

Neutrino Program in China **in a World-wide Picture**

Jun CAO

Institute of High Energy Physics

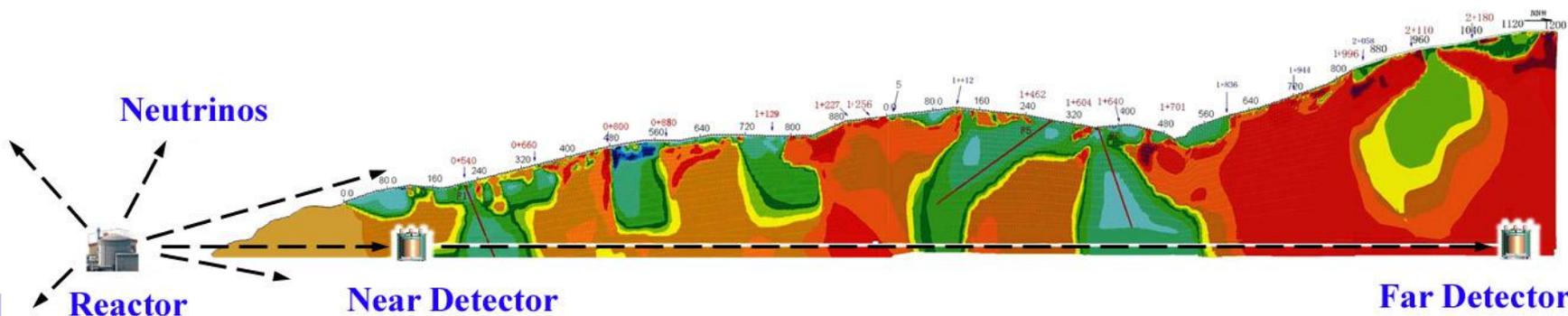
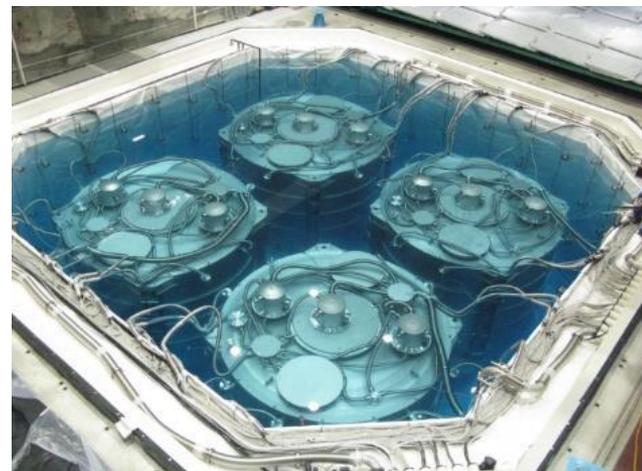
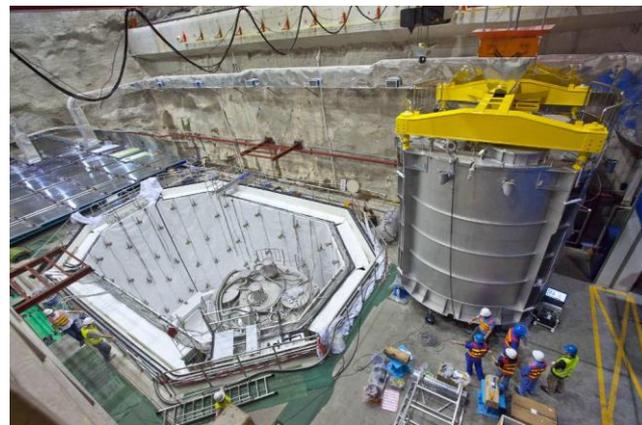
La Thuile, Feb. 27, 2014

