大亚湾中微子实验绝对效率研究
Absolute $\bar{\nu}_e$ Detection Efficiency at Daya Bay

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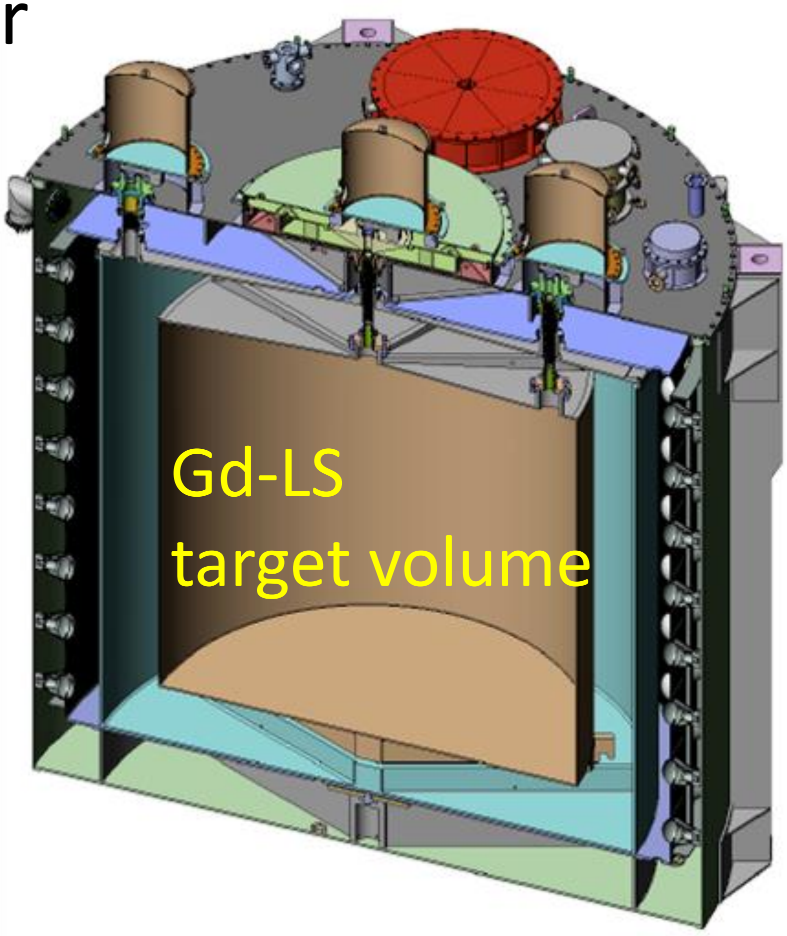
on behalf of the Daya Bay Collaboration

The Daya Bay Experiment

- Six 2.95GW_{th} nuclear reactor
- Eight liquid scintillator detector
- Detector $\bar{\nu}_e$ via inverse beta decay (IBD)

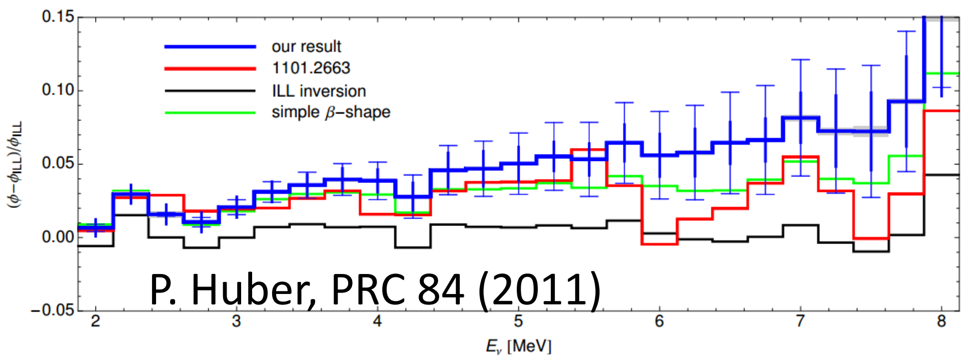
$$\bar{\nu}_e + p \rightarrow e^+ + n$$

- Relative flux + spectrum comparison between near/far sites gives world's best θ_{13} measurement

