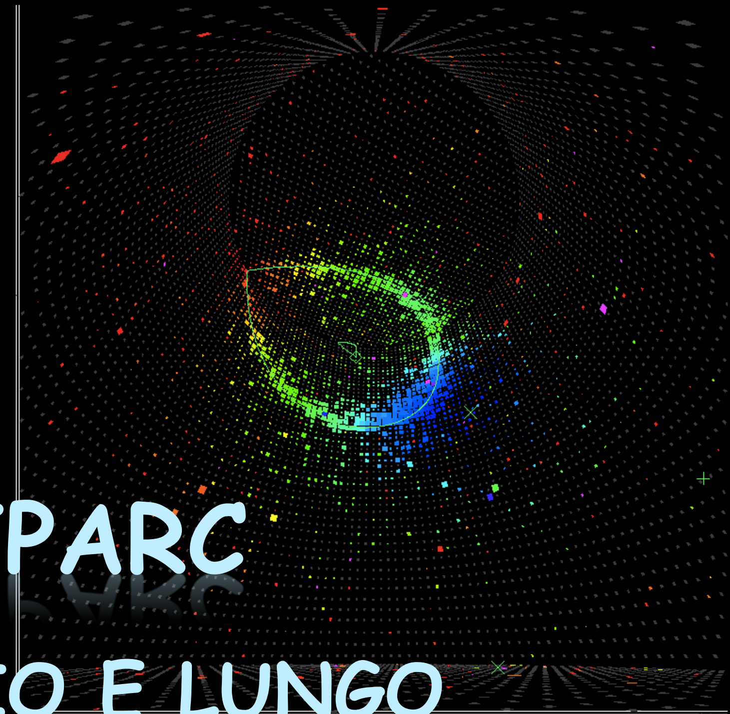


T2K @JPARC

PROSPETTIVE A MEDIO E LUNGO TERMINE

Maria-Gabriella Catanesi INFN-Bari

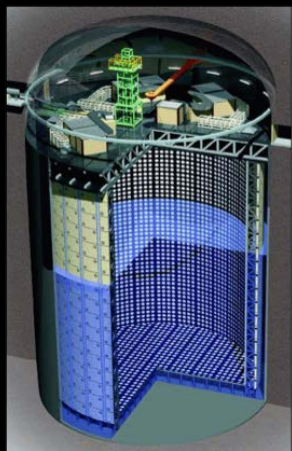
What Next, Padova 1 Dicembre 2014

Outlook

- T2K in a “Nutshell”
- “Discovery Potential” e limiti delle misure in corso
- Prospettive a medio termine
  - Upgrade ND280 (R&D e costruzione)
  - 1Km Detector (R&D e costruzione)
  - Attivita’ alla Neutrino Platform al CERN
- Prospettive a lungo termine
  - JPARC High intensity neutrino beam (0.75-> 1.2MW)
  - HYPERK (T2HK)
- Conclusioni

The T2K Experiment

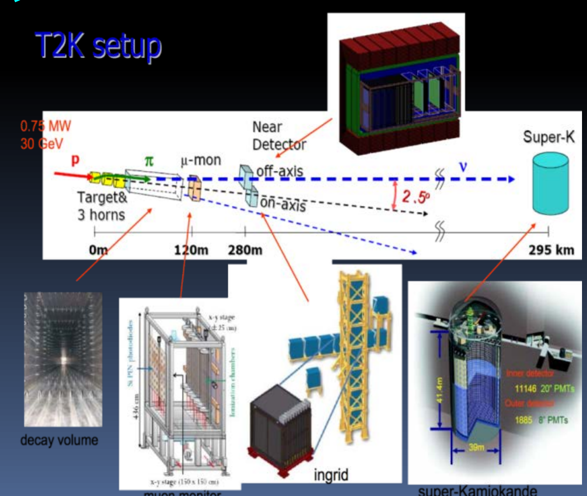
Super-K Detector



J-PARC Accelerator

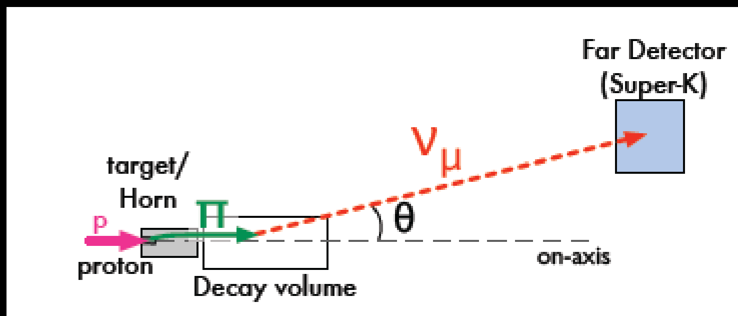
- The T2K experiment searches for neutrino oscillations in a **high purity ν_μ beam**
- A near detector located 280 m downstream of the target measures the unoscillated neutrino spectrum
- The neutrinos travel 295 km to the Super-Kamiokande water Cherenkov detector
  - ν_e appearance (sensitive to θ_{13} & δ_{CP})
  - ν_μ disappearance (sensitive to θ_{23} & Δm^2_{32})

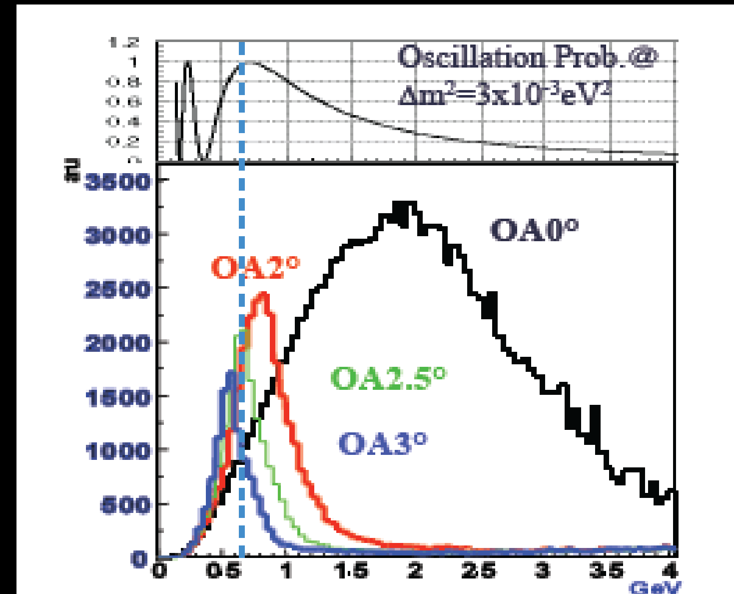
Near Detector



Primo fascio Off-Axis realizzato al mondo

Off-axis beam : intense & narrow-band beam





Beam energy @ oscillation
max. Ev ~ 0.6 GeV

Important to keep beam direction stable (T2K off-axis angle is 2.5°)

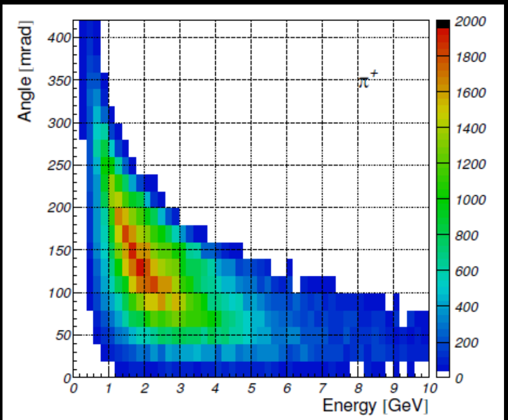
-> maximize physics sensitivity

Small high energy tail

-> minimize background

Il piu' sofisticato complesso di rivelatori vicini (e misure associate) realizzato per un fascio di neutrini

