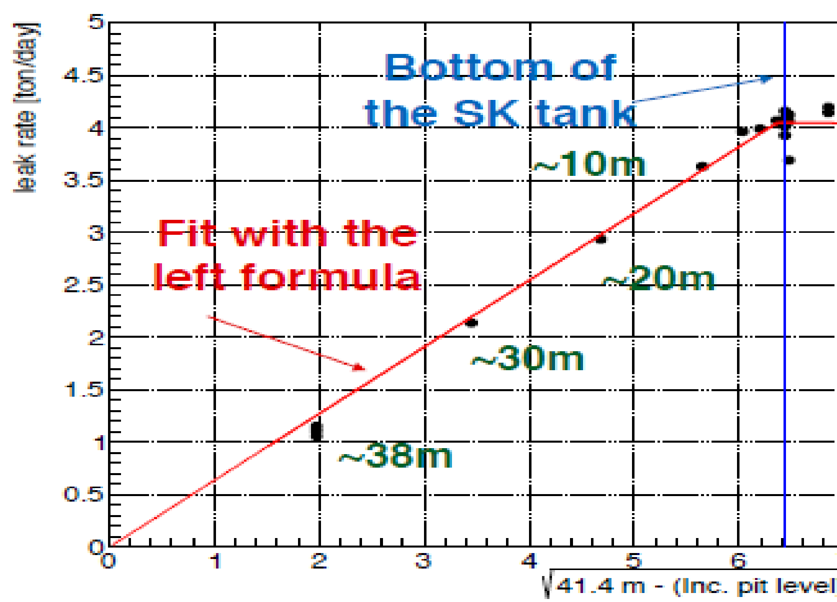
Environmental safety

Minimize negative impacts to current physics programs at SK

Further investigate physics capability with n-tagging

- **Stopping water leak from the SK**
  - Estimation of the leak location
  - Development of leak-fi
- **Reduction of RIs from G**
  - Test of Ra removal rais
  - Material screening witl
  - High sensitivity measu
- **Test with the EGADS de**
  - Continuous monitoring concentration
  - Upgrading the DAQ sy
- **Construction of the new**
- **Improved simulation of (**





Overview of R&D and preparation

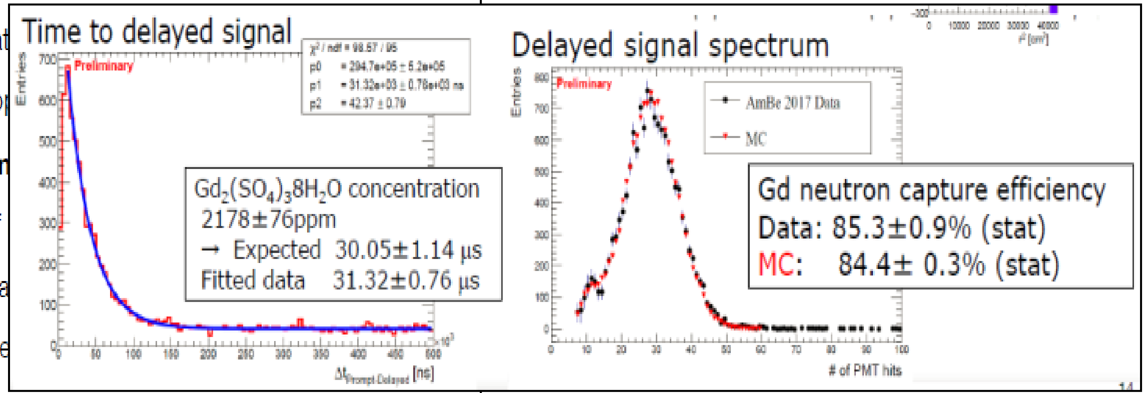
Environmental safety

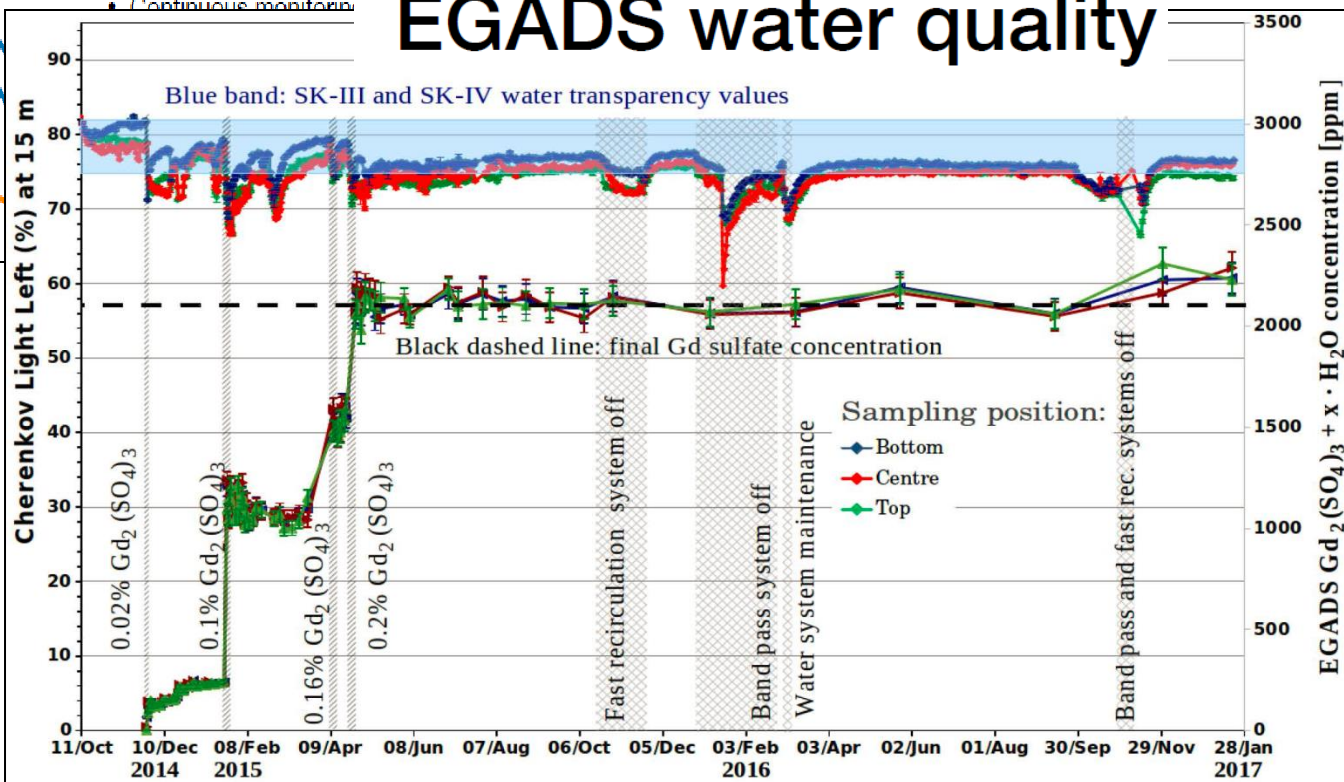
Minimize negative impacts to current physics programs at SK

Further investigate physics capability with n-tagging

- **Stopping water leak from the SK**
  - Estimat
  - Develo
- **Reduction**
  - Test of
  - Materia
  - High se
- **Test with the EGADS demonstrator**
  - Continuous monitorin

Neutron calibration





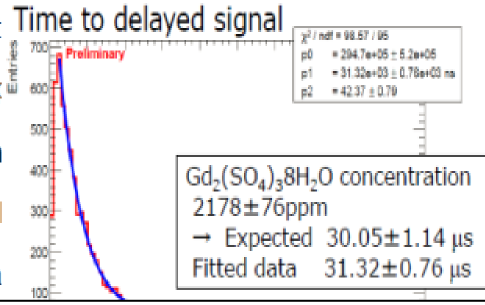
Overview of R&D and preparation

Environmental safety

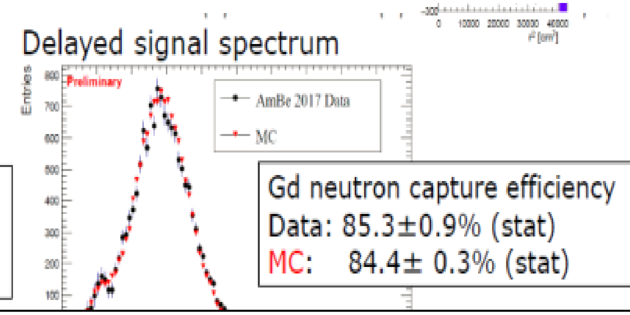
Minimize negative impacts to current

with n-tagging

- Stopping water leak from the SK
  - Estimat
  - Develop
- Reduction
  - Test of
  - Materia