Reactor Proposals for θ_{13}



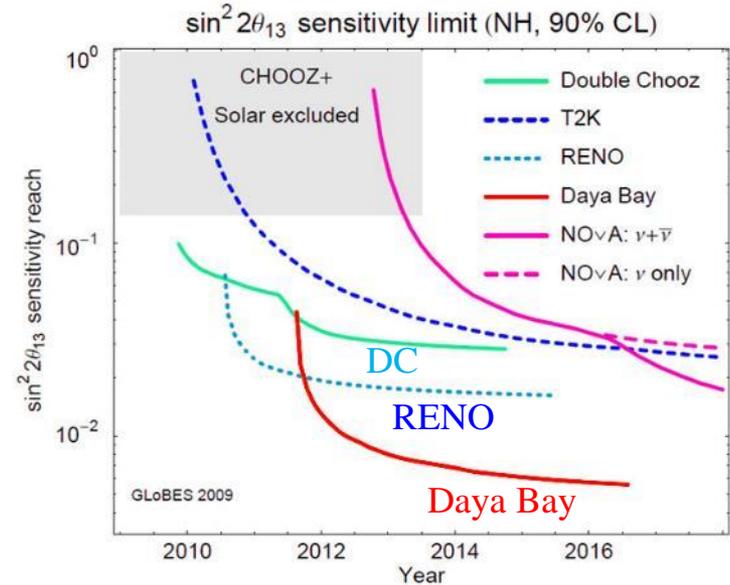
- ◆ Daya Bay was proposed in 2003, the start point of Neutrino Program in China.
- ◆ 3 of the 8 proposals are constructed.

Daya Bay Scheme



The Best Site for θ_{13}

- Top 5 powerful reactor complex.
- Close to mountains → enough shielding, horizontal tunnel enable a large scale experiment.
- Luminosity 5-20 times of DC and RENO.
- Featured design → side-by-side calibration (2-4 ADs at each site) → actual relative det. error 0.2% / \sqrt{N} ,
- Discovered an unexpectedly large θ_{13} in Mar. 2012.

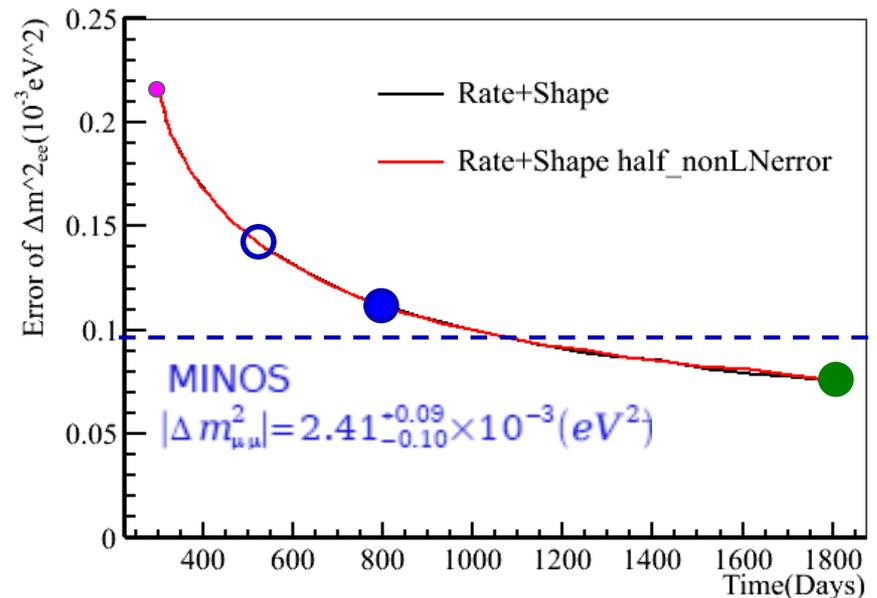
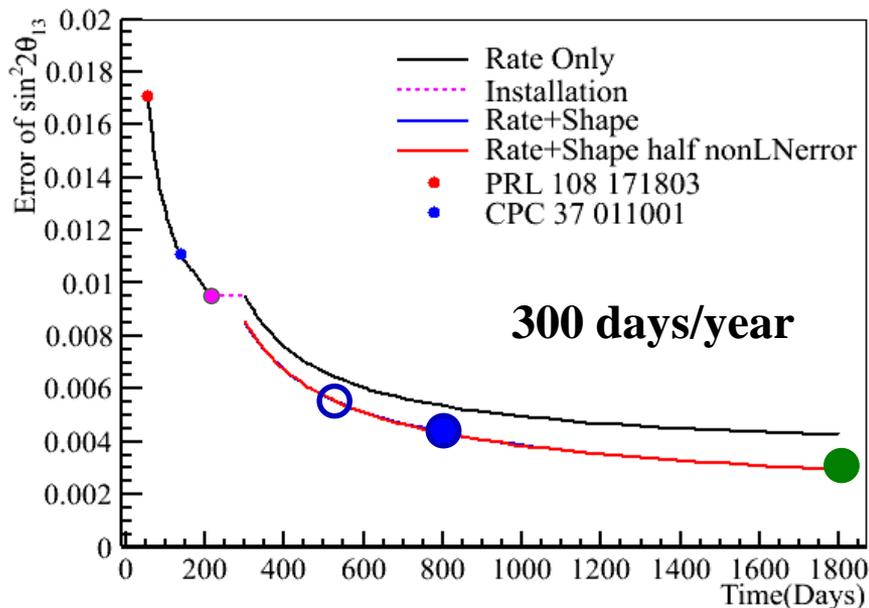