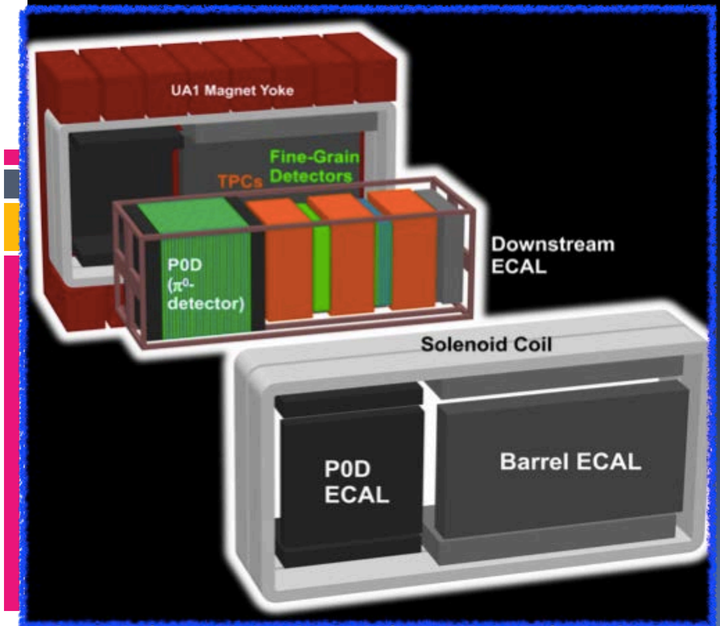
NA61@CERN



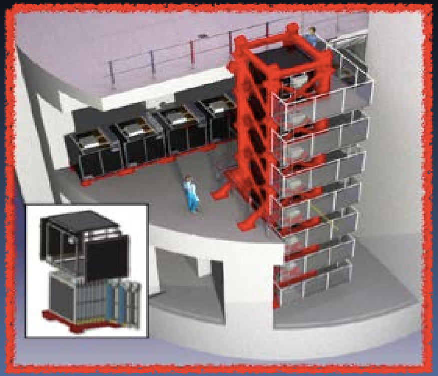
ND280

Near Detector @ 280m from the target

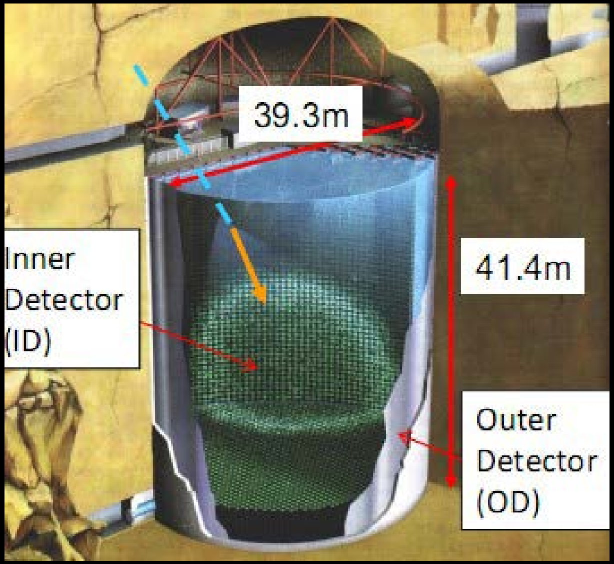
•**INGRID** @ on-axis
ν beam monitor [rate, direction, and stability]

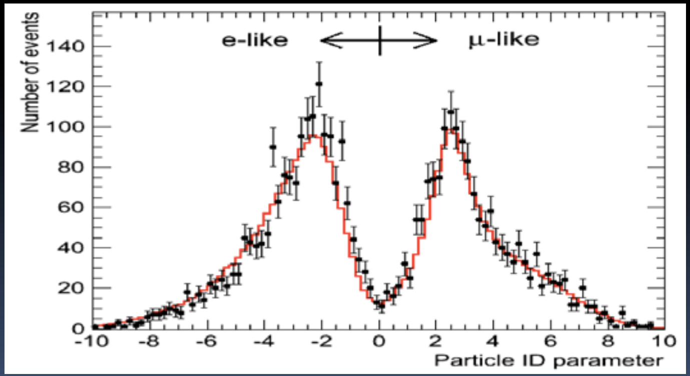


•**ND280** @ 2.5 degree off-axis
- Normalization of Neutrino Flux
- Measurement of neutrino cross sections.



T2K-Far Detector: Super-Kamiokande





Probability to mis-id μ as electron is ~1%

- 50 kton Water Cherenkov detector 1 km underground
- 61% ν_e signal eff. 95% π_0 rejection
- 32 kton inner volume (22.5 kton fiducial volume)
- 2 m outer volume to identify entering particles

NEW ! Enhanced π^0 Rejection

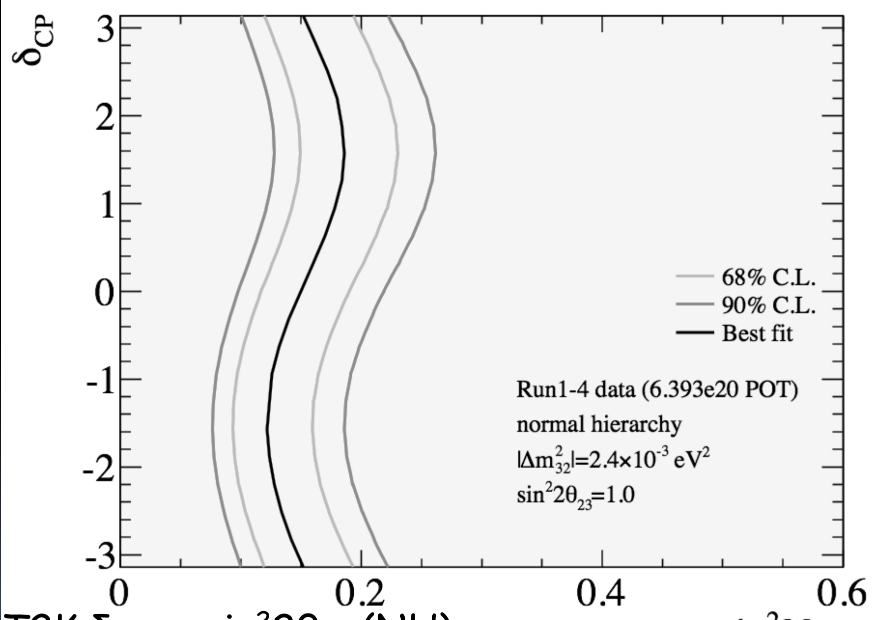
Total background reduced by 27% (6.36 events → 4.64 events, for full Run 1-4 dataset) ("Gaijins" work)

All triggers in +/- 0.5 ms of neutrino arrival time are recorded

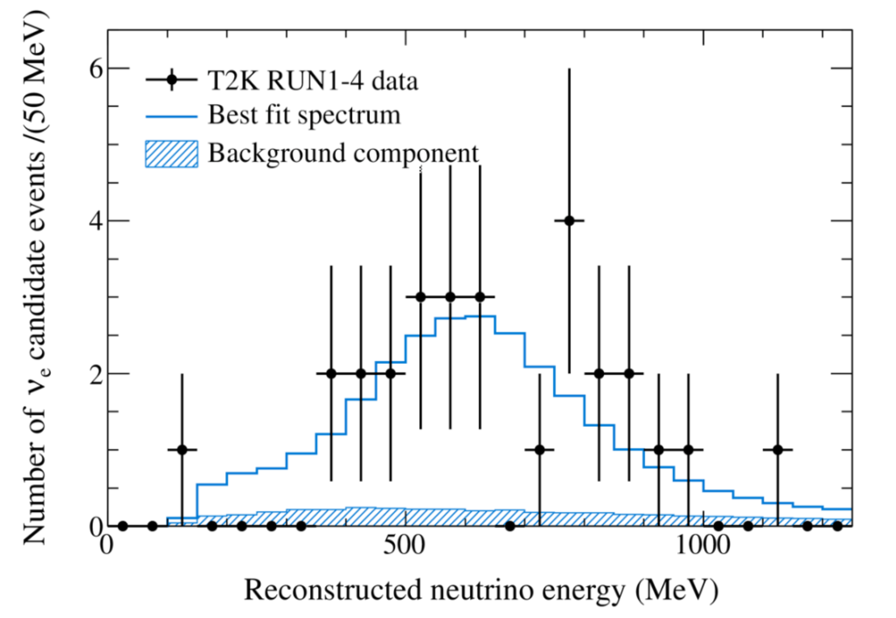
ν_e Appearance Results

- **Observed 28 events** (expected 20.4 ± 1.8 for $\sin^2 2\theta_{13}=0.1$)
- 4.64 ± 0.53 background events
- Comparing the best p-θ fit likelihood to null hypothesis gives a **7.5σ significance for non-zero θ_{13}**

(For $\sin^2 2\theta_{23}=1$, $\delta_{CP}=0$, and NH)



T2K δ_{CP} vs $\sin^2 2\theta_{13}$ (NH)



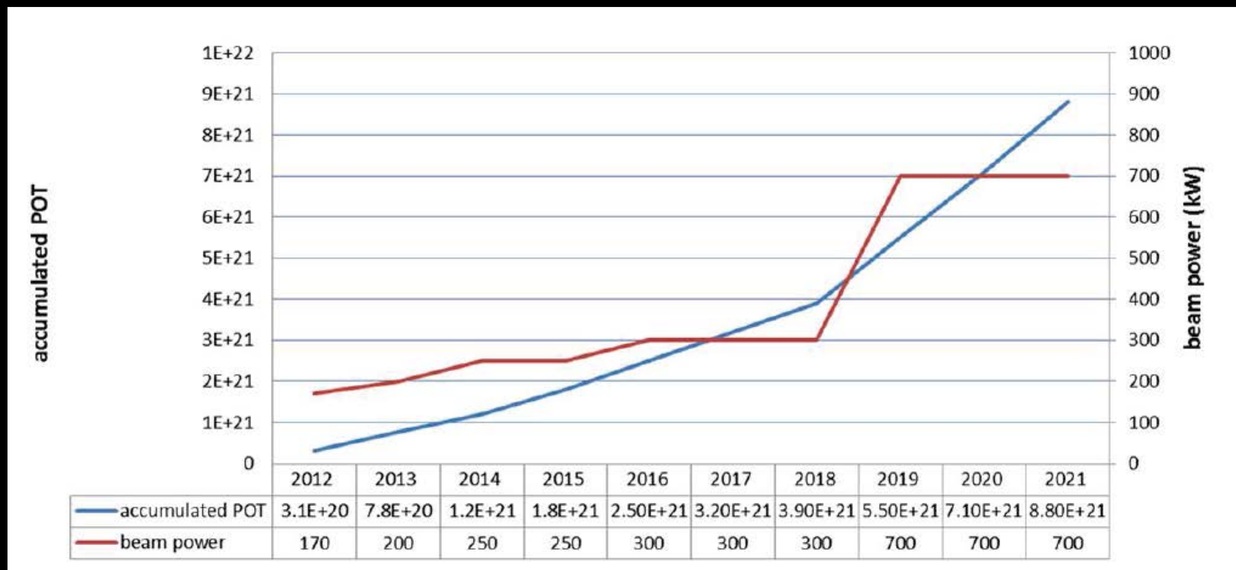
$$P_{\mu\to e} \approx \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin^2\left(\frac{\Delta m^2_{31} L}{4E}\right)$$

+ (CPV term) + (matter term) + ...