Neutron calibration

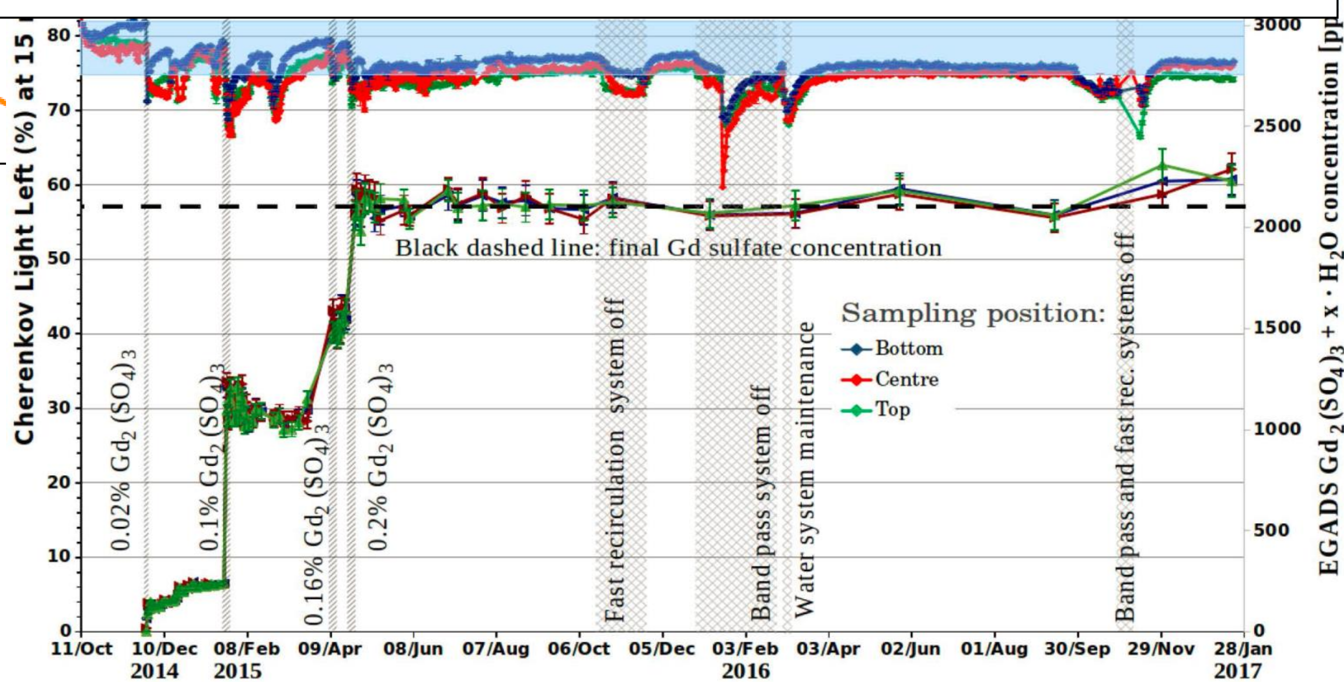


Gd neutron capture efficiency
Data: 85.3±0.9% (stat)
MC: 84.4± 0.3% (stat)

Plan

Gd loaded Super-K:

We will open the tank and start the refurbishment work on June 1, 2018



Non oscillation neutrinos

- ***Solid***
  - ***Reactor anomaly & sterile neutrinos***
- ***PTOLEMY***
  - ***Thermal/relic neutrinos***
- ***CONNIE***
  - ***Coherent neutrinos***

In search for sterile neutrinos: Status of the SoLid experiment

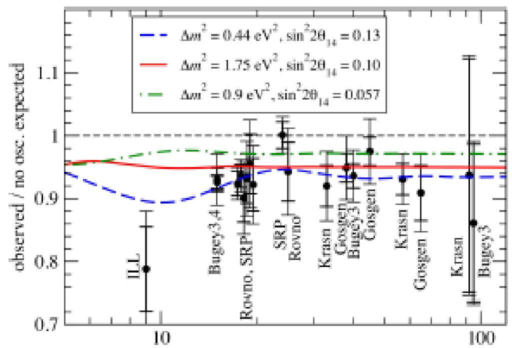
Simon Vercaemer

The reactor anomaly and sterile neutrinos

Reactor anomaly

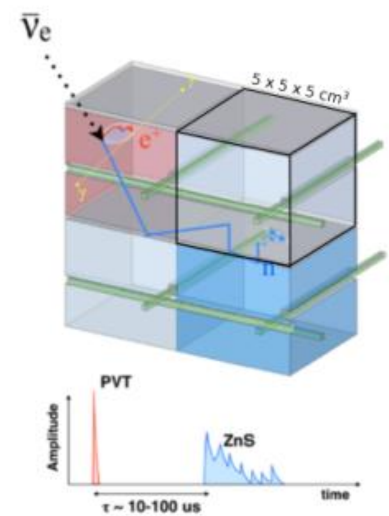
- Short baseline ($< 100m$)
- Several experiments
- Combined 2.7σ deficit

- 3 known neutrinos oscillate, can not explain the deficit
- 4^{th} neutrino could resolve the anomaly
- Number of active light neutrino flavours measured: 2.984 ± 0.008 $\rightarrow$ make new flavour 'sterile'
- Perform a rate and shape analysis on reactor neutrinos to find sterile neutrinos.



Neutrinos are detected via inverse beta decay (IBD) reaction: $\bar{\nu}_e + p \rightarrow e^+ + n$

1. Prompt positron signal
   - Scintillation light in PVT cube
   - In IBD cube
   - Provides neutrino energy
2. Delayed neutron signal
   - Two ^{6}LiF:ZnS(Ag) screens per cube
   - High cross section for thermal neutron capture in ^{6}Li
   - $^6\text{Li} + n \rightarrow \alpha + T + 4.78MeV$
   - Distinct scintillation pattern of α and T in ZnS(Ag)



SM1 (prototype)

- 9 planes, 16×16 cubes each
- 288 kg, 45 cm baseline
- Operational 2014-2015

Phase 1 (full scale)

- 5 modules, 10 planes each
- 1.6 ton, 250 cm baseline
- Construction completed, being commissioned

Detector updated to Phase 1
Phase 1 commissioning and calibration
  Perfect linear response
  Uniformity neutron efficiency
  Uniformity light yield
Data taking starts next month (Nov. 2017)

SM1 (prototype)

- 9 cm shielding (HDPE)
- room temperature ($\sim 25^\circ C$)

Phase 1 (full scale)

- 50 cm shielding (H_2O) → decreased BG
- cooled to $5^\circ C$ → decreased dark counts

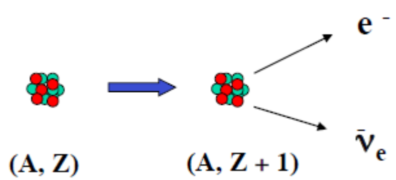
The PTOLEMY experiment
Towards Cosmological Relic Neutrino detection

Alfredo G. Cocco
Istituto Nazionale di Fisica Nucleare
(Italy)

Neutrino capture on $\beta^{\pm}$ decaying nuclei

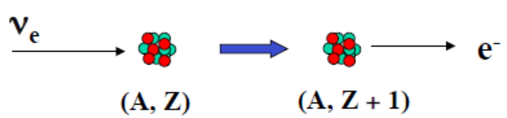
Known

Nuclear Beta decay

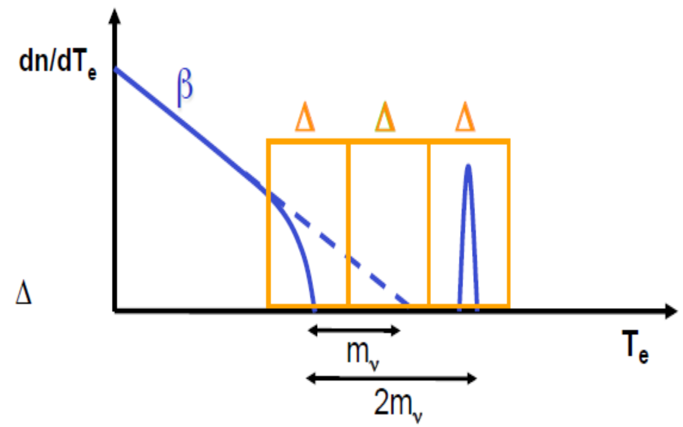


Possible

Neutrino Capture on a Beta Decaying Nucleus (NCB)



This process has no energy threshold !
Cross section is non vanishing !