Huber et al. JHEP 0911:044, 2009

Designs	Luminosity (ton·GW)	Detector Systematics	Overburden (near/far, mwe)	Sensitivity (3y, 90%CL)
Daya Bay	1400	0.38%/√N	250 / 860	~ 0.008
Double Chooz (France)	70	0.6%	120 / 300	~ 0.03
RENO (Korea)	260	0.5%	120 / 450	~ 0.02

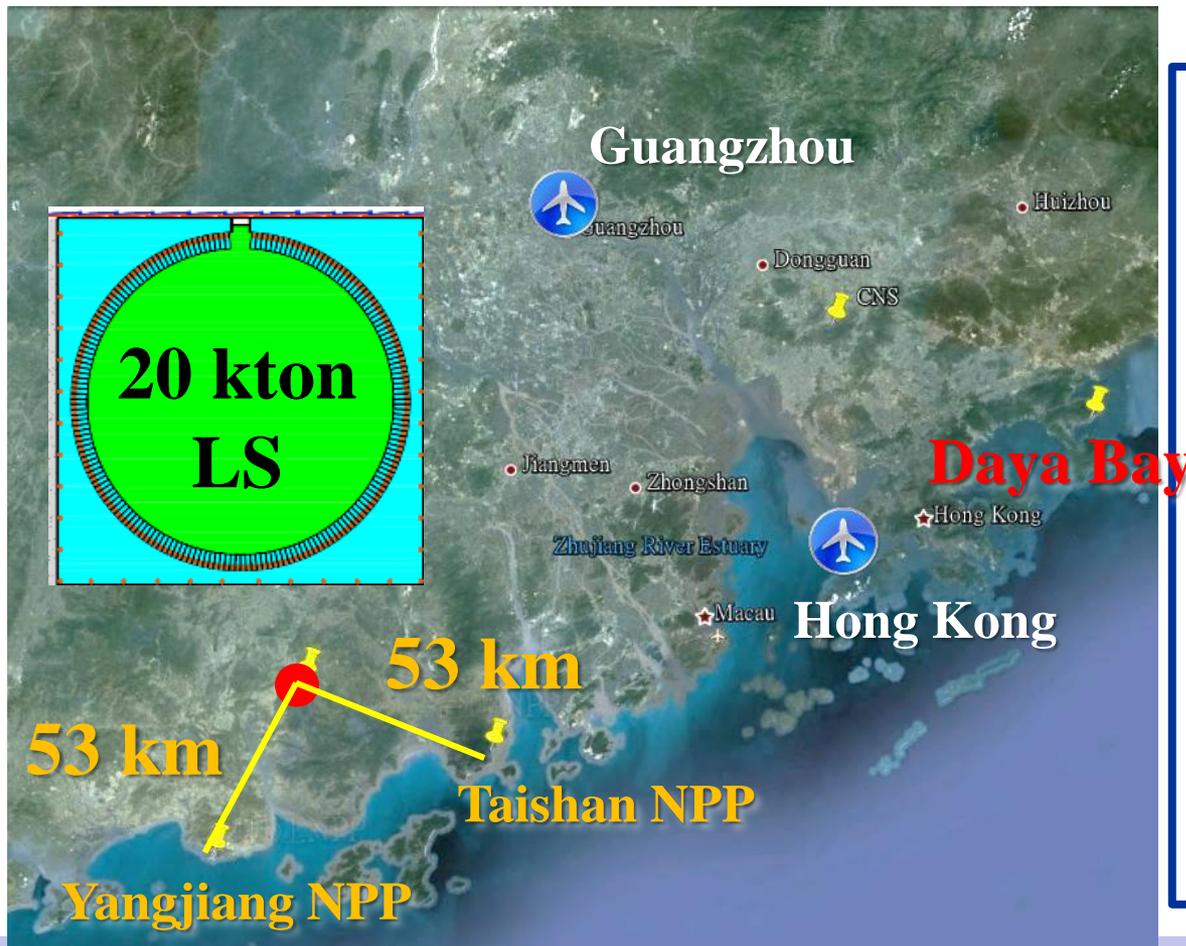
Daya Bay Future

- ◆ **Collaboration:** China (22 institutions) + US (16) + Russia (1) + Czech (1)
- ◆ Daya Bay will run to **2017**. Measuring $\sin^2 2\theta_{13}$ to 3-4% precision, the best in tens of years.
- ◆ First and most precise direct measurement of $|\Delta m_{ee}^2|$, better than $|\Delta m_{\mu\mu}^2|$ from accelerator exp. The most precise reactor neutrino spectrum, and ...