Prospettive future: (cosa cambia con θ_{13} "grande")

T2K e' approvato per 7.8×10^{21} POT (10% raccolti)

Ci servono protoni, protoni protoni …….



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
accumulated POT	3.1E+20	7.8E+20	1.2E+21	1.8E+21	2.50E+21	3.20E+21	3.90E+21	5.50E+21	7.10E+21	8.80E+21
beam power	170	200	250	250	300	300	300	700	700	700

- assess sub-leading effects such as CP violation, possible new physics from ν_e appearance.
- measurement of θ_{23} with the θ_{13} value from reactor experiments relevant to explore sub-leading terms. $\delta(\Delta m^2{}_{23}) \sim 10^{-4}\mathrm{eV}^2$ and $\delta(\sin^2 2\theta_{23}) \sim 0.01$ (~1% level)
- Θ_{13} in anti-neutrino mode

Ma non solo protoni....

Year	2011	2012	2013
POT (10^{20})	1.43	3.01	6.39
$N_{\nu_e}^{\text{obs.}}$	6	11	28
$N_{\text{BG}}^{\text{exp}}$	1.5 ± 0.3	3.3 ± 0.4	4.6 ± 0.5
$\sin^2 2\theta_{13}$(T2K)	0.11	$0.088^{+[illegible]}_{-0.033}$	$0.150^{+[illegible]}_{-0.034}$
Significance	2.5σ	3.1σ	7.5σ
Systematic Error (%) on $N_{\text{tot}}^{\text{exp}}$	17.5	9.9	8.8
Publication and Presentation	PRL [2]	PRD [16]	EPS-HEP [3]

S/B >>

T2K systematic uncertainty 2014

		ν_μ sample	ν_e sample
ν flux and cross section	w/o ND measurement	21.8%	26.0%
	w/ ND measurement	2.7%	3.1%
ν cross section due to difference of nuclear target btw. near and far		5.0%	4.7%
Final or Secondary Hadronic Interaction		3.0%	2.4%
Super-K detector		4.0%	2.7%
total	w/o ND measurement	23.5%	26.8%
	w/ ND measurement	7.7%	6.8%

ND/FD <<<

Xsec non soddisfacente

Utilizzare tutte le informazioni disponibili (incluse quelle esterne) aiuta moltissimo

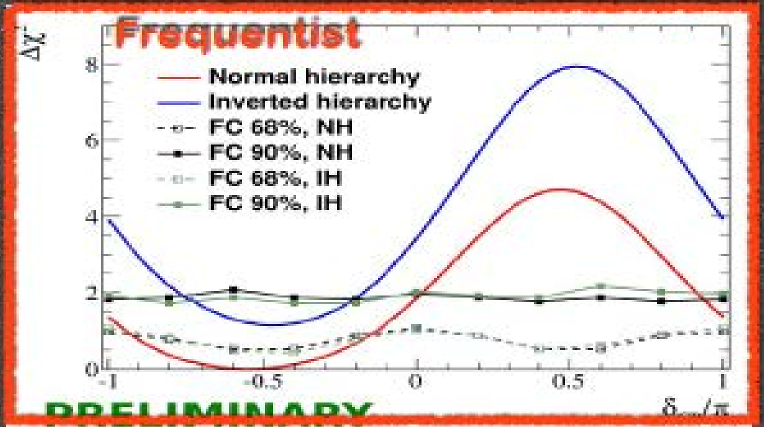
Joint fit analysis

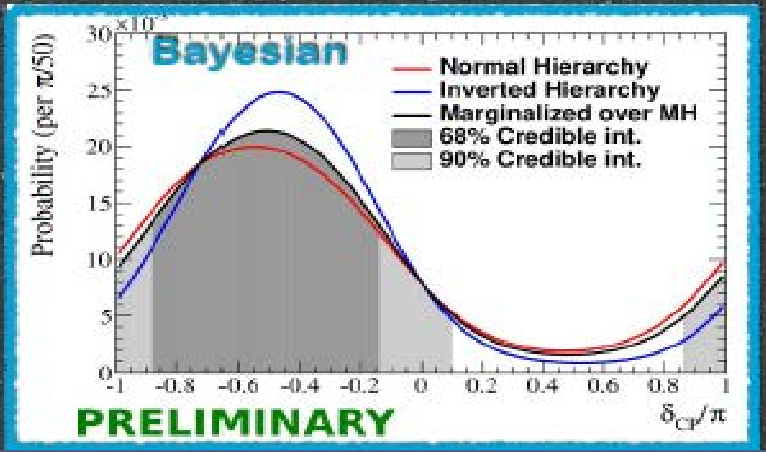
T2K

2 different analyses:
- Frequentist based on Feldman-Cousins
- Bayesian based on Markov Chain MC

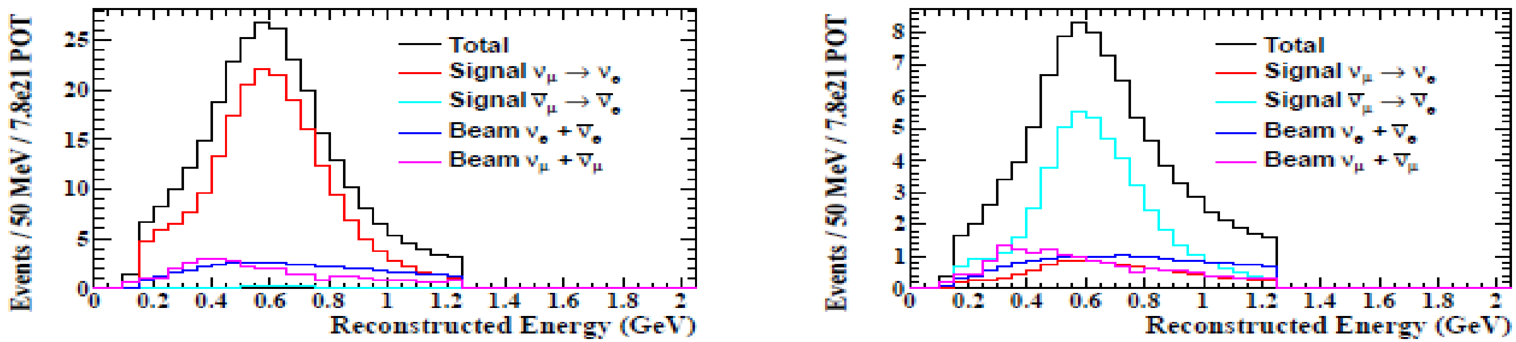
- Use reactor constraint $\sin^2(2\theta_{13})=0.095\pm0.010$
- Both analyses give similar results
- Best fit value of $\delta_{CP} \sim -\pi/2$
- Values of $\sim0.2<\delta_{CP}<\sim0.8$ excluded at more than 90% CL
- Very weak preferences for NH and second octant

(%)	NH	IH	Sum
$\sin^2\theta_{23} \leq 0.5$	18	8	26%
$\sin^2\theta_{23} > 0.5$	50	24	74%
Sum	68%	32%	





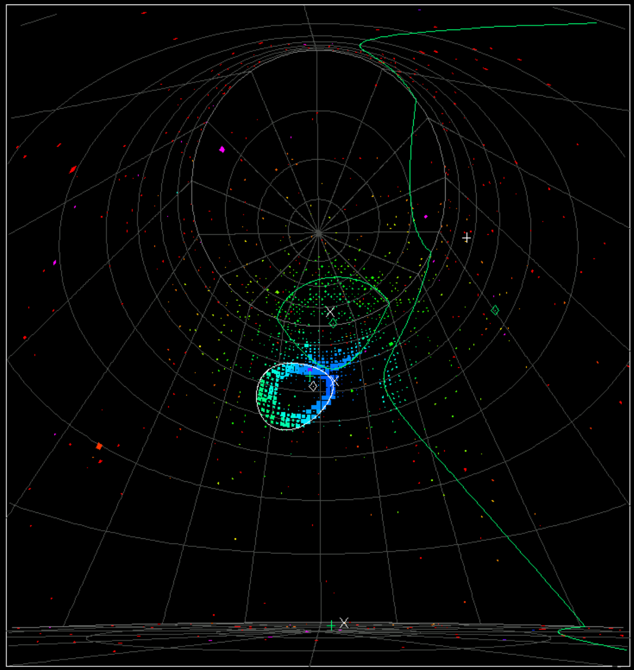
Cosa si puo' fare prima del 2020….



(a) ν_e appearance reconstructed energy spectrum, 100% ν-mode running.

(b) $\bar{\nu}_e$ appearance reconstructed energy spectrum, 100% $\bar{\nu}$-mode running.