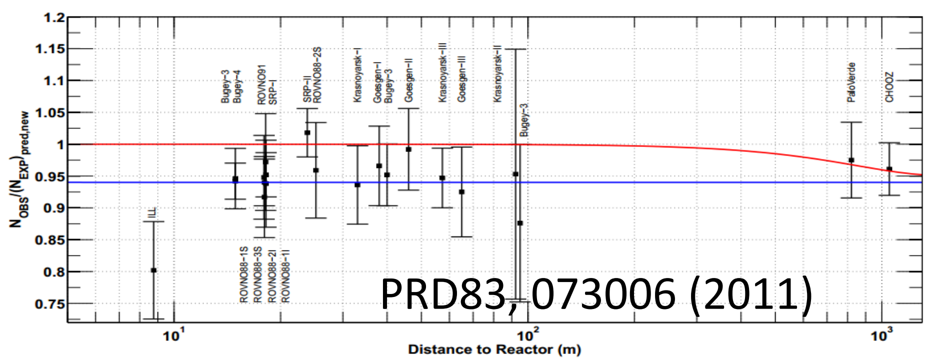


Measuring Absolute Reactor Flux

- **How many neutrinos are coming out of nuclear reactor per fission?**
- Current models are based on measurement of fission isotope beta spectra
- Direct measurement of flux at Daya Bay can serve as further validation of existing models, and as a benchmark for use by future reactor experiments



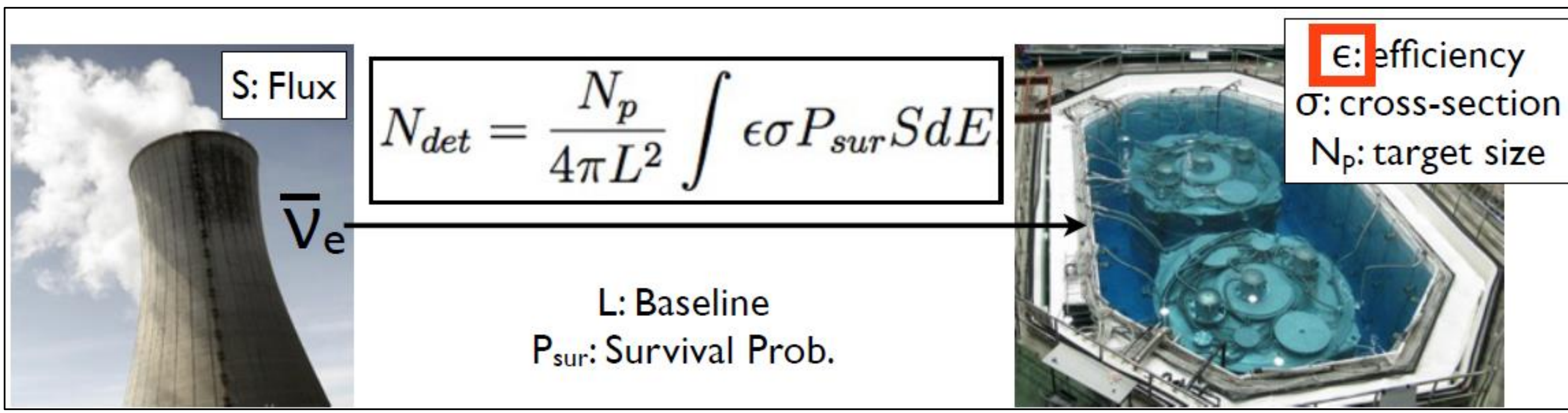
P. Huber, PRC 84 (2011)



PRD83, 073006 (2011)