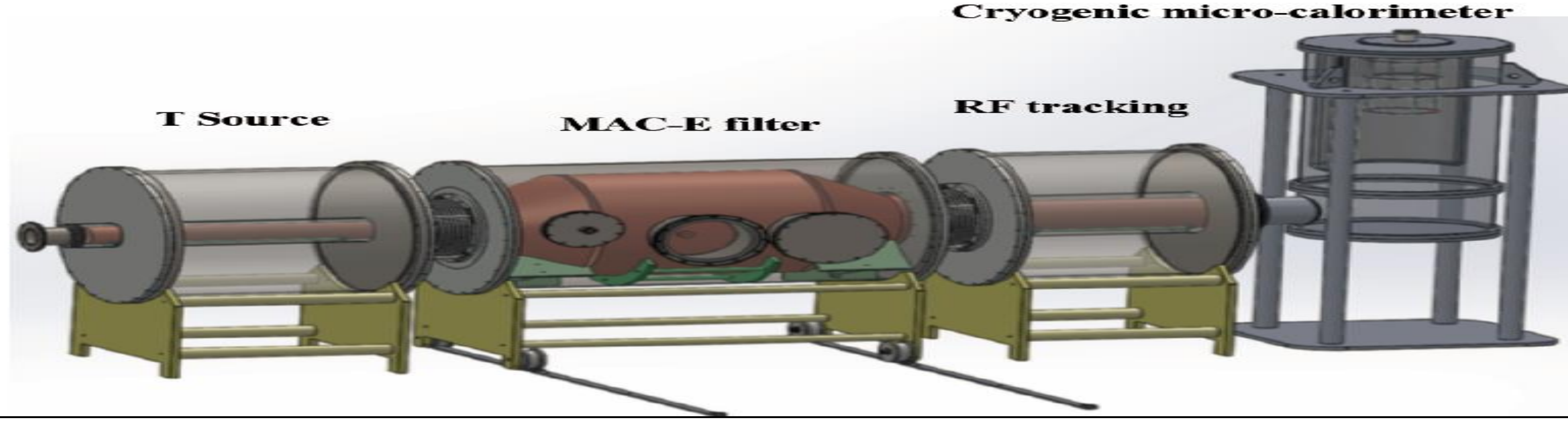
m_ν (eV)	FD (events yr^{-1})	NFW (events yr^{-1})	MW (events yr^{-1})
0.6	7.5	90	150
0.3	7.5	23	33
0.15	7.5	10	12

FD = Fermi-Dirac NFW= Navarro,Frenk and White
MW=Milky Way (Ringwald, Wong)

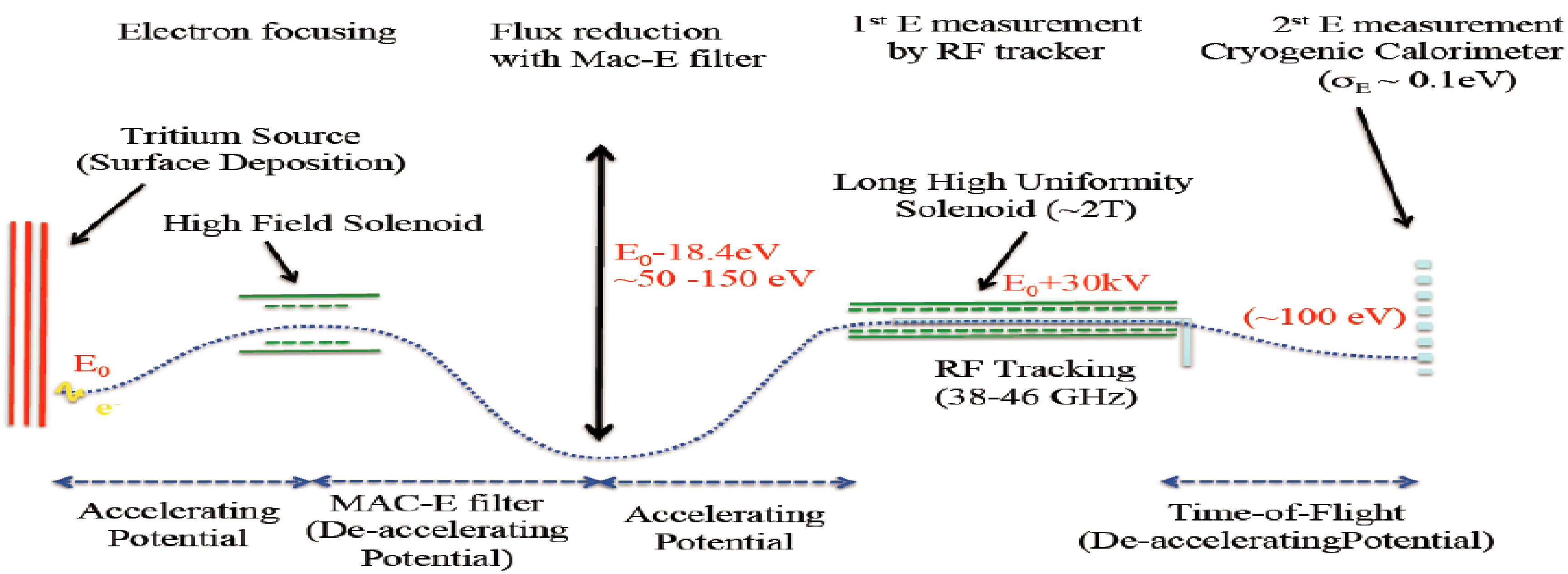
Cosmological Relic Neutrino Background (CνB)

In the Big-Bang scenario neutrinos decoupled when T ~ MeV

The PTOLEMY prototype
@ Princeton



100 g T source + MAC-E filter + RF tagging + sub-eV resolution μ-cal



Data-taking tests with full setup scheduled by the end of the year

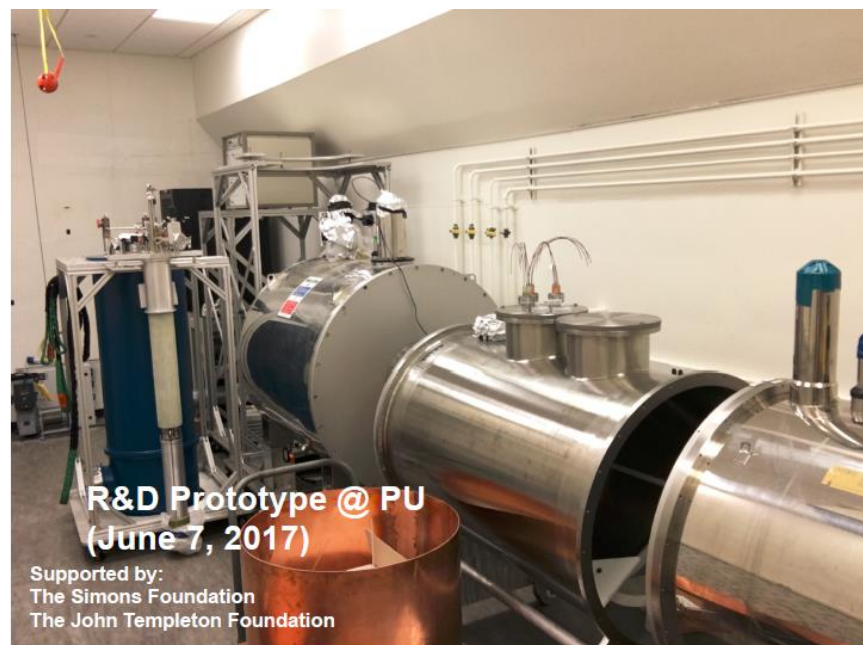
The prototype will be moved to Laboratori Nazionali del GranSasso (ITALY) in 2018 to perform tests in a background free underground environment

The PTOLEMY "kick-off" meeting will take place in LNGS (Italy) on 11-12 December in order to start focusing on the full scale project

(enthusiastic collaborators are welcome !)