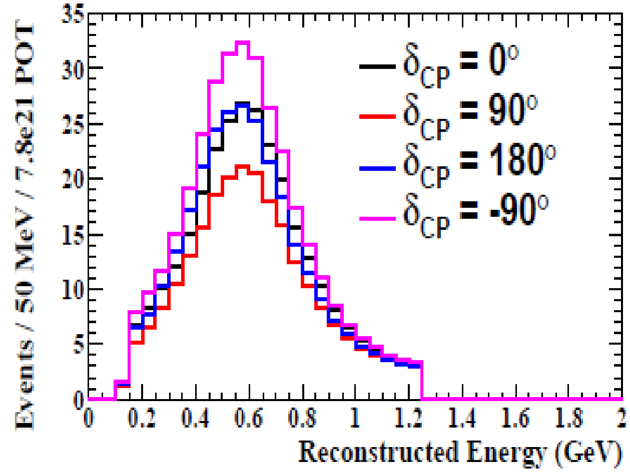
- Studiata la sensibilita di T2K ai nuovi obiettivi, sia nell'ipotesi "T2K-alone", sia nell'ipotesi di analisi combinate con altri esperimenti.
- Rimodulata la frazione di "data taking" con fascio di neutrini e anti-neutrini in modo da ottimizzare l' "outcome" di fisica.
- Share medio fra i due tipi di fascio pari a circa 50% e 50%

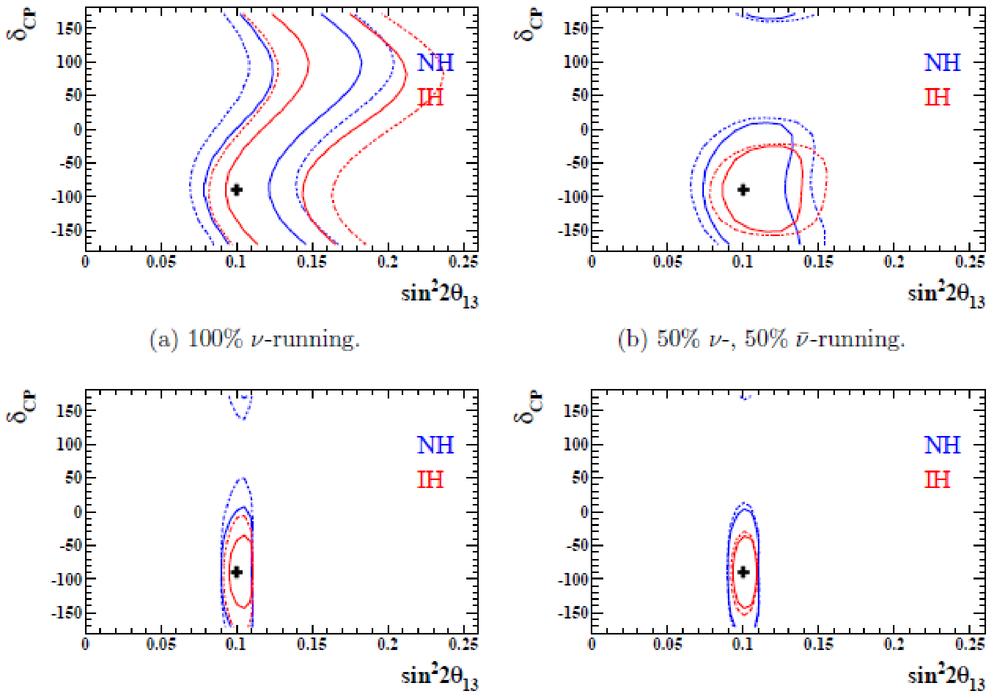


T2K attualmente prende dati in anti-nu mode

δcp discovery potential (esempi)

< 2019





(a) 100% ν-running.

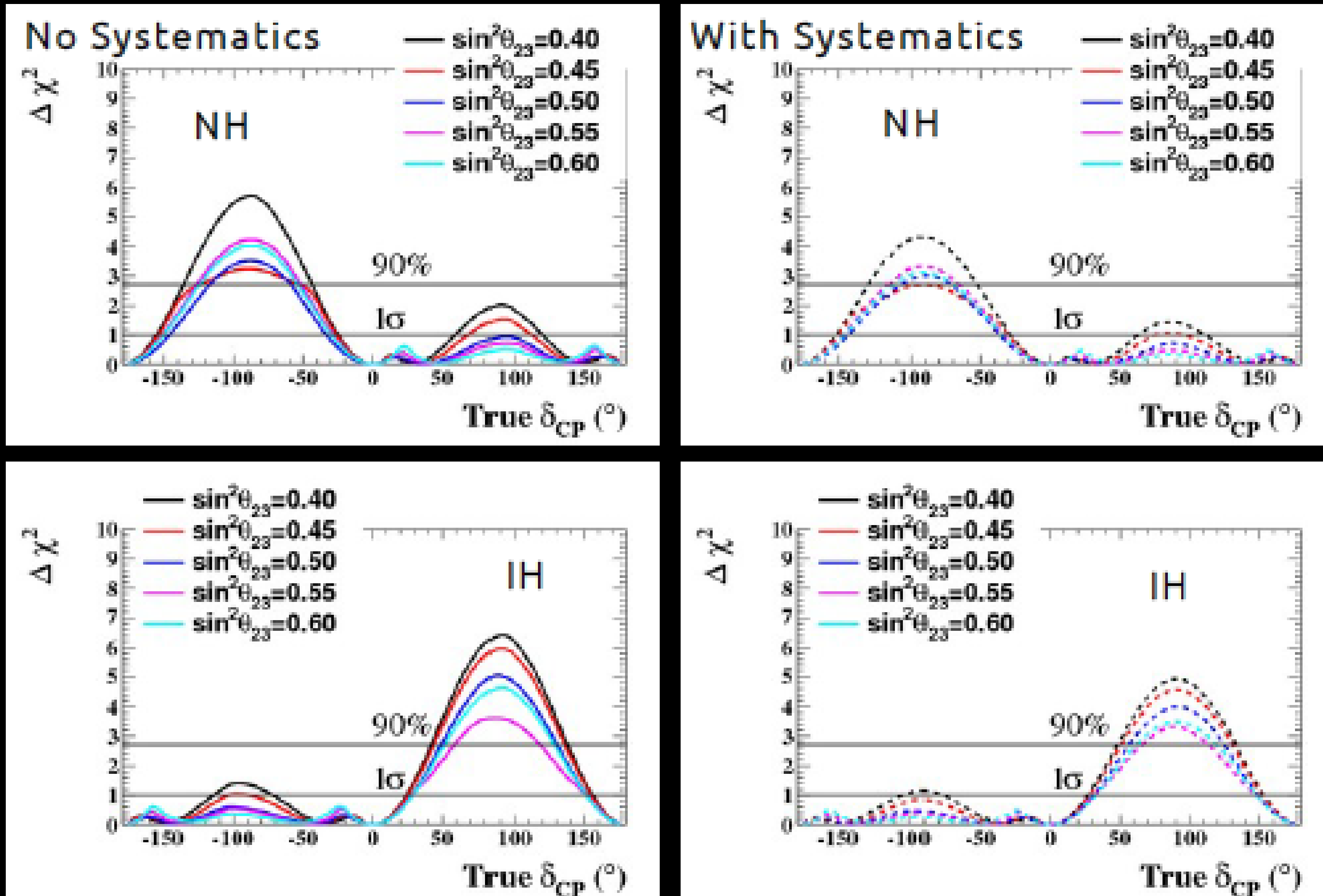
(b) 50% ν-, 50% $\bar{\nu}$-running.

(c) 100% ν-running, with ultimate reactor constraint.

(d) 50% ν-, 50% $\bar{\nu}$-running, with ultimate reactor constraint.