JUNO Experiment

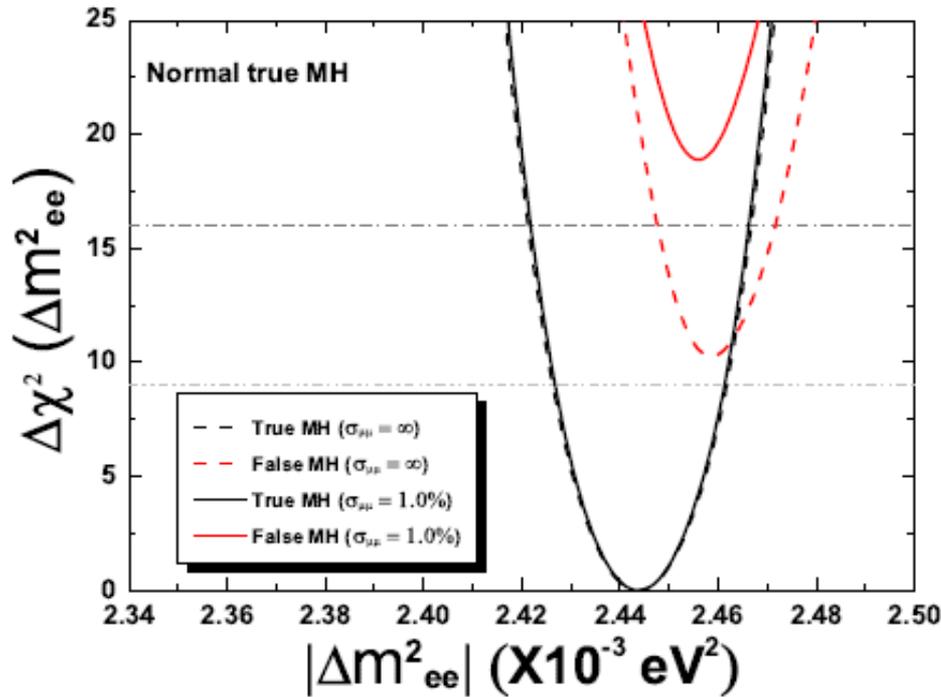
- **JUNO: Jiangmen Underground Neutrino Observatory**
- Aims at **mass hierarchy** and **precision meas.**, rich physics.
- Proposed in 2008, approved in Feb. 2013, ~300 M\$



Rich physics

- **Mass hierarchy**
- Precision measurement of oscillation parameters
- Supernovae neutrino
- Geo-neutrino
- Solar neutrino
- Atmospheric neutrinos
- Sterile neutrino
- Exotic searches

Sensitivity on MH and Parameters



	Current	DYB II
Δm^2_{12}	3%	0.6%
Δm^2_{23}	5%	0.6%
$\sin^2\theta_{12}$	6%	0.7%
$\sin^2\theta_{23}$	20%	N/A
$\sin^2\theta_{13}$	14% → 4%	~ 15%

