PandaX III: A 200kg High Pressure Xe Gas TPC

Searching for ^{136}Xe Neutrino-less Double Beta Decay

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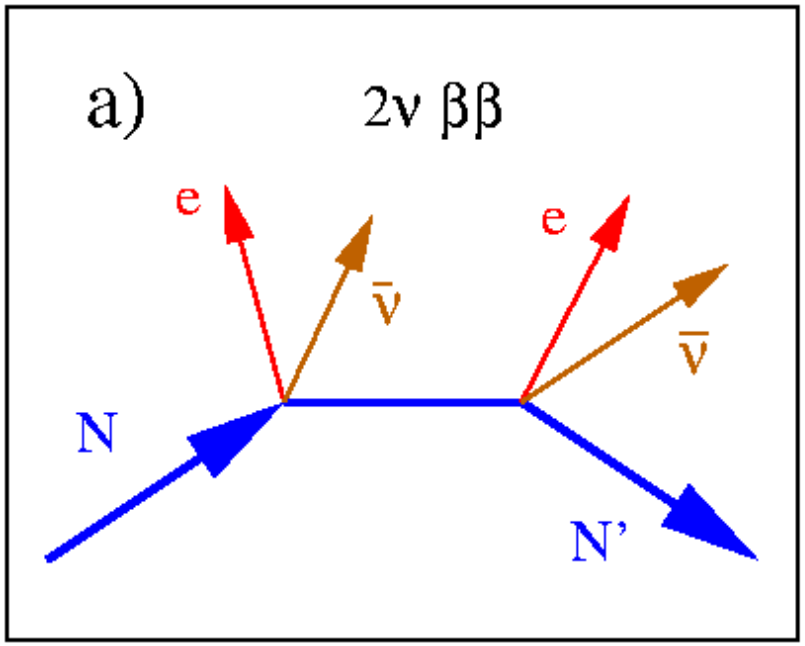
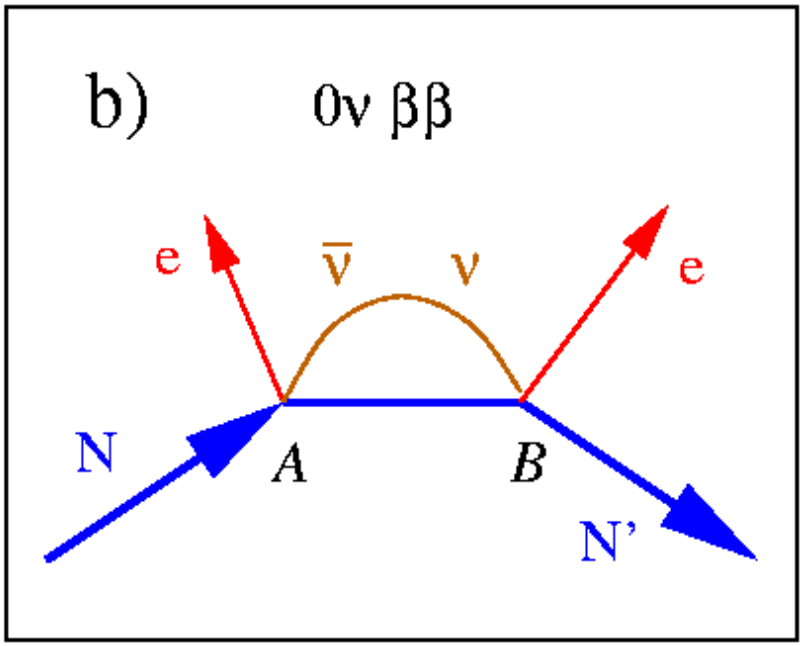
Two Types of Double Beta Decay





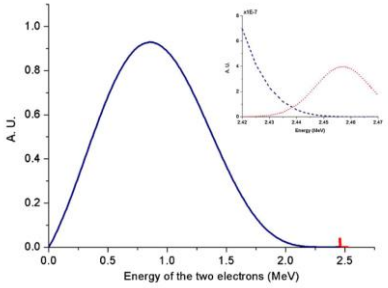
2νββ mode:
- a conventional
- 2nd order process
- in Standard Model