T2K Alone

arXiv:1409.7469



Ability to determine CP violation as a function of true δ_{cp}

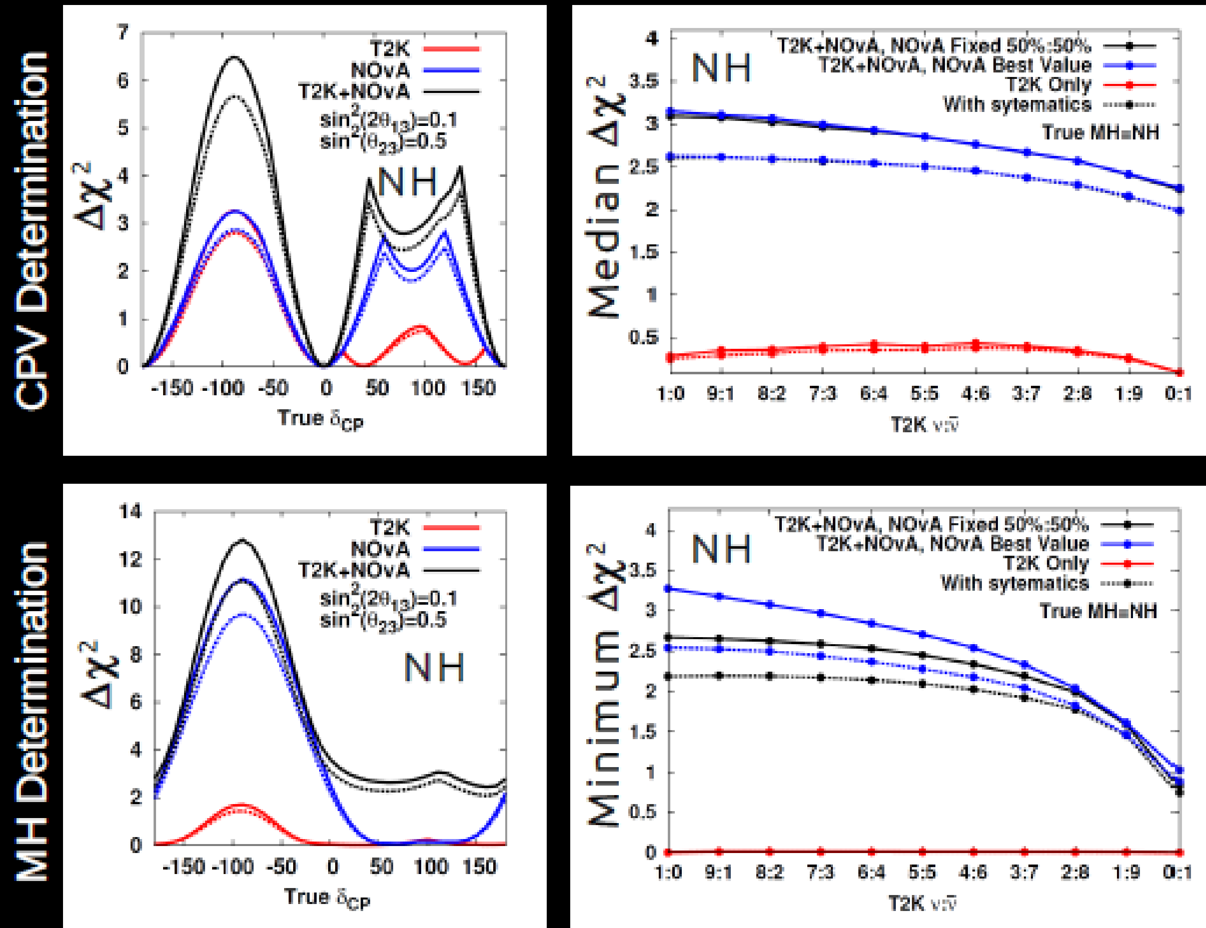
- With systematics (**dashed**) ~10% for ν_e and ~13% for ν_μ
  - ν samples assumes 2012 level systematics
  - $\bar{\nu}$ samples assume +10% additional uncertainty

arXiv:1409.7469

T2K+Nova (2020)

Combined Sensitivities and Optimal Run Plan

- CPV sensitivity
  - Greatly enhanced by combined fit
  - Flat for run ratios ν > 30%/70% $\nu/\bar{\nu}$
- Mass Hierarchy
  - Almost no sensitivity alone
  - Large enhancement to NOvA degenerate region
  - Prefers more ν running in combined fit
- Evaluated other metrics
- Metrics mostly flat for: 70%/30% < $\nu/\bar{\nu}$ < 30%/70%

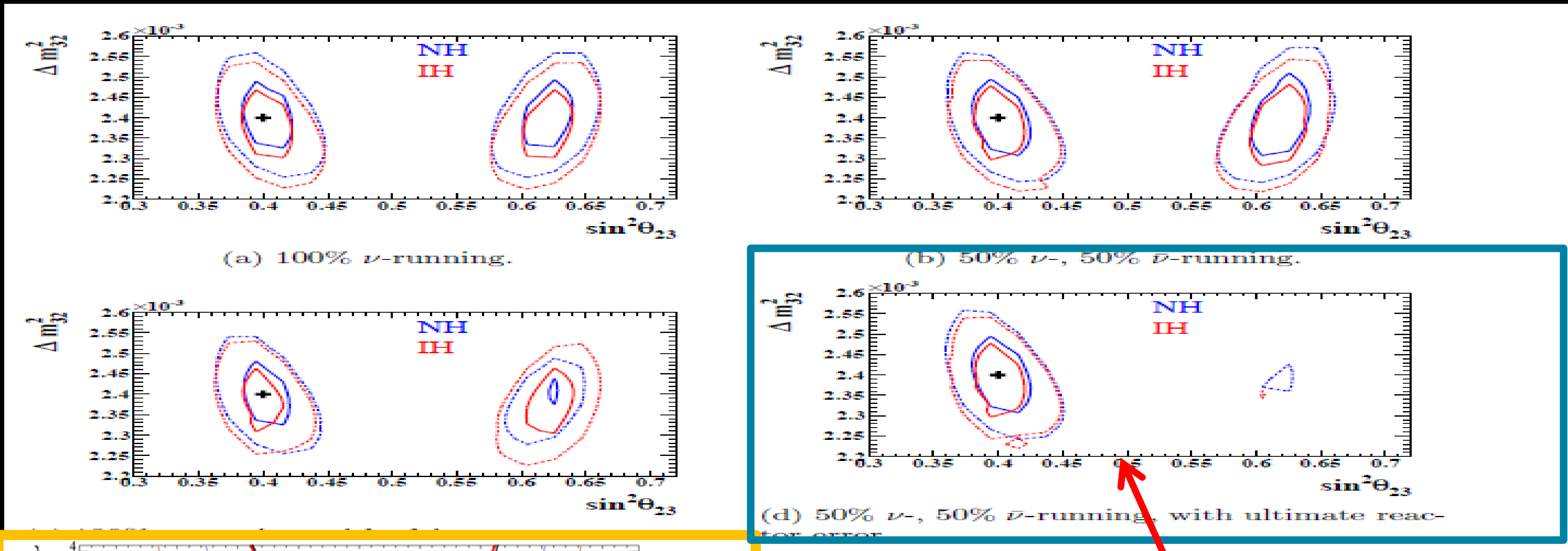


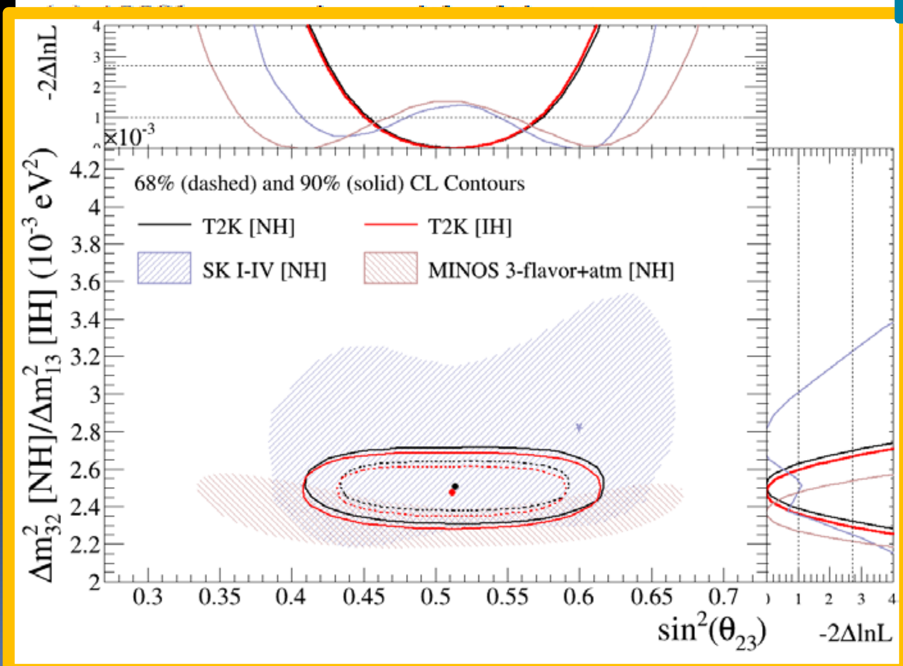
50%/50% $\nu/\bar{\nu}$ running

Variable $\nu/\bar{\nu}$ running

Determination of θ_{23} octant

arXiv:1409.7469





T2K 2019 (se siamo fortunati)

T2K(2014) Phys.Rev.Lett. 112 (2014)

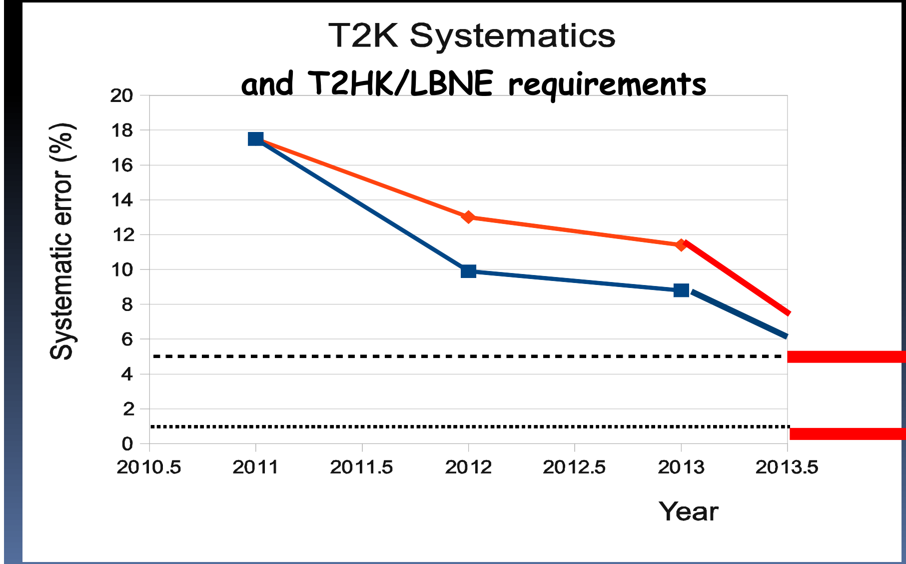
- Questo (salvo sorprese…) e' il massimo che possiamo pensare di ottenere dagli esperimenti di questa generazione
- Tuttavia ci possono insegnare molte cose su come progettare al meglio gli esperimenti della prossima gnerazione…