**New physics searches:
Check the unitary of mixing
matrix to ~1%**

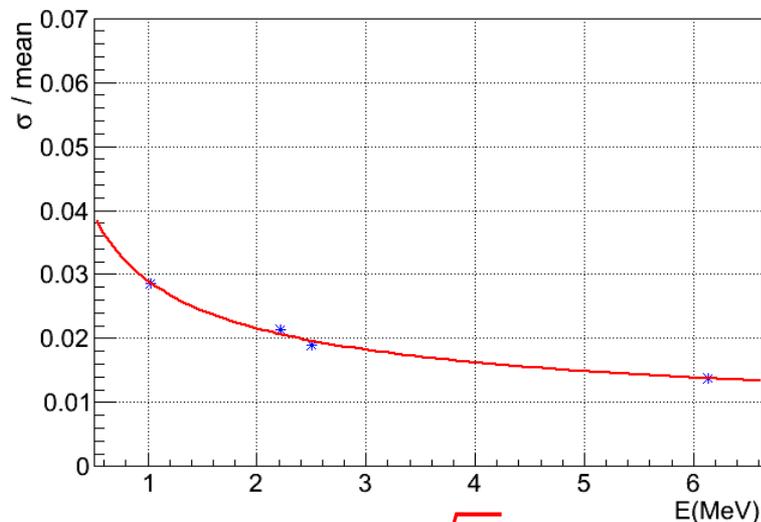
MH sensitivity with **6 years'** data of DYB-II (Y.F.Li, et al. PRD88, 013008 (2013))

- **Ideal case: 4σ** with relative measurement, **5σ** with absolute Δm^2 measurement
- Taking into account the spread of reactor cores, uncertainties from energy non-linearity, etc. **3σ** with relative measurement, **4σ** with absolute Δm^2 measurement

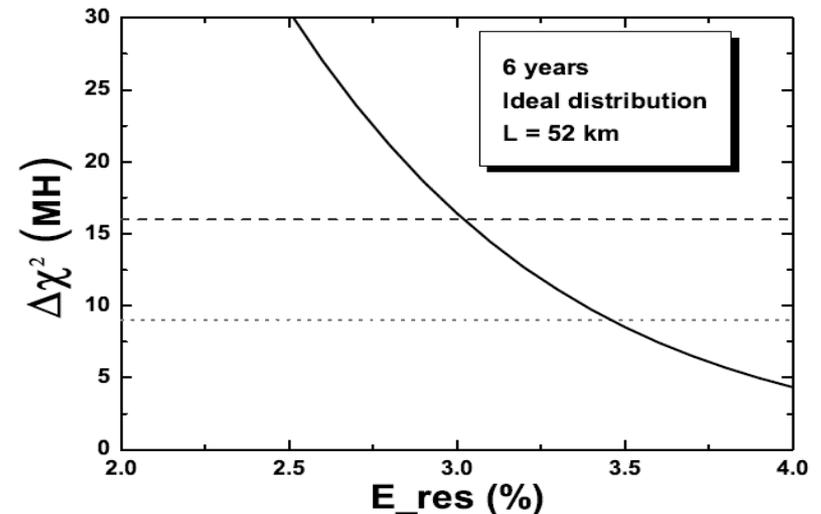
JUNO Energy Resolution

- ◆ JUNO MC, based on DYB MC (p.e. tuned to data), except
 - ⇒ DYBII Geometry and **80%** photocathode coverage (76%)
 - ⇒ High QE PMT: maxQE from 25% -> **35%** ?
 - ⇒ Increase light yield of LS (**+13% light**) ?
 - ⇒ LS attenuation length (1 m-tube measurement@430 nm)
 - from 15 m = absorption 24 m + Raylay scattering 40 (Raylay 27m?)
 - to 20 m = **absorption 40 m** + Raylay scattering 40 m