R&D prototype @PPPL
August 2016

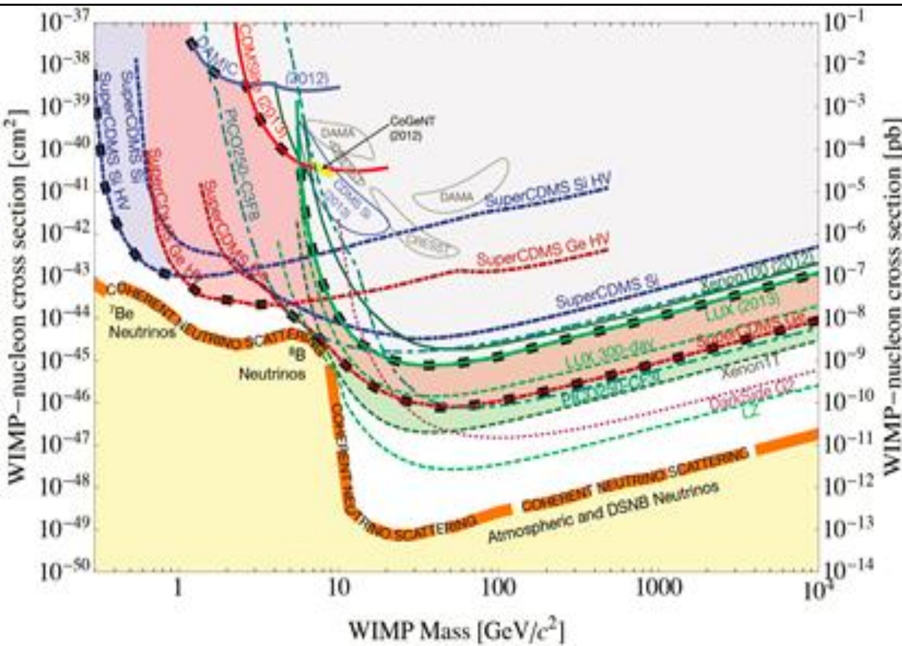
R&D prototype @PU
June 2017



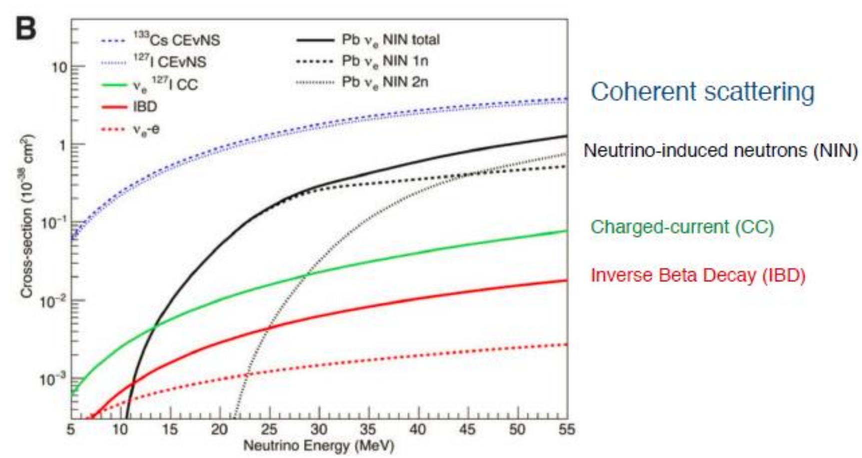
CONNIE

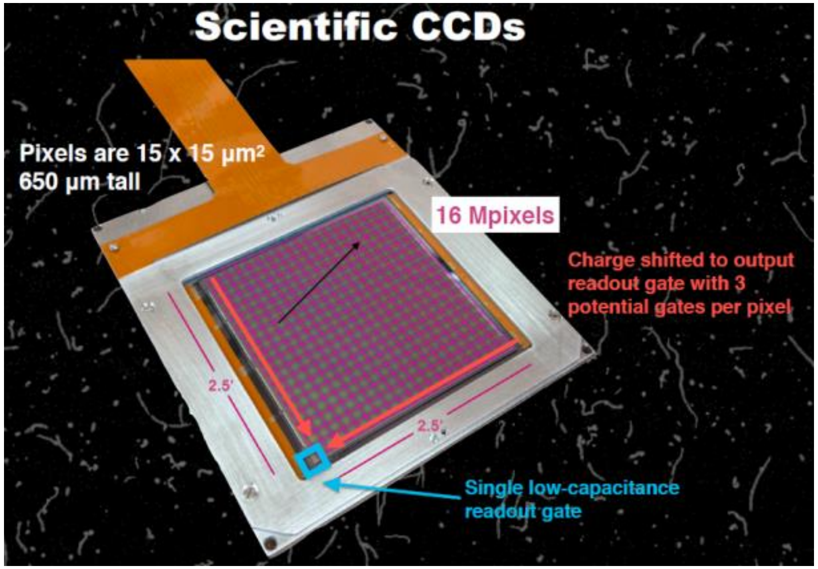
Coherent Neutrino Nucleus Interaction Experiment in CCDs

Ben Kilminster
U.Zürich

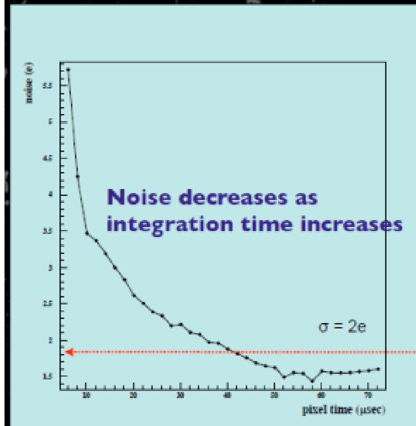


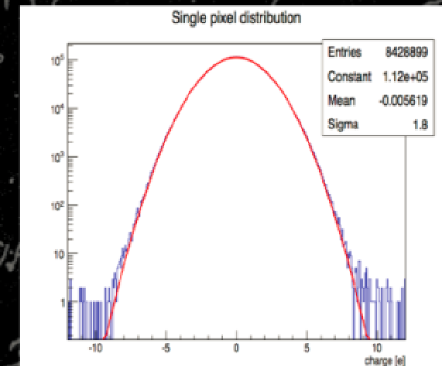
- Cross-section for CENNS much larger than for other neutrino interactions