Infatti …per migliorare le misure in corso abbiamo bisogno di (…anche in vista dei progetti futuri)

- Protoni,protoni, protoni (alta intensita')
- Massa Massa Massa (cerchiamo effetti di subleading)

> 2020

- Ridurre gli errori sistematici (6.8% oggi)
  - Controllo accurato del flusso (Hadroproduzione, monitor)
  - ND/FD ratio
  - Misure di Neutrino x-sec (possibilmente stesso bersaglio)
  - Studio dei meccanismi di produzione (MEC etc. etc.)
- Riduzione dei fondi (sviluppo algoritmi piu' performanti)
- Analisi combinate (+ uso di risultati esterni)

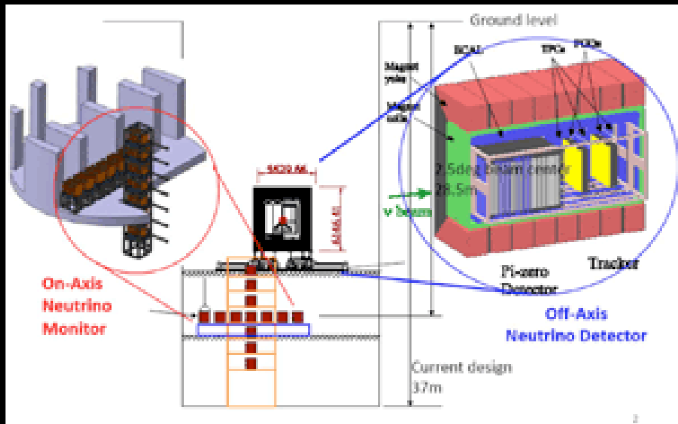


Dobbiamo lavorarci gia' da oggi !

T2HK (5%)

LBNE(1%)

Near Detectors



ν_e	Systematic sources(%)	ν_μ
3.1	Flux & Combined Cross-Sections	2.7
4.7	Independent Cross Sections	5.0
2.4	Pi Hadronic Interactions (FSI)	3.0
2.7	SK Detector Efficiencies	4.0
6.8	**TOTAL**	**7.6**

Three options currently envisages for Hyper-K to reduce current systematic errrs. Some options may happen earlier for the T2K upgrade.

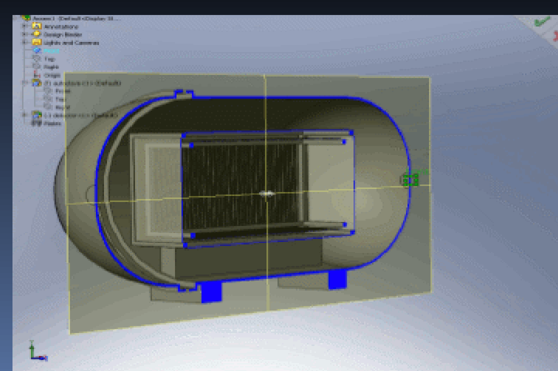
1) ND280 improvements:

Replace with D_2O to the FGD2 and PØD water layers. Quasi-free neutron target.

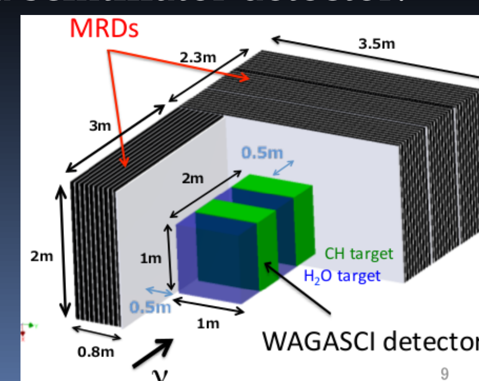
Replace scintillator with WbLS to measure deposited charge from water/D_2O layers.

2) Add new detectors in the 280m pit:

High Pressure TPC (HPTPC):



Water-grid scintillator detector:



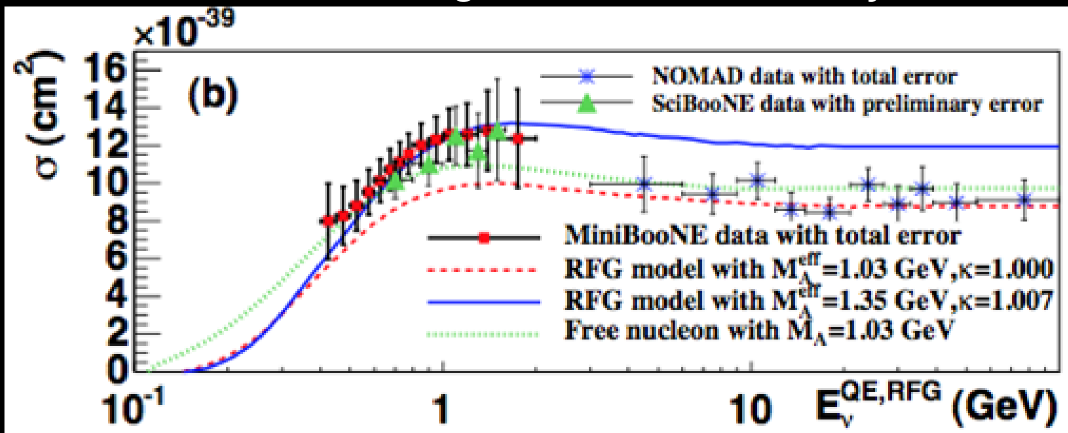
Dettagli nel talk di GF. De Rosa

Near Detectors (High Pressure TPC)

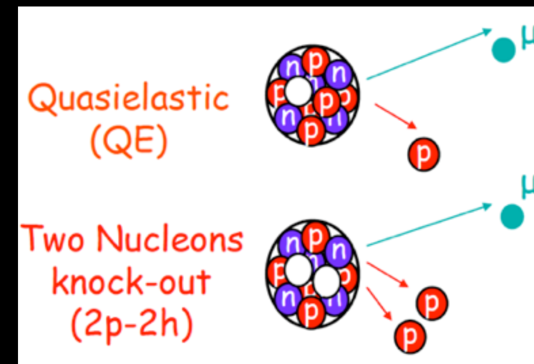
Add new detectors in the 280m pit

final state particles and in particular resolve vertex

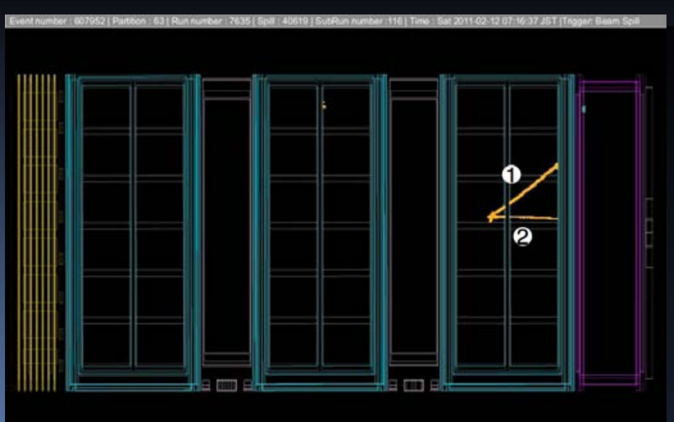
HPTPC detector design to reduce xsec systematics



arXiv:1002.2680 [hep-ex]



- Significant discrepancies on proton multiplicity and momentum distributions
- Need low momentum thresholds to reduce xsec systematics
- Important difference lie below threshold for liquid detectors
- Need new strategy to reduce systematics

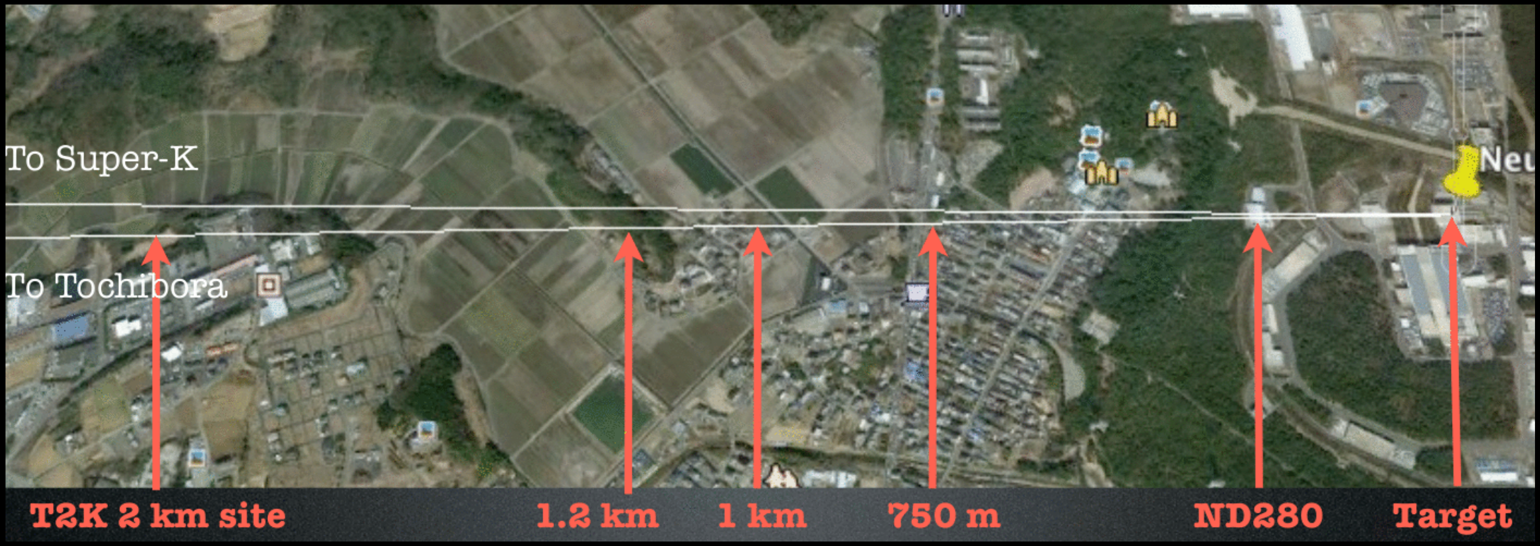


- T2K has pioneered (~1 bar) gas TPCs for accelerator neutrinos
- Need a path to high pressures for sufficient statistics
- Generic to next generation LBL experiments