Red parts denote the R&D requirements to reach 3% energy resolution



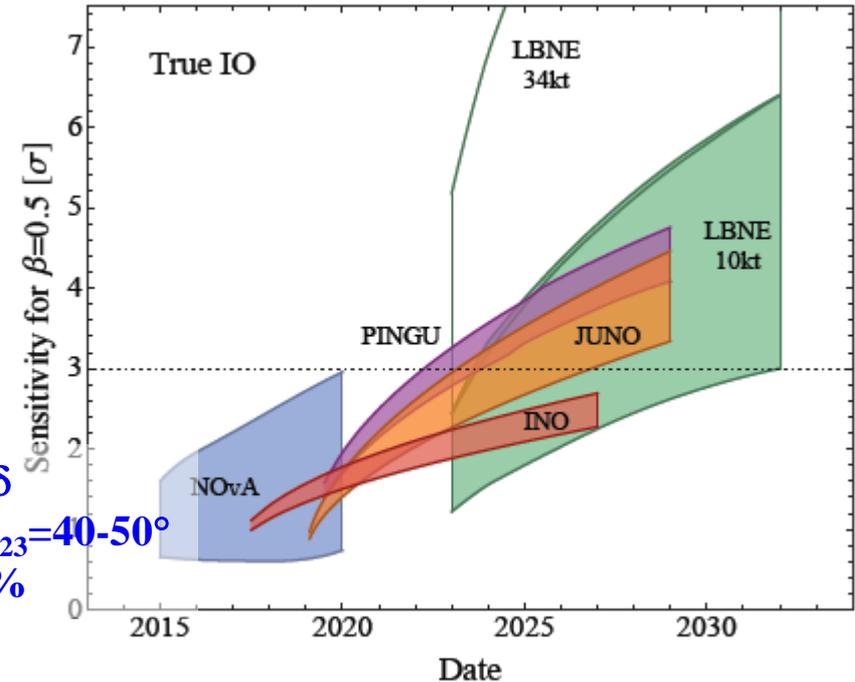
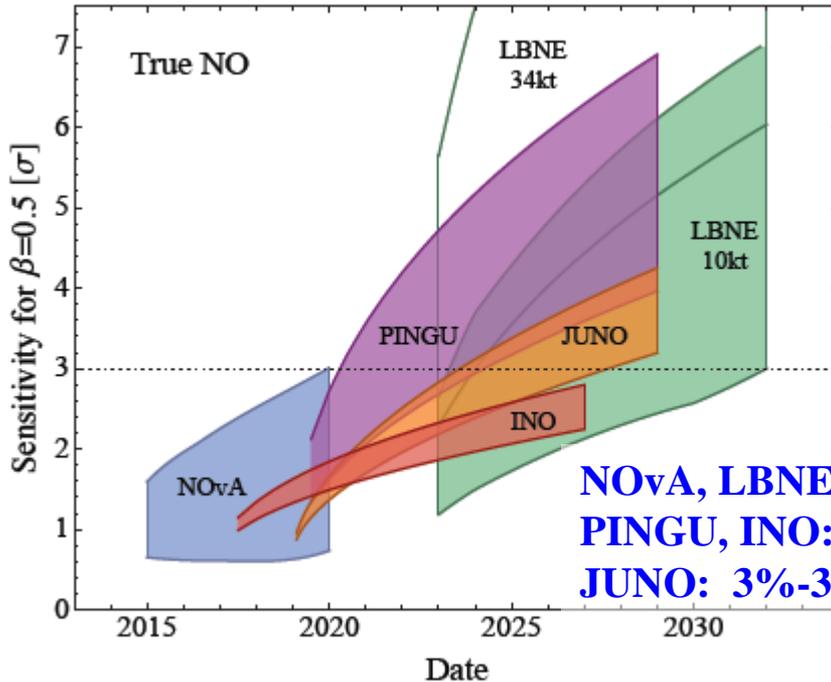
$3.0\% / \sqrt{E}$



Discovery power vs energy resolution

Other Experiments/Proposals for MH

M. Blennow et al., arXiv:1311.1822(2013)



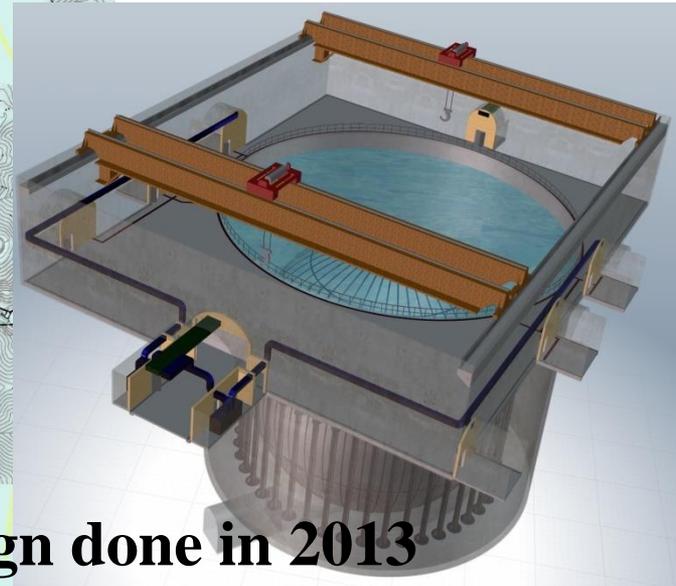
JUNO: the only reactor neutrino experiment, Competitive in schedule and Complementary in physics.