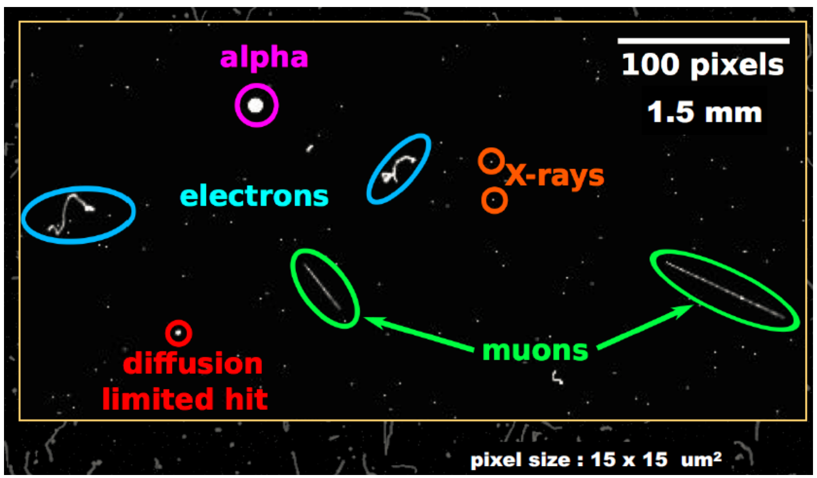


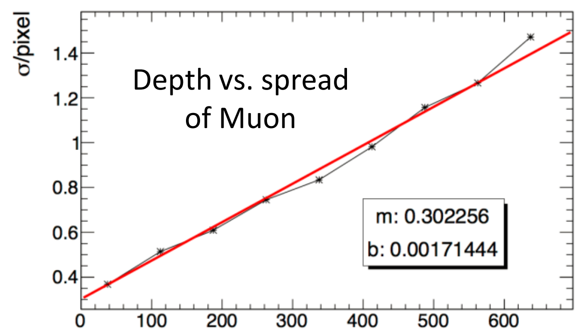
Detectors operate at -140 C
So dominant noise component is from readout
- Can be reduced by sampling pixel signals slower



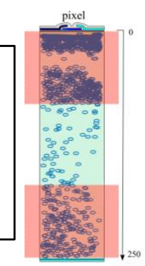


RMS noise of 1.8 electrons, or 6.5 eV in ionization energy !
- **Can run with 5σ threshold above noise of ~35 eVee**





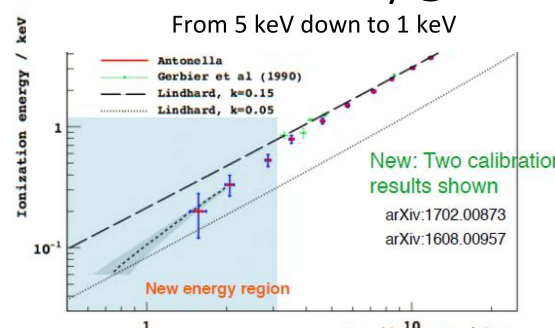
Useful for removing surface events

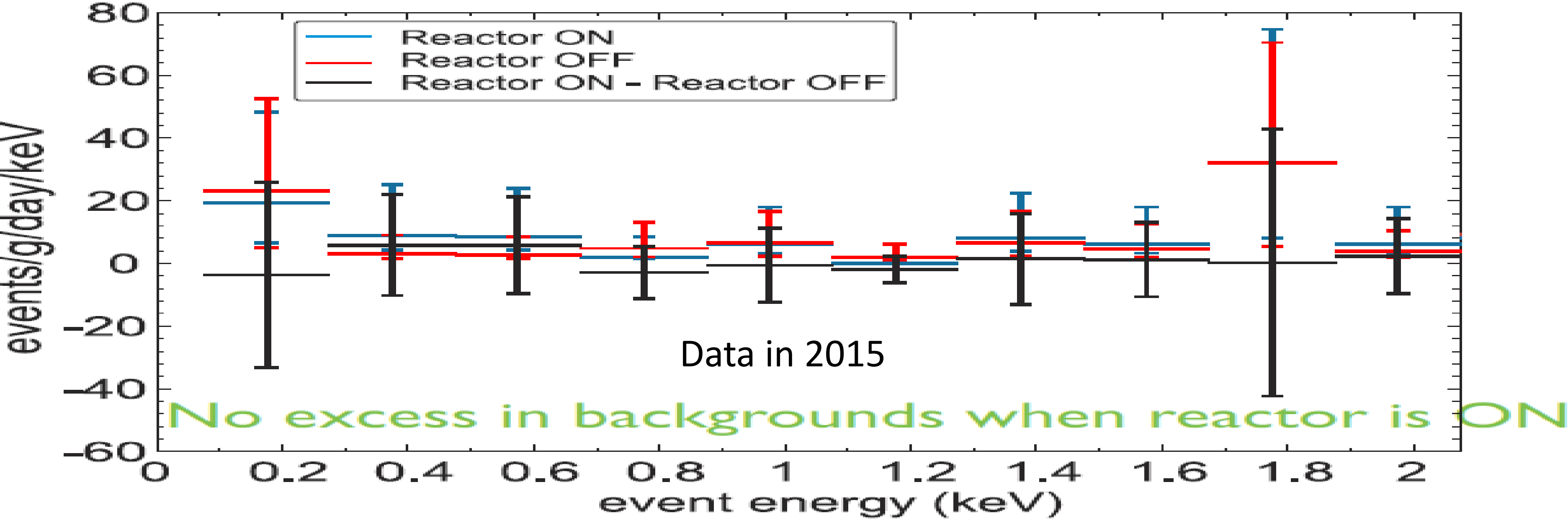


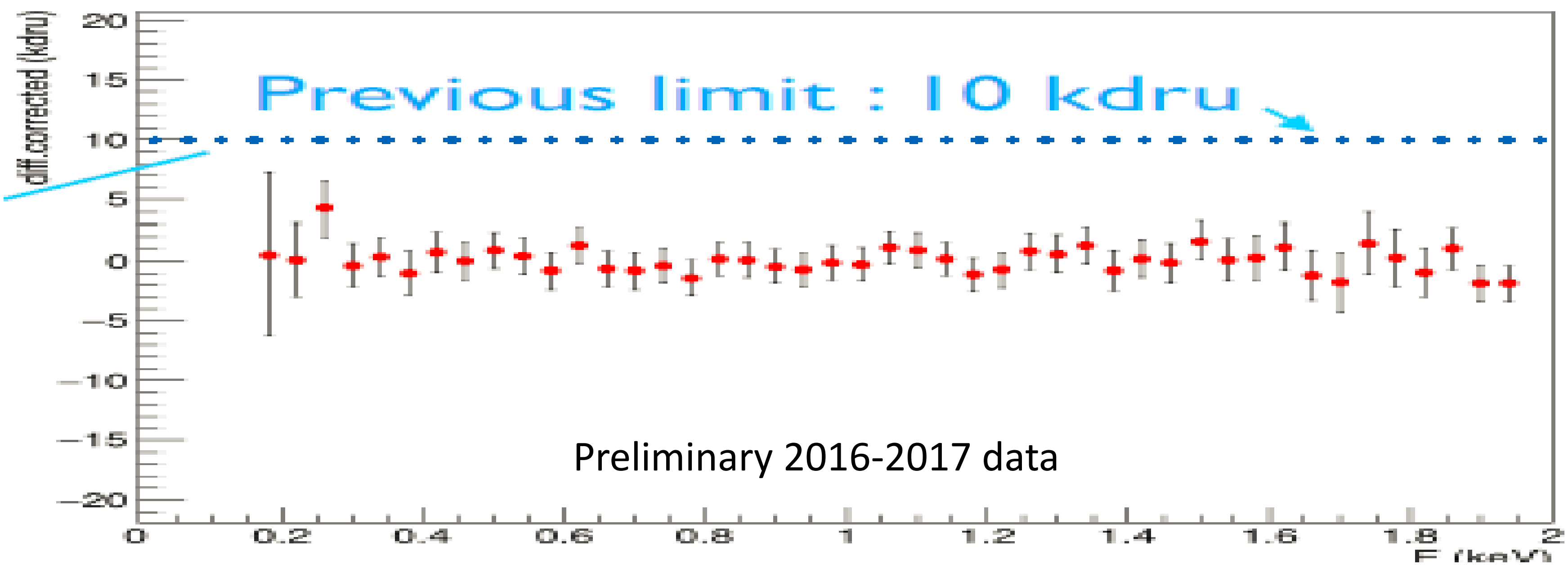
- Advantages : low noise, very good position and energy resolution
- Disadvantages : CCD only 1- 5 grams, no timing information