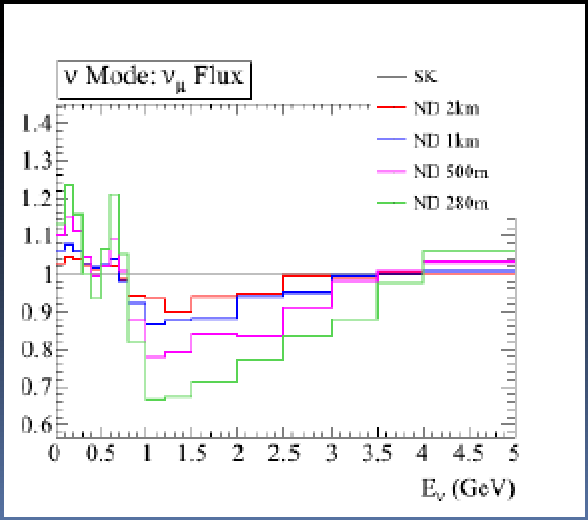
*Possibile interesse INFN

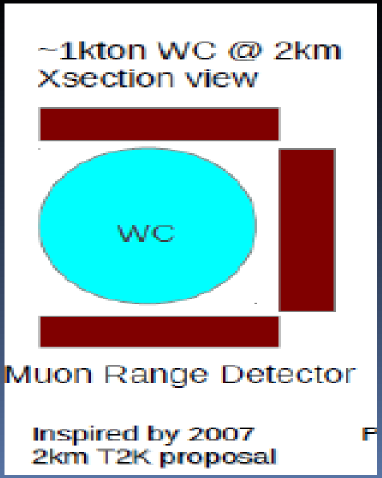
1 km Detectors

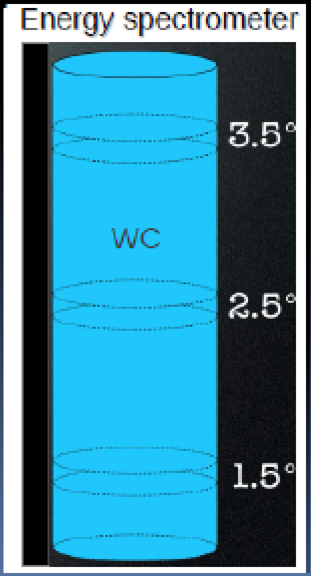
Build new detectors at 1-2km



- TITUS (see next slide)



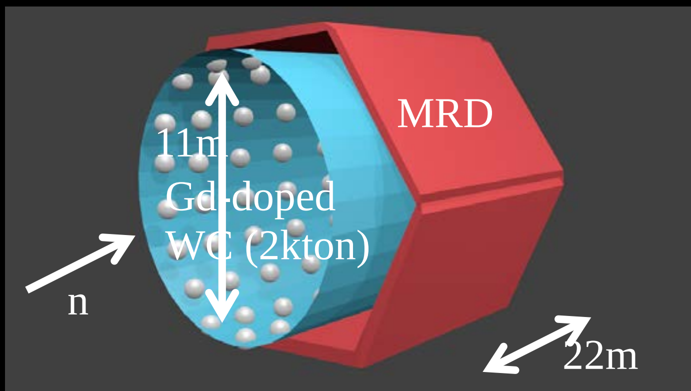




- NuPrism ((~1Kmm)
- Tall (~50 m) WC detector spanning wide range of off-axis angles

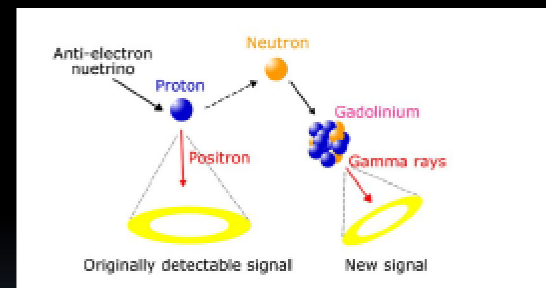
Near Detectors (TITUS)

Tokai Intermediate Tank for Unoscillated Spectrum ”TITUS” (~2 km)



*Possibile interesse INFN

Baseline design includes:
2 ktonne water Cherenkov tank
0.1% Gadolinium-doping
Partly enclosed by Muon Range Detector
Fe & plastic scintillator
End: 100 or 150 cm Fe
Side: 50 cm Fe (up to 75% coverage)



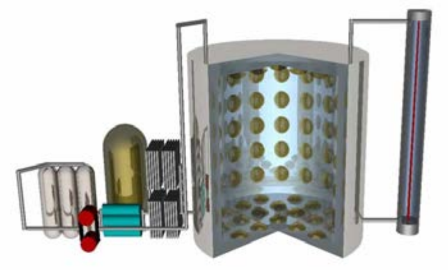
- Use measured neutron multeplicity spectrum to:
  - Select “almost background-free” signal events
  - Highly improved neutrino and antineutrino separation in beam
- Enhanced sample purities:
  - ν_μ CCQE: 37% → 63% with n = 0 requirement
  - $\bar{\nu}_\mu$ CCQE: 55% → 82% with n = 1 requirement

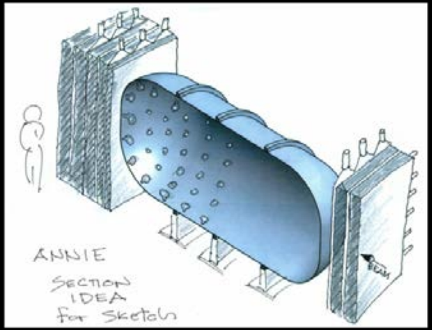
TITUS Physics Programme

- Measure intrinsic ν_e component of J-PARC beam
- Neutron multiplicity measurements
    - Provide input to neutrino generator models
    - Distinguish CCQE from other modes
    - Measure main background for proton decay searches
- Cross-section measurements
    - Inclusive NCπ^0 – sub-dominant ν_e appearance background
    - Charged current cross section measurements (CC0π, CC1π etc.)
- Sterile neutrino searches
    - Compare CC & NC rates at 280 m & ~2 km to look for ν active disappearance
- Supernova burst neutrinos
    - Approx. 650 events expected from SN burst (570 ν_e IBD + 80ν_e ES)
    - Evaluating feasibility as an independent alarm for the SNEWS network

Future Gd-doped WC Detectors

- Gd-doping of the detectors is currently planned for the Super-K detector (GADZOOK! project) for supernova reinmant neutrino detection.ns-det])
- R&D is currently ongoing with a 20ton EGADS detector in Kamioka
  - Testing water purification system