- Have chance to be the first to determine MH
- Independent of the yet-unknown CP phase and θ_{23} (Acc. and Atm. do)
- Combining with other experiments can significantly improve the sensitivity
- **Precise Δm_{31}^2 , θ_{12} , Δm_{21}^2 , Geo-, solar, supernova, ..., neutrinos**

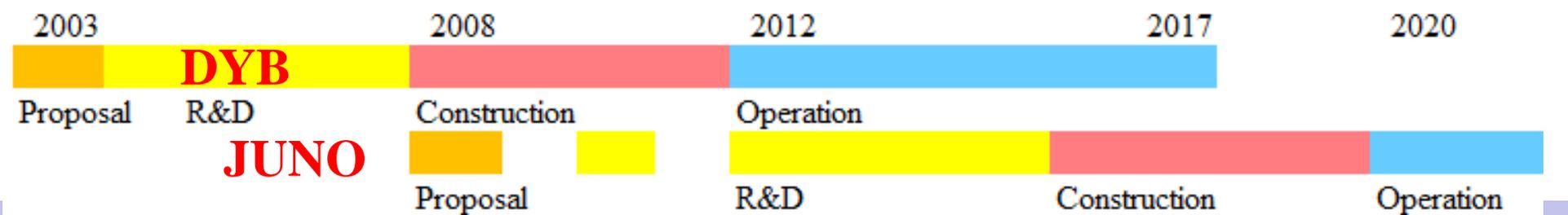
Progress and Schedule

Expected in 2014

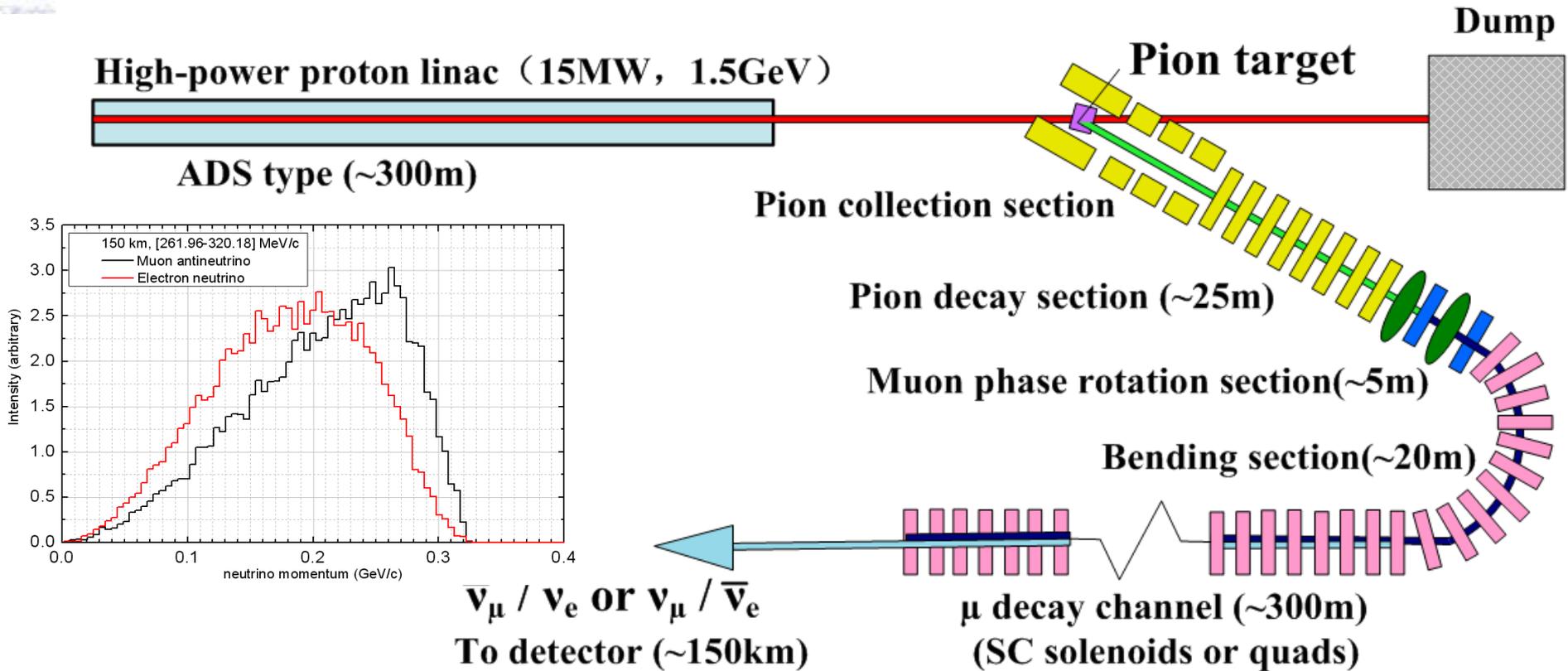
- Ready for civil construction (takes 3 years)
- Form international collaboration (strong involvement from EU and US)
- Publish a physics book and CDR.