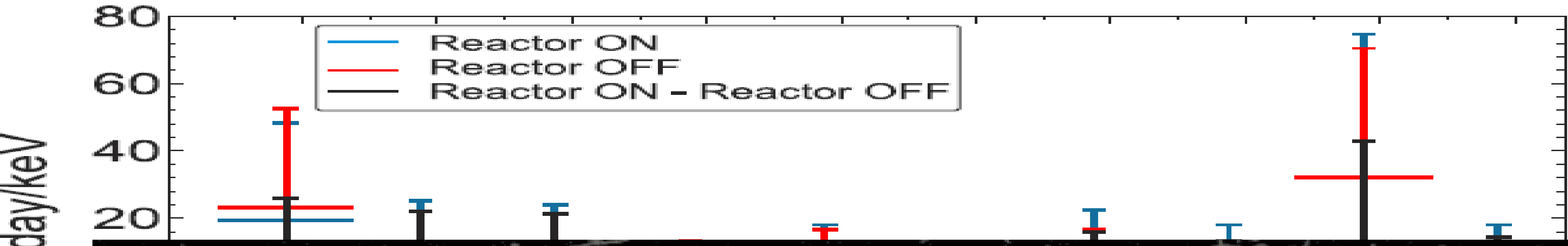
Ionization efficiency @ silicon

From 5 keV down to 1 keV




Reactor ON
Reactor OFF
Reactor ON − Reactor OFF
events/g/day/keV
80
60
40
20
0
−20
−40
−60
Data in 2015
No excess in backgrounds when reactor is ON
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
event energy (keV)


diff.corrected (kdru)
Previous limit : 10 kdru
20
15
10
5
0
−5
−10
−15
−20
Preliminary 2016-2017 data
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2



Improvements for CONNIE 2016	2015	2016
# CCDs	4	14
Detector mass [g]	4	83
CCD noise [e-]	2.7	1.8
Energy threshold [eV]	75	35
# ν / kg / d	8	13
Total # neutrinos per year	~12	~400
Backgrounds	15 keV background from ^{238}U in CCD AlN packaging	No AlN packaging

Summary

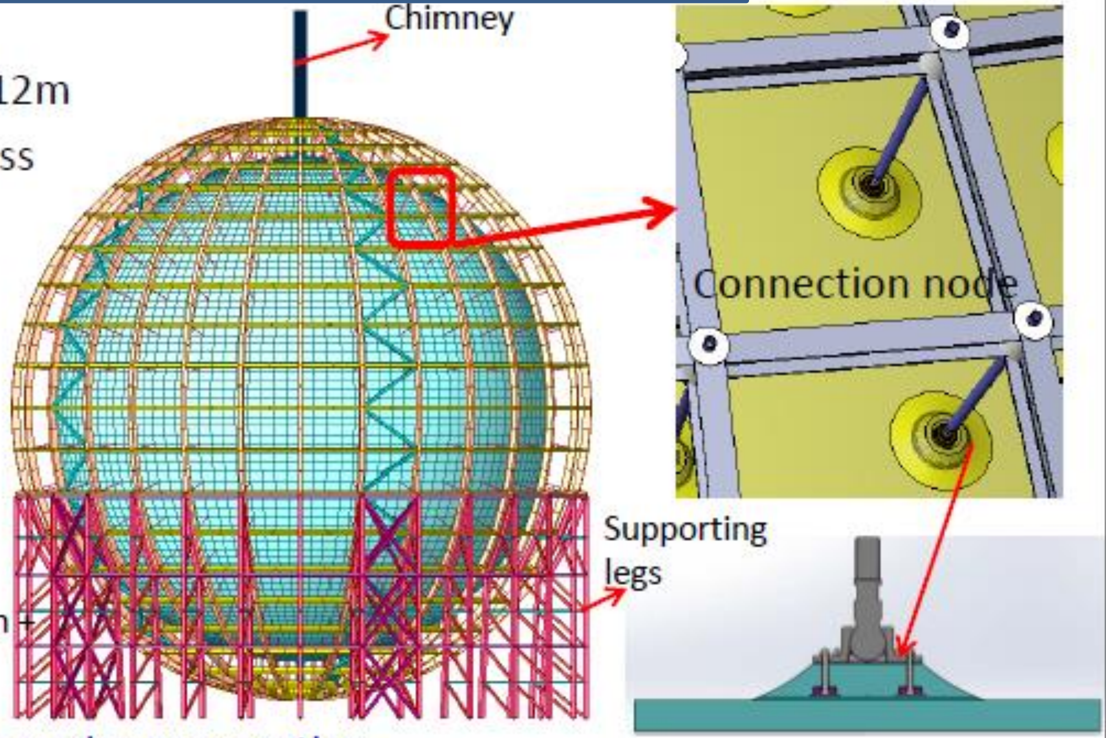
- Always on the way to NNN detector R&D: Working on projects with various target materials and technologies
  - Search for CP violation
  - Determination of MH
  - Precise measurements of oscillation parameters
  - Search for sterile neutrinos
  - Fundamental non-oscillation neutrino physics
- Good progressing on
  - Beam detectors
    - R&D and going to decision
  - Reactor/astro-neutrino detectors
    - Ongoing as planed
  - non-oscillation neutrino detectors

Thanks for your attention!

Backup

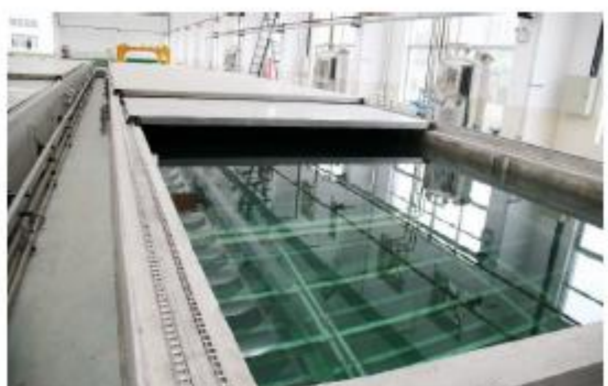
Acrylic sphere and Steel truss

- Engineering design is finished
  - 265 acrylic sheets of 3m x 8m x 0.12m
  - 23 (longitude) x 30(latitude) of truss
  - ~600 connection nodes
  - 1200 tons of weight
- Bidding is finished and contract is signed
  - acrylic sphere: Donchamp Acrylic company LTD.
  - steel truss: Nanjing AEROSUN Corporation + ZHEJIANG SOUTHEAST SPACE FRAME CO., LTD.



- Mass production of acrylic sheets is under preparation

MMA storage tank



water pool for acrylic polymerization

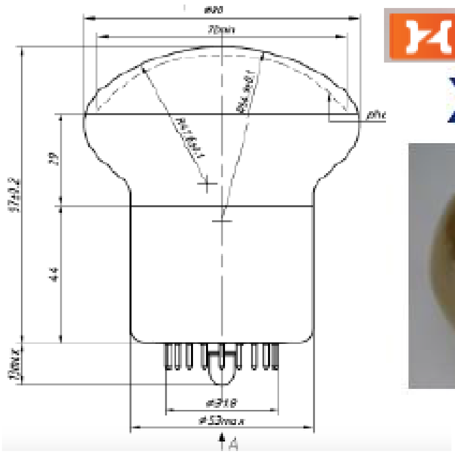
spherical sheet by thermal bending

Signed bidding with HZC for 25000 3” tubes

- Bidding is finished and contract has been signed with HZC company

  JUNO custom design: XP72B22
  - Upgrade of XP72B20
  - Dedicated R&D of better timing with JUNO input

  Start production from the beginning of 2018;



海南展创光电技术有限公司 HZC PHOTONICS

XP72B22

- XP72B22 performance requirements

Parameters	HZC’s response
QE×CE @ 420 nm	24% (>22%)
TTS(FWHM) of SPE	<5ns
P/V ratio of SPE	3 (>2)
SPE signal width (sigma)	35% (<45%)
Dark rate @ ¼ PE	1kHz (<1.8kHz)
QE uniformity	<30% in Φ60mm
Pre/after pulse ratio	<5%, < 15%
Nonlinearity	<10%@1-100PE
Radioactivity	238U: <400ppb, 232Th: <400ppb, 40K: <200ppb