Observation of 0νββ:
- **Majorana neutrino**
- **Neutrino mass scale**
- **Lepton number violation**

Key requirements for discovering 0νDBD

1. Low radioactivity (more stringent requirement than for DM search)
2. Good energy resolution (sub% level)
3. Distinguishing Background from 0νDBD (Tracking, Cerenkov Radiation)
4. Scalability

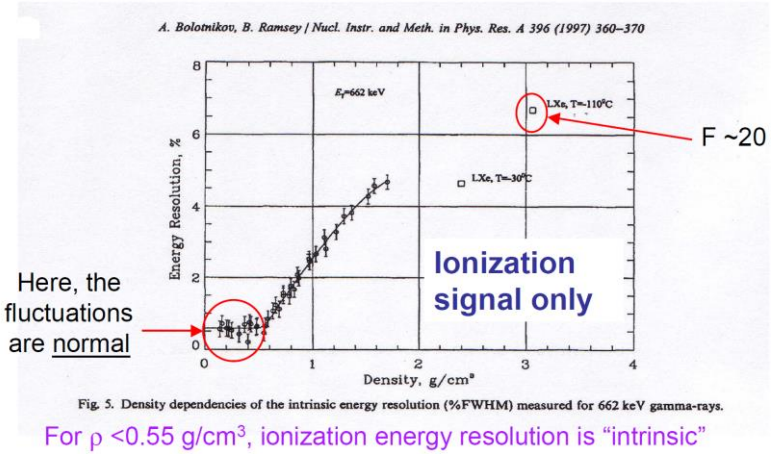
(price of isotope, exp expandability)



New Game: HP Gas TPC

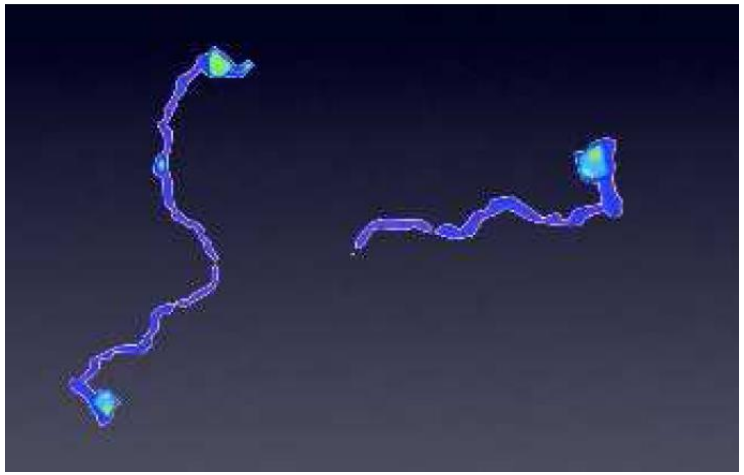
- possibly excellent energy resolution: intrinsic 0.3% FWHM (7.5 keV)
- Low-background (10^{-3} counts/keV/kg/yr)
- Tracking capability
- Scalability (there is already 1 ton ^{136}Xe in the world, $30M)

- Advantages of High Pressure



For ρ <0.55 g/cm^3, ionization energy resolution is “intrinsic”