Geological survey and preliminary civil design done in 2013



MOMENT: A New Idea on ν Beam



- Neutrinos from muon decay
- Proton LINAC for ADS **~15 MW**
- Energy: 300 MeV/150 km
- **arXiv:1401.8125**

Neutrinos after the target/collection/decay:
~ 10^{21} ν /year

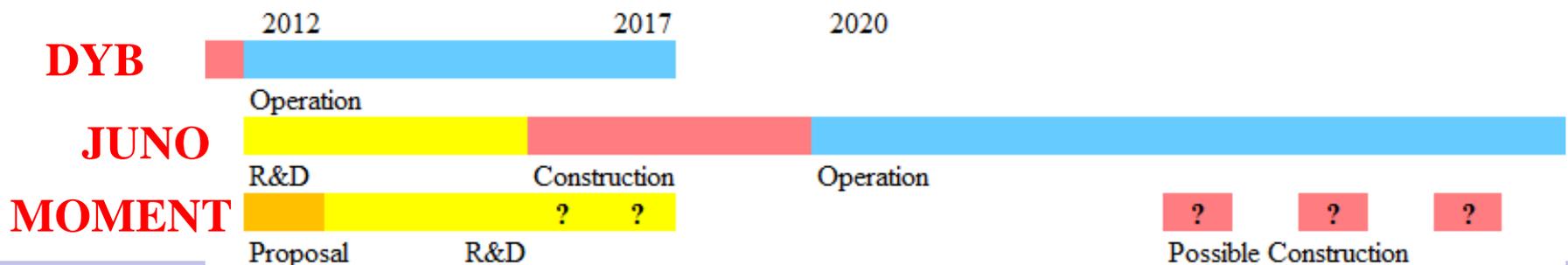
How Serious Are We on MOMENT?

- ◆ Design study by a team of ~10. A new idea worthy to study.
- ◆ Progress of ADS proton LINAC? Will China build CEPC?
- ◆ What's the physics, after LBNE and Hyper-K?
- ◆ If there is physics, will a neutrino factory be built?

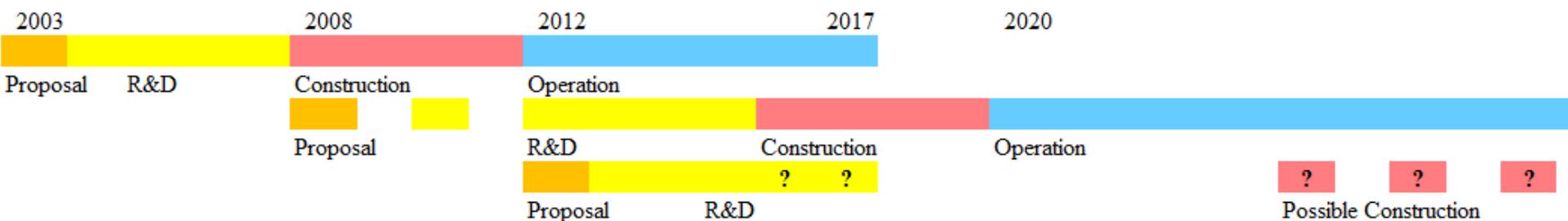
ICFA-neutrino panel:

- Aiming at headline discoveries
- Looking for emerging scenarios

- ◆ The same team also collaborate in ProjectX(Targetry & decay beam window) and is in close contact with NuFact and ESSnu.



Summary



- ◆ Daya Bay is the best site for θ_{13} measurement. It is the start point of neutrino program in China (2003).
- ◆ JUNO has a rich and very attractive physics program. It will take data in 2020. As a reactor experiment, it is complementary to T2K, NOvA, LBNE, Hyper-K, PINGU, INO, etc.
- ◆ Design study for MOMENT. Will consider it in a world-wide picture.
- ◆ Due to lack of manpower, China has only a little involvement in other neutrino programs (ProjectX, EXO)

Thanks!