- Test results of XP72B22 samples

  - QE: 23.5% - 26%; P/V: 3;

  - SPE resolution: <30%; TTS: 2-5ns

No.	Resolution	P-V Ratio	Gain@1350V	TTS(ns)
70195	0.231	4.889	2.5e+07	2.2
70197	0.276	6.818	2.3e+07	2.3
70215	0.245	2.832	0.4e+07	2.0
70218	0.251	5.239	1.0e+07	2.7
70219	0.279	4.592	0.6e+07	3.2
70222	0.269	6.657	1.5e+07	2.6
70226	0.239	7.800	2.3e+07	5.0
70236	0.249	6.440	2.2e+07	4.4

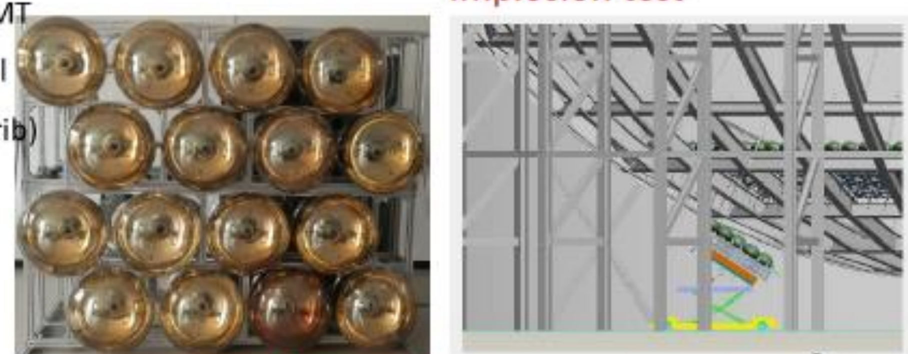
Progressing on PMT instrument

- Waterproof potting: Designed as multiple waterproof layers: putty tape + glue+ moisture prevention, to reach failure rate < 0.5% for the first 6 years;
- Implosion protection: acrylic + stainless steel protection covers; 50 prototypes and many implosion tests done.; thickness optimized;
- Single PMT assembly: parts integration;
- Installation: designed to achieve 75% coverage; Installation in parallel to acrylic sphere construction;


Waterproof potting

Implosion test

ıgle PMT assembly


PMT module design and installation

In the case of Tritium we estimate that 7.5 neutrino capture events per year are obtained using a total mass of 100 g

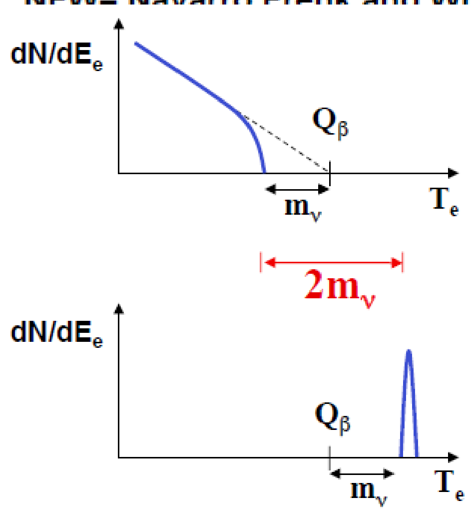
In case of CνB gravitational clustering we expect a significant signal enhancement

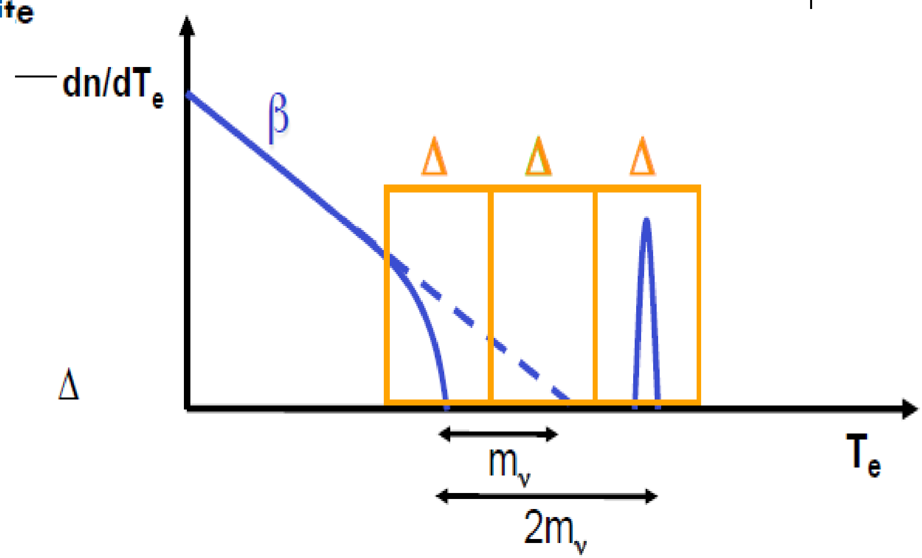
m_ν (eV)	FD (events yr^{-1})	NFW (events yr^{-1})	MW (events yr^{-1})
0.6	7.5	90	150
0.3	7.5	23	33
0.15	7.5	10	12

FD = Fermi-Dirac, NFW= Navarro Frenk and White

Nuclear Beta decay

Neutrino Capture on a Beta Decaying Nucleus



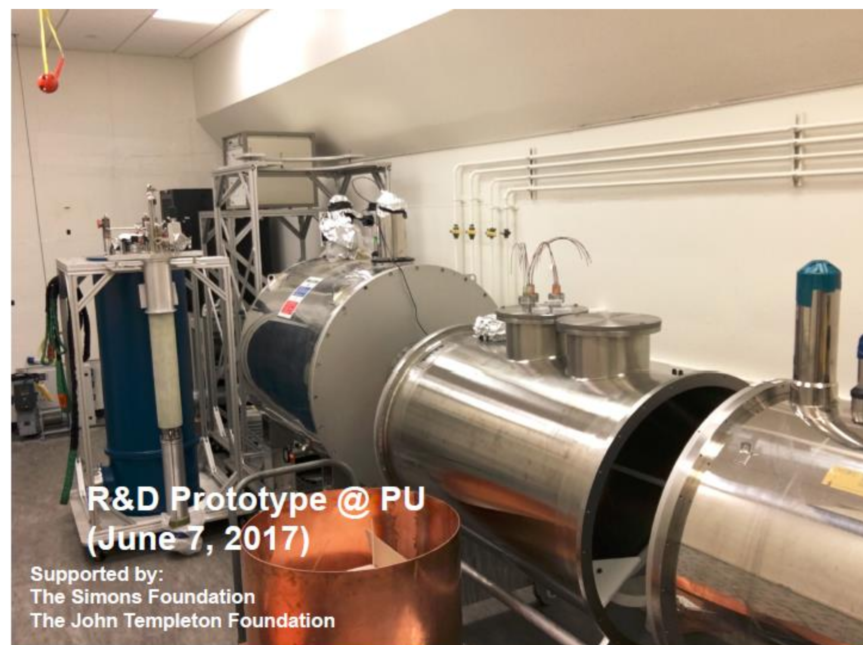


Three major challenges

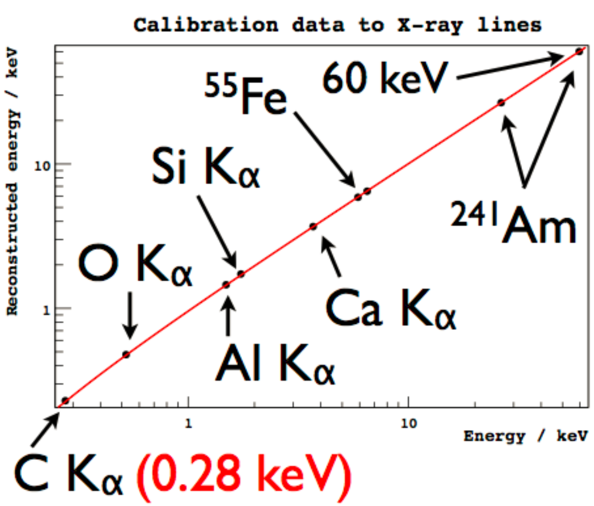
- Reduce target induced E_e smearing (molecular effects)
  New source (Tritiated-Graphene or Cryogenic Au(111))
- Compress a 70m spectrometer length (KATRIN) down to cm scale and replicate it 10^4-10^6 times (lower precision since final measurement made by the microcalorimeter)
  - New ExB filter concept
  - RF tag/triggering (Project 8 development)
  - Graphene-FET (G-FET) as a potential trigger system
  Phys. Lett. B 772(2017)239
- Measure the energy spectrum directly with σ_E ~ O(0.1 eV) or better
  High-resolution electron microcalorimeter