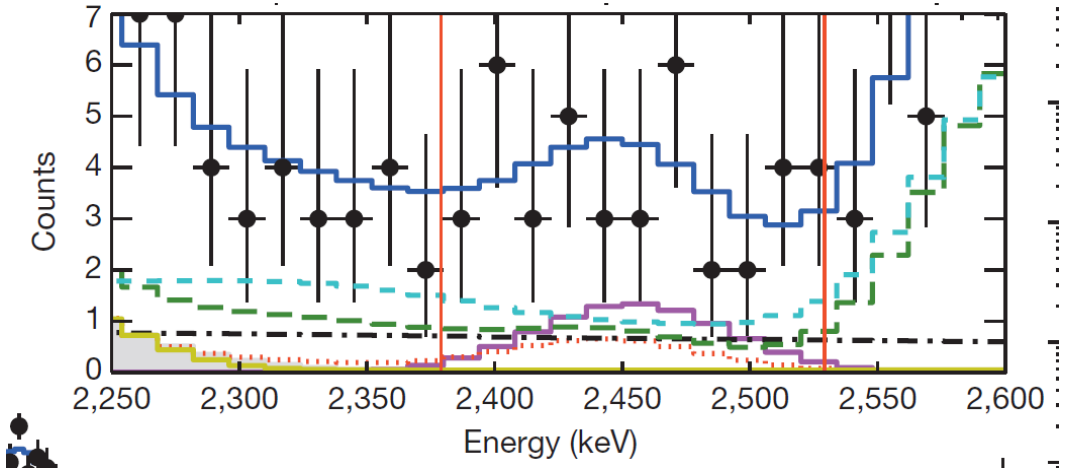
- Tracking capability



Best Result with ^{136}Xe: EXO200

EXO200: Nature 2014

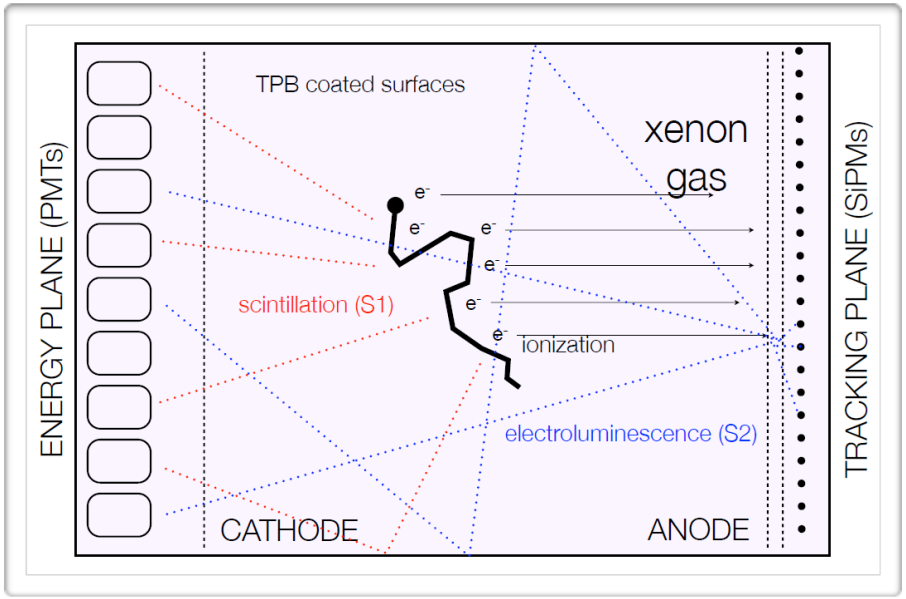
- 200kg Liquid Xenon TPC, 2 years of running
- Superb control in radioactivity and energy resolution (3%)
- 39 events observed in 2σ region. 31 background events expected



Comparison with EXO200 Results

- Same mass: 200 kg of enriched ^{136}Xe
- Similar radioactive background
- Similar energy resolution < 3% FWHM
- Tracking capability (99% γ-ray rejection)
- Background Free: In 2 years, 31 events are reduced to 0.3 events!

NEXT Experiment Fundamentals



EL mode is essential to get lineal gain, therefore avoiding avalanche fluctuations and fully exploiting the excellent Fano factor in gas

- It is a High Pressure Xenon (HPXe) TPC operating in EL mode.
- It is filled with 100 kg of Xenon enriched at 90% in Xe-136 (in stock) at a pressure of 15 bar.
- The event energy is integrated by a plane of radiopure PMTs located behind a transparent cathode (energy plane), which also provide t0.
- The event topology is reconstructed by a plane of radiopure silicon pixels (MPPCs) (tracking plane).