$\bar{\nu}_e$ Detection Efficiency: A Key Input

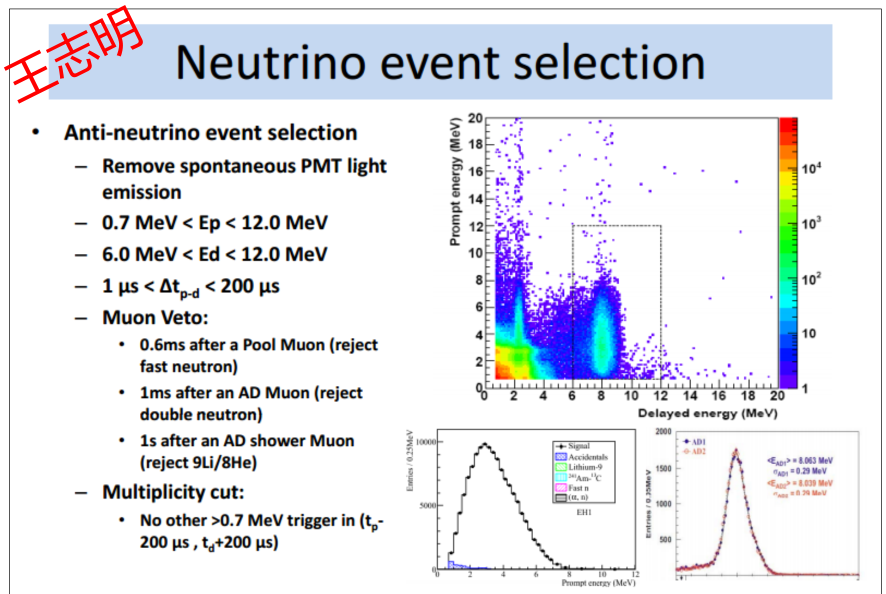
- Daya Bay has already detected well over 300,000 inverse beta decays
- Dominant error on flux measurement comes from efficiency uncertainty

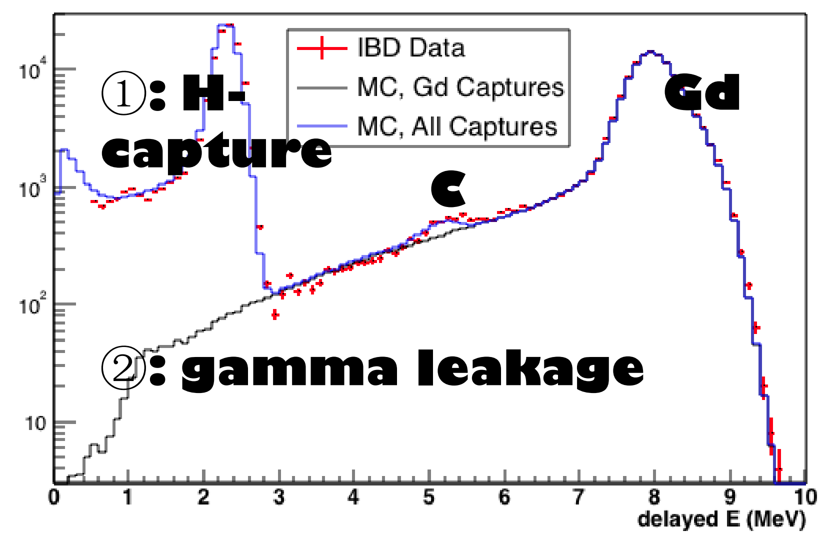


Main idea

- Detection efficiency predicted by Monte Carlo (MC)
- But how good/bad is our MC? MC-data comparison.
- Major contributors to detection efficiency uncertainty:
  - ① Gd capture fraction
  - ② Gd-capture gammas detection efficiency
  - ③ $\bar{\nu}_e$ interactions outside the GdLS target

By 王志明



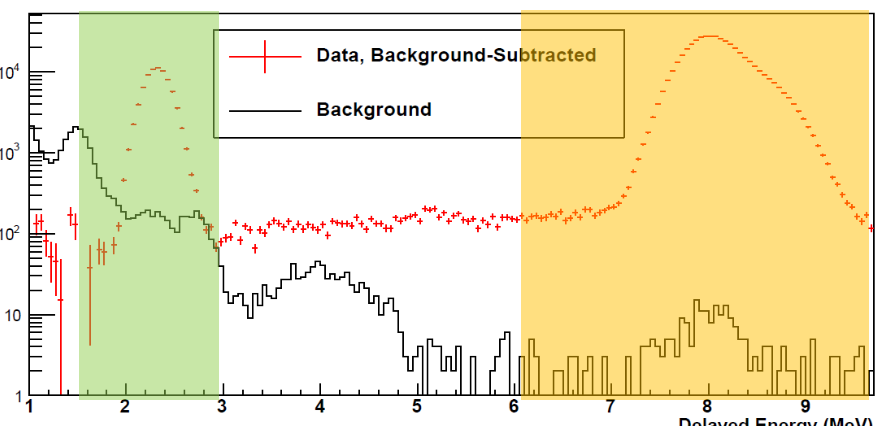


Delayed energy spectra

(I) Target Gd Capture Fraction

- 6 MeV delayed energy signal selection cut removes all non-Gd capture (nH & nC)
- Monte Carlo (MC) predicts Gd capture fraction, need constraint from calibration.
- Detector-center Gd fraction measured in many datasets, compared to MC