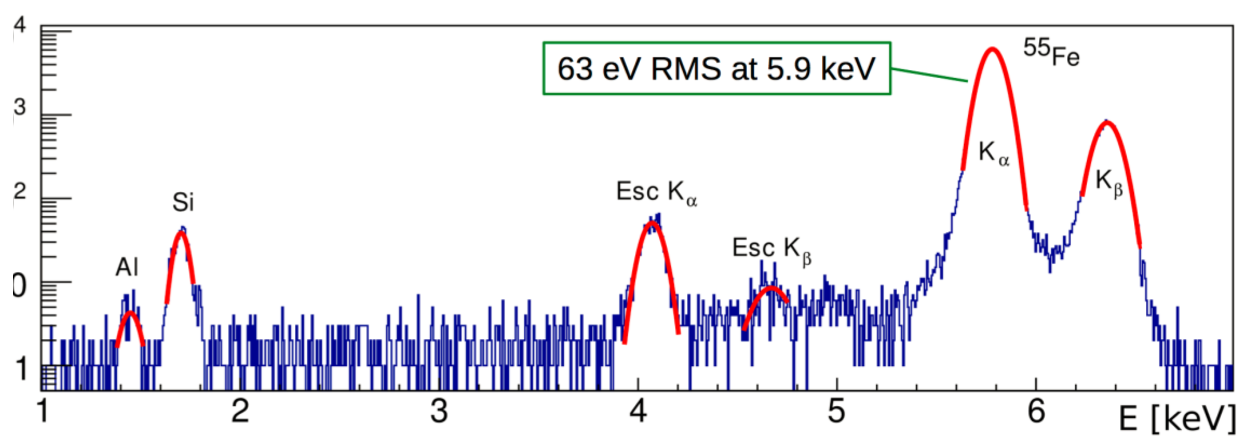
Data-taking tests with full setup scheduled by the end of the year

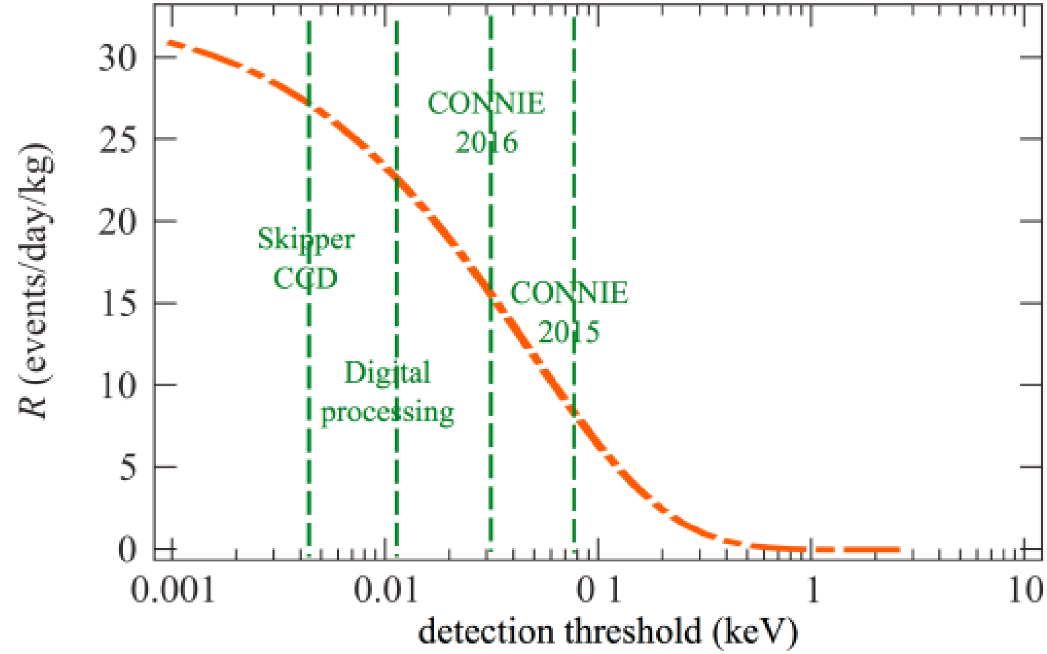
The prototype will be moved to Laboratori Nazionali del GranSasso (ITALY) in 2018 to perform tests in a background free underground environment



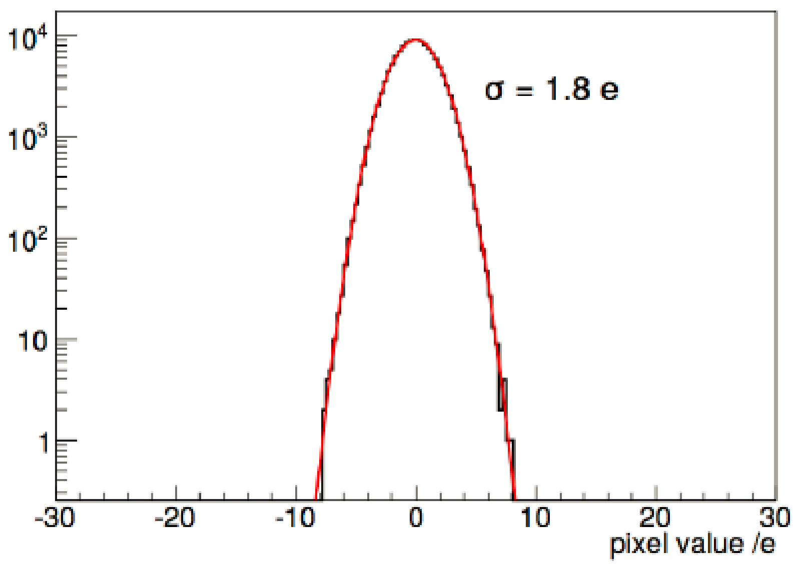
Flux at detector of 7.8·10^12 ν/s/cm2





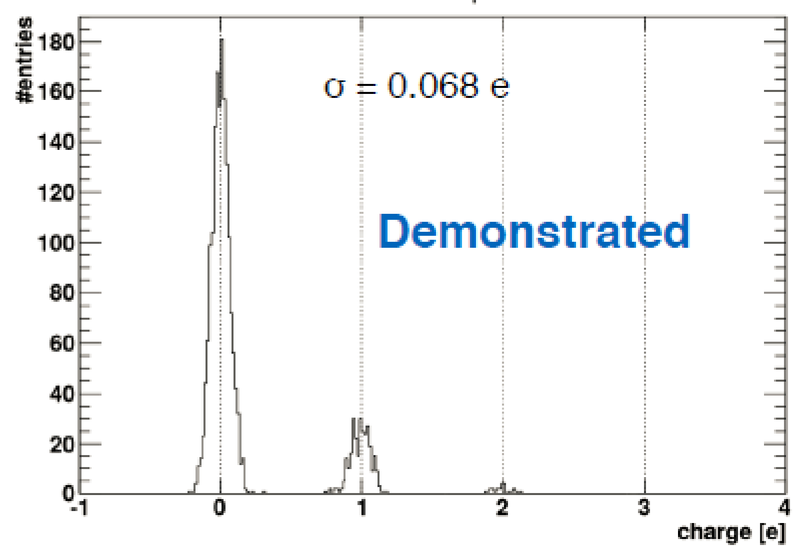


CONNIE now



Skipper CCD

4000 samples



Javier Tiffenberg et al, Phys.Rev.Lett. 119 (2017) no.13 , arXiv:1706.00028 (arXiv:1706.00028)