PandaX-III High Lights

- Alternative Realization For Read out: Symmetric Charge Read out
  - Stage1:MircoMegas, energy resolution 2-3% FWHM
  - Stage2:TopMetal (modified CMOS), energy resolution 0.5%
  - Benefits: radiopurity, scalability, and ultimate energy resolution, tracking
- Light readout? (optional)
- New type HP vessel
- 200 kg modules for scalability to 1 ton
- Deepest underground lab (CJPL)

PandaX-III Physical goals

- 200kg module
  - Demonstrate Potential of Technology
  - Possibly Discovery of 0vbb
- Easy upgrade to 1 ton (5 modules)
- Timely realization of G2 neutrino experiment Covering the Inverse Mass Hierarchy Range
  - JUNO, LBNF, INO, known by 2020?
  - What if it is inverse mass hierarchy?

^{136}Xe 0νDBD Events

- 2 electrons with total energy 2.458 MeV

  Roughly 100k ionization electrons

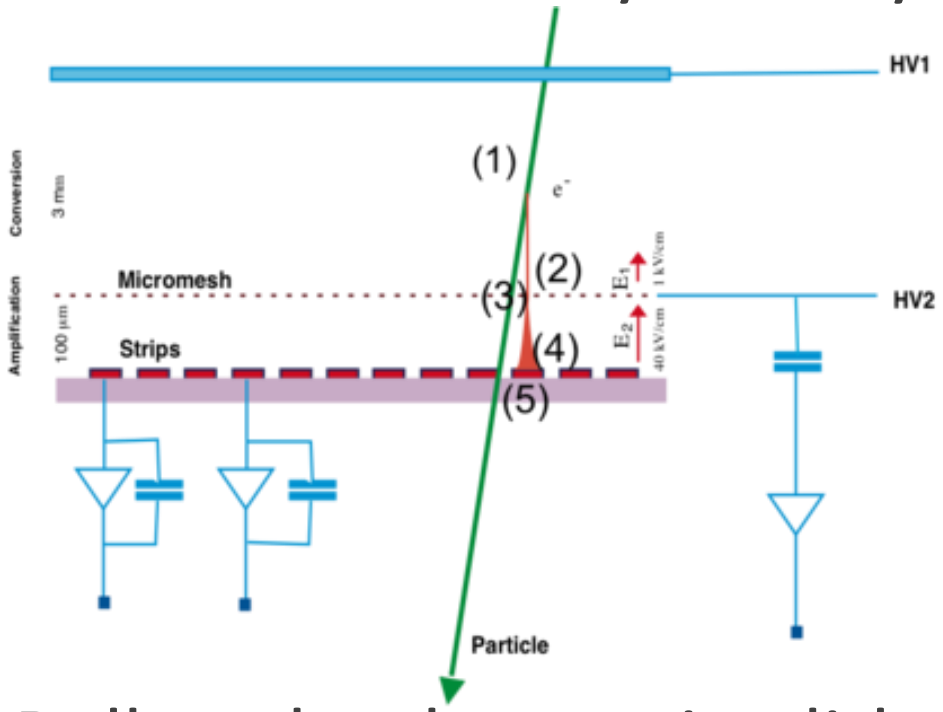
- Track size in 10 bar gas, about 30 cm

  2 tracks from same vertex, roughly back to back, increasing ionization density towards ends of tracks