$$F_{Gd} = N_{nGd} / (N_{nGd} + N_{nH})$$



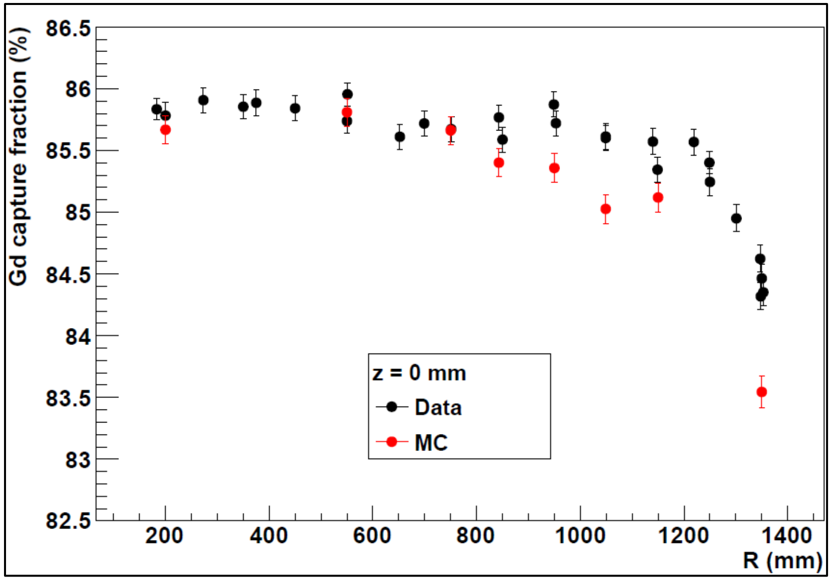
AD-center F_{Gd} using spallation neutrons

Data Set	$E_{rec,p}$ (MeV)	KE_n (MeV)	E_γ (MeV)	F_{Gd}	Unc_{stat}
Spallation n	-	range	range	85.7	0.2
AmC	0-4	3-5.5	-	85.4	0.15
AmBe	0-7	4-10	-	85.4	0.1
PuC, Ground State	0-4	3-7.5	-	85.5	<0.01
PuC, 1^{st} Excited	0.5-1	<0.6	-		
PuC, 2^{nd} Excited	5.5-7	<0.6	6.13	85.5	<0.1
IBD MC	0.7-12	<0.1	-	85.7	<0.1

AD-center F_{Gd} for various datasets

Target Gd Capture Fraction (cont')

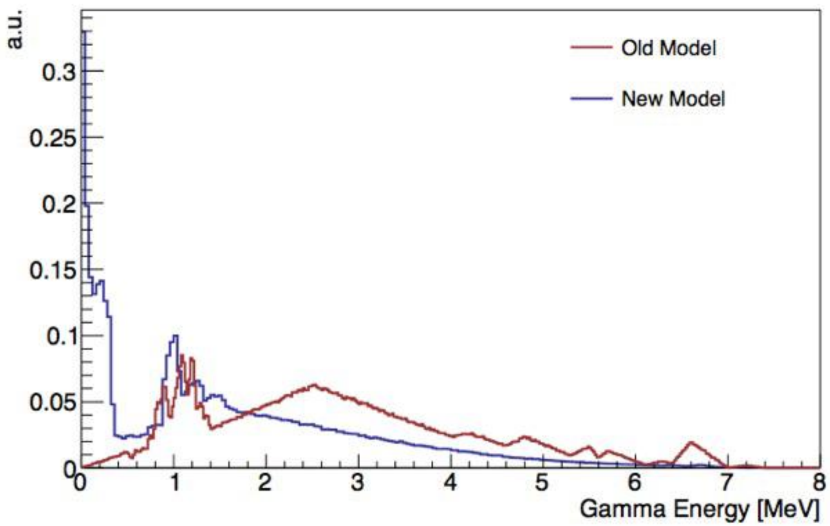
- Full-volume fraction determined by Gd concentration, leakage of neutrons out of GdLS
- Full-volume Gd fraction measured with PuC neutron source deployed via articulating arm, compared to MC
- Total uncertainty (δε/ε) of 0.95%