- Ionization measurement along track

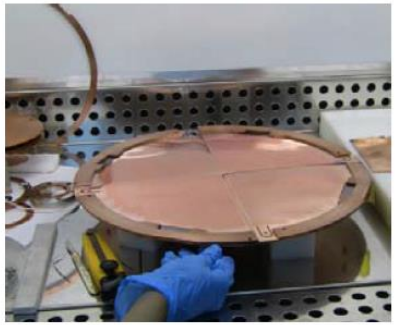
Read Out Option 1: Micromegas

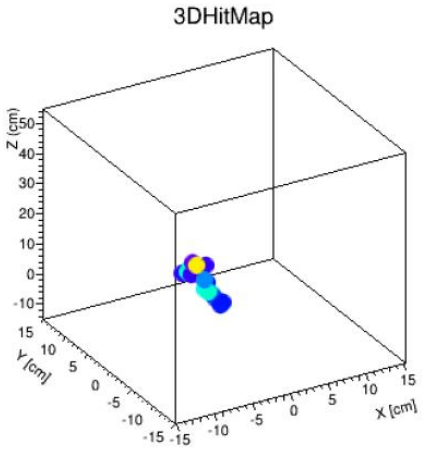
- Micromegas working principle: gas amplification across very thin layers 50µm

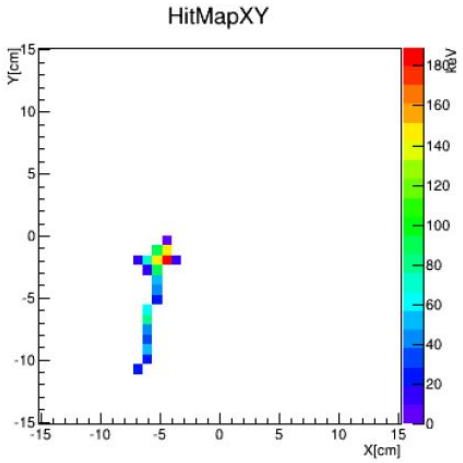


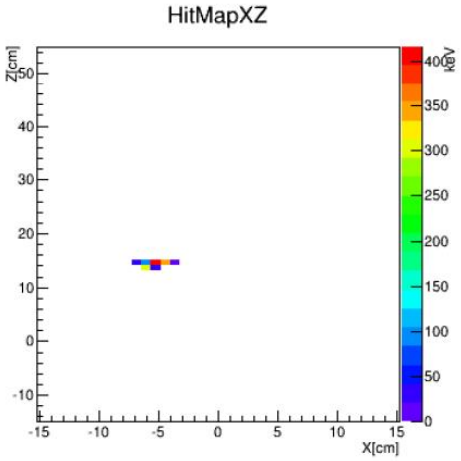
- MicroBulk technology, using lithographic techniques. Superb quality!

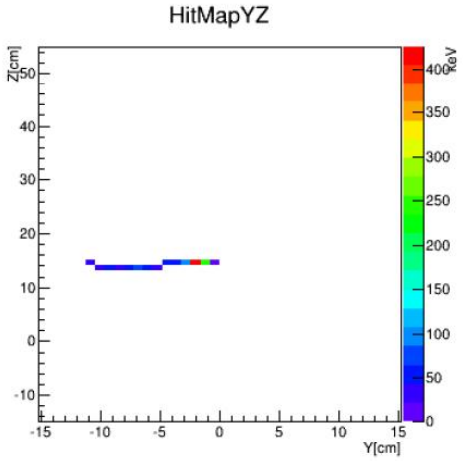
Real tracks in NEXT-MM @ UNIZAR









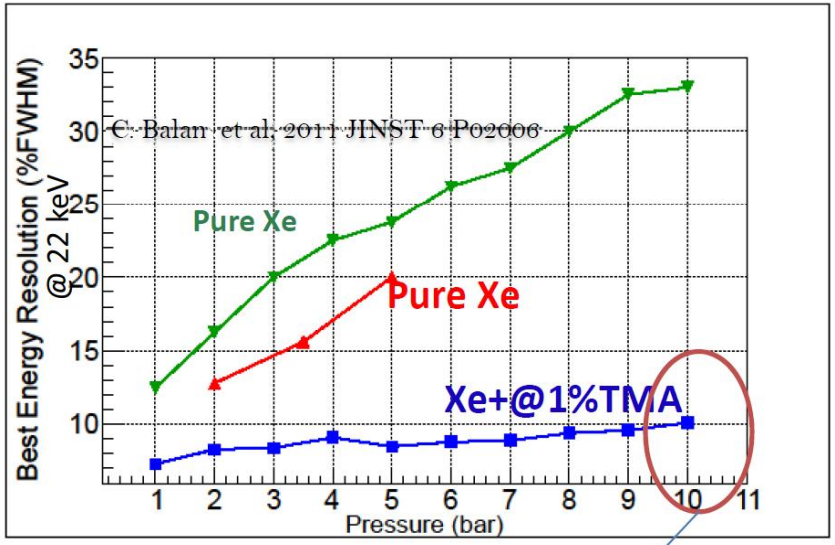


Energy
~1274 keV
(Na-22
photo peak)

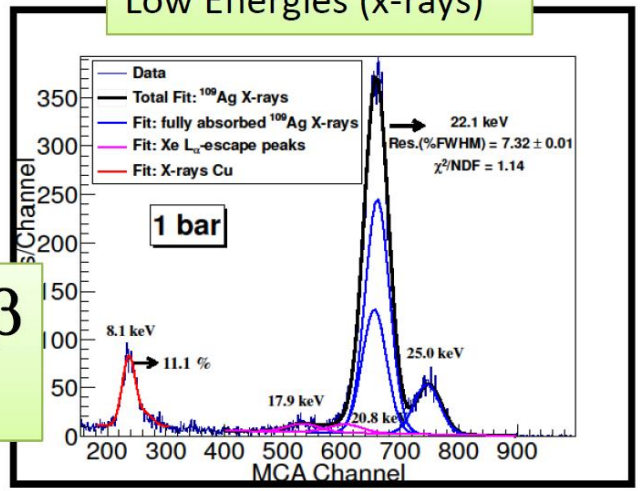
"half a $2\nu\beta\beta$
event"

Energy resolution … in Xenon?

- Addition of TMA to Xe: perfect combination!
- higher gains, better E res, more stable operation



Small setup TREX-BB-0
Low Energies (x-rays)



0.9% FWHM @ Qββ
10 bar

Read Out: Two Ends Plates

- Area = πr^2 = (0.70)^2 π = 1.5 m^2
- Either Pixel Size = 0.5cm^2
- Total Number of **Pixels**: 30, 000 x 2 = **60 k**
- Or Strips (X – Y), 0.5 cm Wide, 20 cm Long
- Total Number of **Strips**: 3,000 x 2 = **6 k**