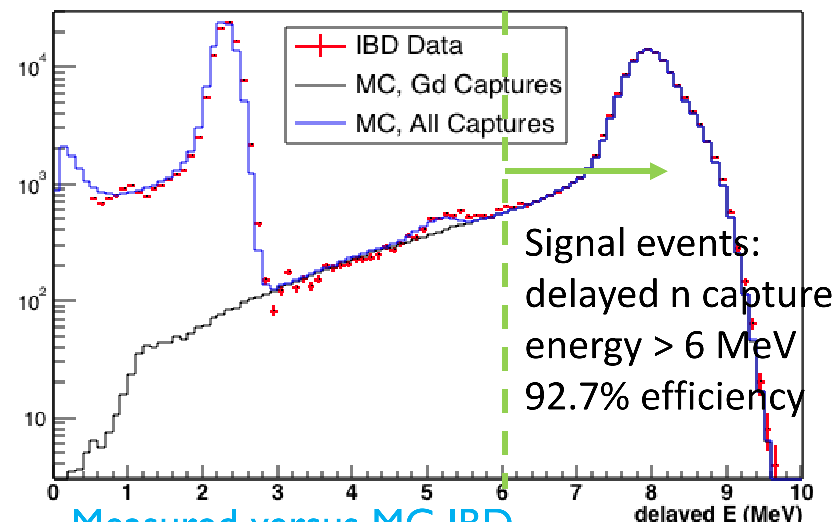
F_{Gd} versus R position of PuC neutron source, detector Z-center

(II) Gd Capture Detection Efficiency

- Gamma spectrum for nGd capture is complicated(~ 8MeV)
- GEANT4 provides good fit to data > 3MeV
- Treat region below 3 MeV (0.9% of MC nGd) with 100% uncertainty, since nH peak obscures nGd tail in data
- HPGe measurement of nGd γs: a input from MC cross-check
- Total uncertainty (δε/ε) of 0.97%



nGd gamma spectra in MC

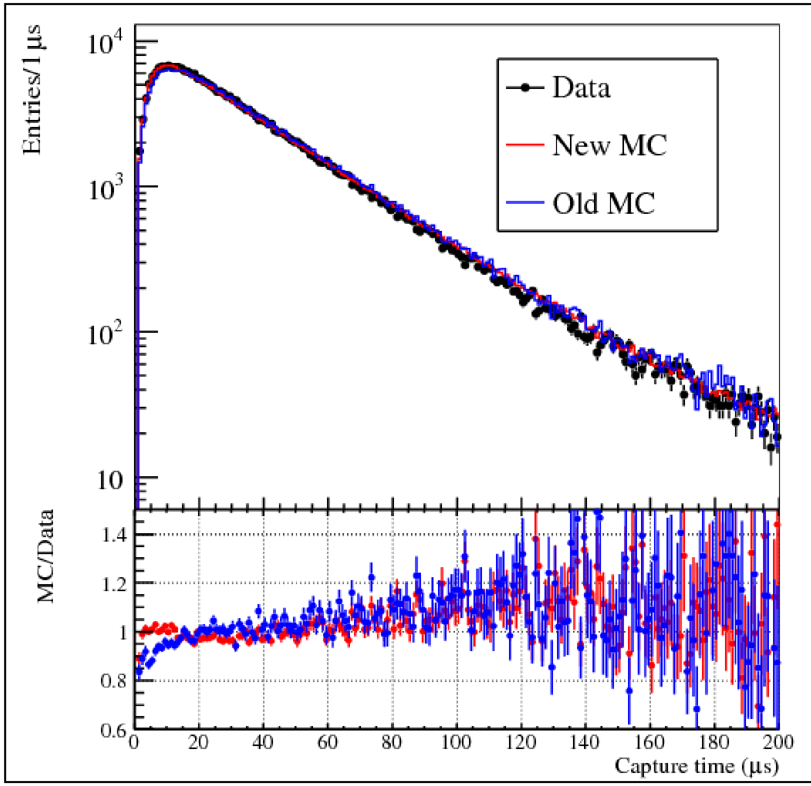


Measured versus MC IBD delayed energy spectra

(III) Spill-In Contributions

- IBD candidates originating from $\bar{\nu}_e$ outside the target: estimated with MC. How about the systematic error?

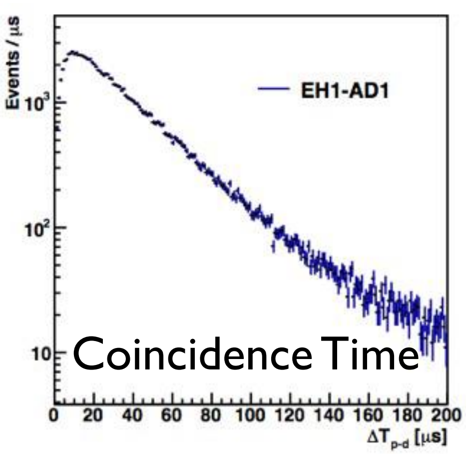
- MC calibrated with high-energy AmC n source in LS: MC, data agree to 1%
- Tuning of neutron thermal scattering model (<4eV) impacts on both **spill-in** & neutron's **capture time**. So constrain spill-in with IBD neutron's capture time via data-MC comparison.
- These constraints give conservative uncertainty (δε/ε) of 1.5%

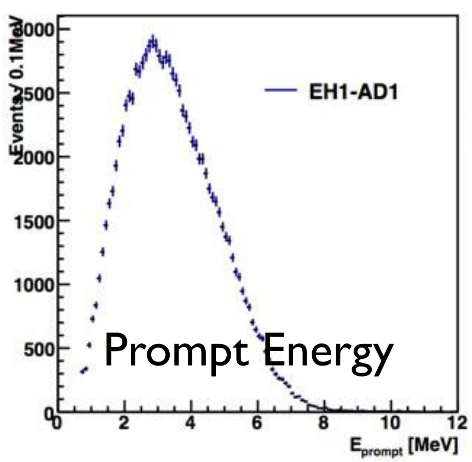


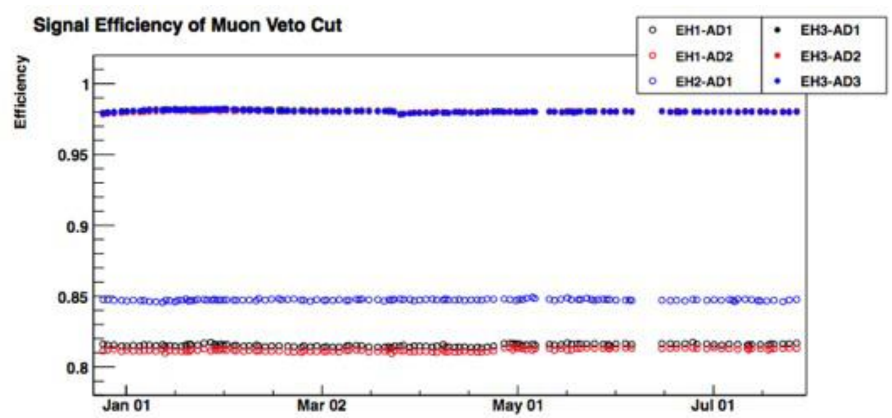
IBD neutron's capture time: Measured vs MC

Other Contributions

- High-efficiency cuts common between detectors: Ep, timing, and flasher cuts
- Muon-veto, multiplicity cut efficiencies vary with site; small uncertainty
- Target protons uncertainty from target mass, proton density measurements







Results and Future Improvements

- Total absolute detection efficiency common between all detectors of 80.6%
- Total efficiency is a major input in measuring abs. reactor flux at Daya Bay
- Looking to improve uncertainties through further analysis, collection of additional GdLS full-volume calibration data
- Alternate event selection may minimize major uncertainty contributions

Input	ϵ	$\delta\epsilon/\epsilon$
Target protons	-	0.47%
Flasher cut	99.98%	0.01%
Muon veto cut	-	0.02%
Multiplicity cut	-	0.02%
Capture time cut	98.70%	0.12%
Prompt energy cut	99.81%	0.10%
Gd capture ratio	84.2%	0.95%
nGd detection efficiency	92.7%	0.97%
Spill-in correction	104.9%	1.50%
Combined	80.6%	2.08%

Preliminary

Thank you!

谢谢!