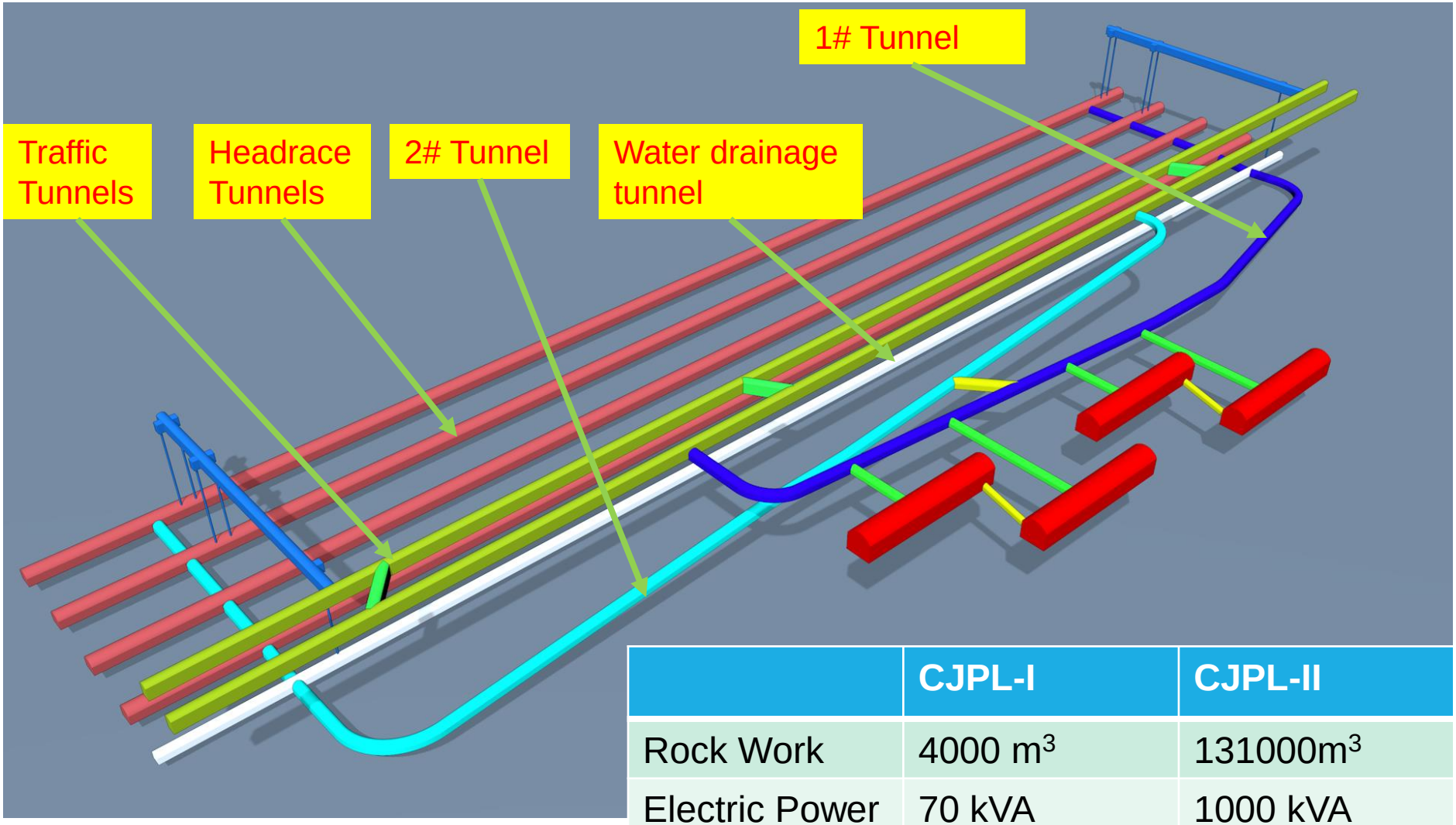
Requirement for FE Electronics

- ASIC chips, mature technology

  AGET (AFTER) , 64 channel

- Radioactivity? Need to be integrated as much as possible,
- High-pressure 10-15bar

Preliminary Design of CJPL-II



	CJPL-I	CJPL-II
Rock Work	4000 m^3	131000m^3
Electric Power	70 kVA	1000 kVA
Fresh Air	2400 m^3/h	40000 m^3/h

Schedule

- (Aggressive) and Competitive among next generation of DBD expts
- Research and design during 2015
- Construction and Installation during 2016
- Start commissioning early 2017

Prospective Collaborators

Country	Institution	Main Interest
China	SJTU	Gas System, ASIC design
	USTC	Electronics, MicroMegas
	PKU	Background Counting
	ZSU	Background Counting, Simulation
	CCNU	Alt. Detection(Topmetal)
France	CEA	Electronics, ASIC Design (AGET)
Russia	MEPHI	Vessel, ^{136}Xe Enrichment
Spain	Zaragoza	MicroMegas, TMA Doping
US	Maryland	Alt. Detection (Topmetal), Simulation
	LBL	Alt. Detection (Topmetal)
	Princeton	Radioactive Background Reduction

Summary

- $0\nu\beta\beta$ might be most important discovery in particle/nuclear physics in next 5-10 yrs.
- Current generation of experiments has not shown scalability to 1 ton, necessary to cover inverted ν mass hierarchy
- HP xenon gas TPC is the most promising technology to reach 1 - 5 ton
- Many key ingredients already in place