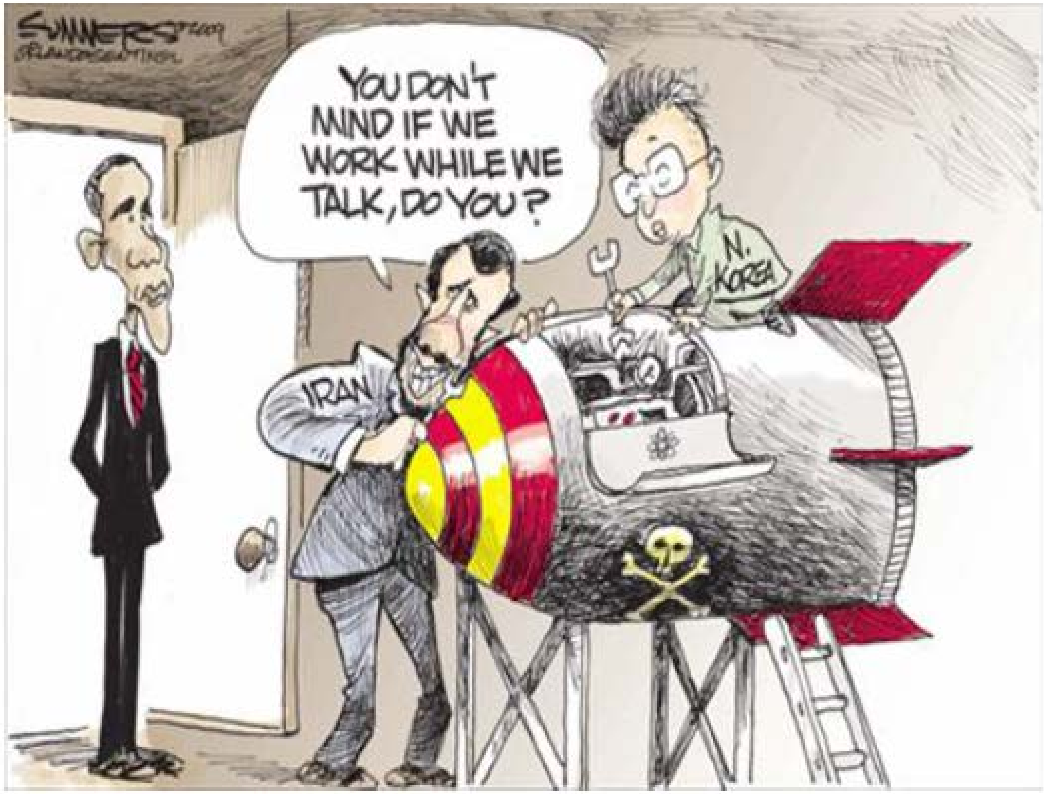


- ANNIE (Atmospheric Neutrino Neutron Interaction Experiment) detector is currently planned at Fermilab (arXiv:1402.6411 [physics.ins-det]) in MiniBooNE beam (small fiducial volume):
  - Neutron spectrum measurement
  - LAPPs test

- WATCHMAN (WATer Cherenkov Monitoring of AntiNeutrinos):
  - Measure reactor antineutrinos from nuclear power plans using a gadolinium-doped (light) water detector
  - Approved in the US

- Advanced Scintillator Detector Concept (ASDC): A Concept Paper on the Physics Potential of Water-Based Liquid Scintillator (arXiv:1409.5864 [physics.ins-det]), Wb LS that could be doped with Gd.
  - Proposed for near site for BNE/F in conjuction with LAr detector.

Of course, very large scale anti-neutrino detection just might have another application or two…



T2K (HyperK) vs CERN

- T2K is a Recognized experiment at CERN starting from 2009 (RE13)
- The ND280 Magnet is a donation of CERN
- The design of the TPC (and test beams) was done at CERN (HARP TPC set-up)
- The production and the calibration of the TPC readout planes (MM) was also done at CERN
- Next renewal end of 2015

- Decided at the EU Hyper-K/T2K meeting at CERN to start a discussion among interested people toward the design of the WC prototype
- Timescale for a design of the prototype: next year.
- Other possible interest in a longer timescale is for the high pressure TPC, currently ongoing developments in the universities.

I gruppi Europei, lavorano gia' attivamente insieme !

CERN Neutrino Platform

Major need for a water Cherenkov prototype at CERN is to test several components for the final design of the experiment and also to help in testing components for a new WC near detector.

- A prototype at CERN will complement a test facility (EGADS) in Japan, mainly dedicated to test photosensors (PMT vs HPD etc.)
- The CERN facility is aimed at mainly testing calibration techniques and automatic deployments methods. Eg a small package (LED, SiPM, and electronics) next to each PMT, to monitor gain, noise, timing….
- It can also test underwater electronics and DAQ (Hyper-K aims to have the electronics underwater to minimize the cabling)
- Photo-sensor accessories, i.e. cover+geomagnetic shield+electronics

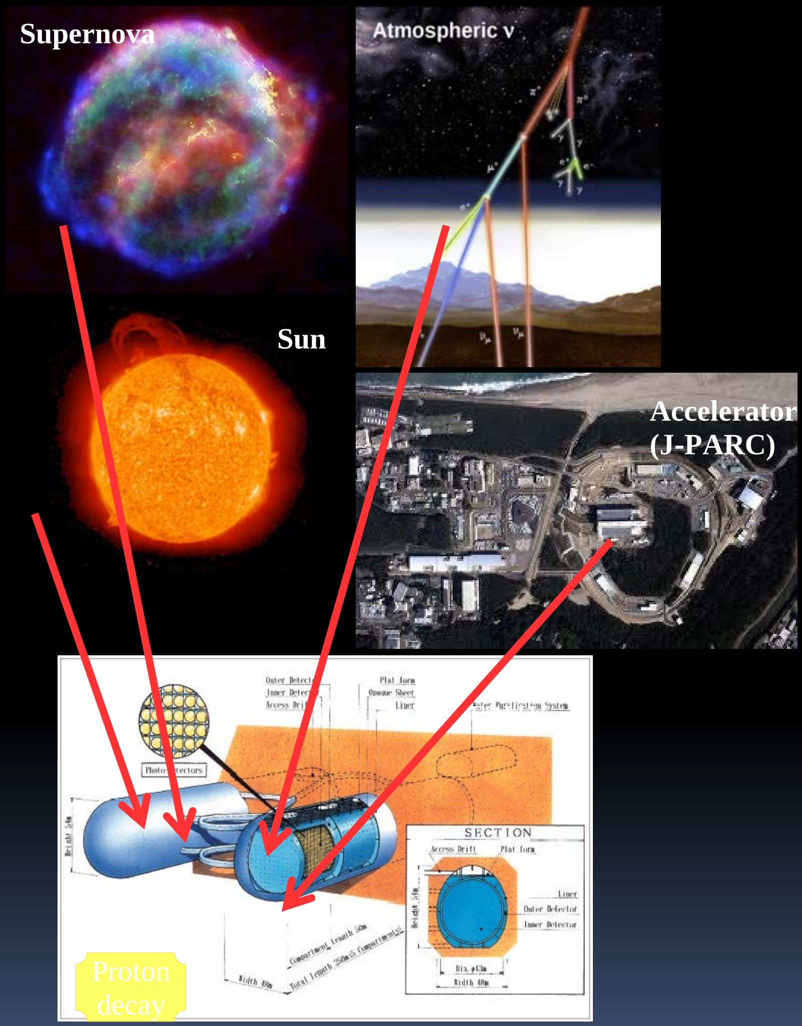
*Possibile interesse INFN

Hyper-Kamiokande Experiment

Multi-purpose neutrino experiment.

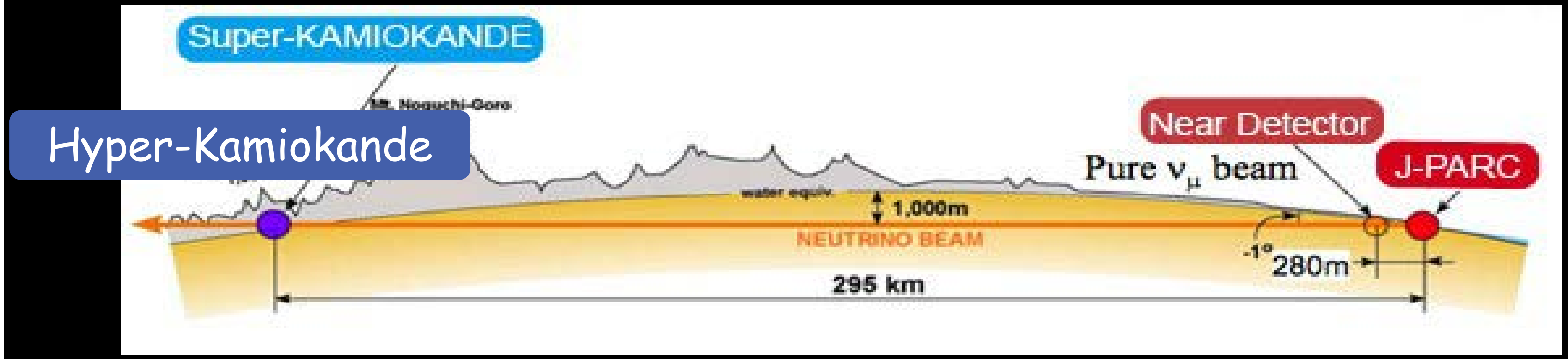
Very rich physics portfolio:

- Neutrino oscillations:
  - ➢Neutrino beam from J-PARC
  - ➢Atmospheric neutrinos
  - ➢Solar neutrinos
- Search for proton decay
- Astrophysical neutrinos
  - ➢Supernovas bursts
  - ➢Supernova relic neutrinos
  - ➢Indirect Dark Matter
  - ➢Transient astrophysical objects



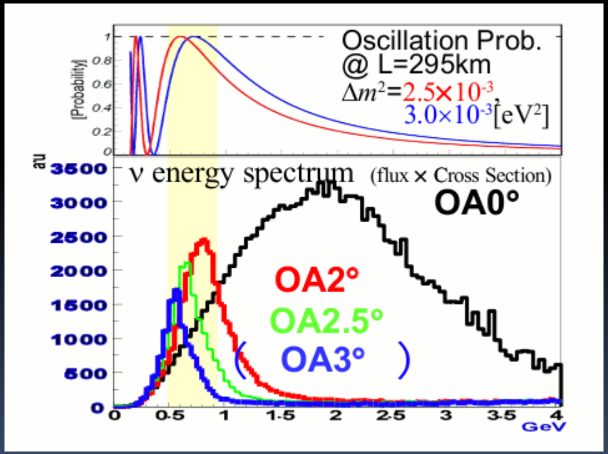
- Geophysics with neutrinos:
- neutrino radiography w/ atmospheric neutrinos for surveying Earth internal structure

Tokai-2-Hyper-Kamiokande (T2HK)

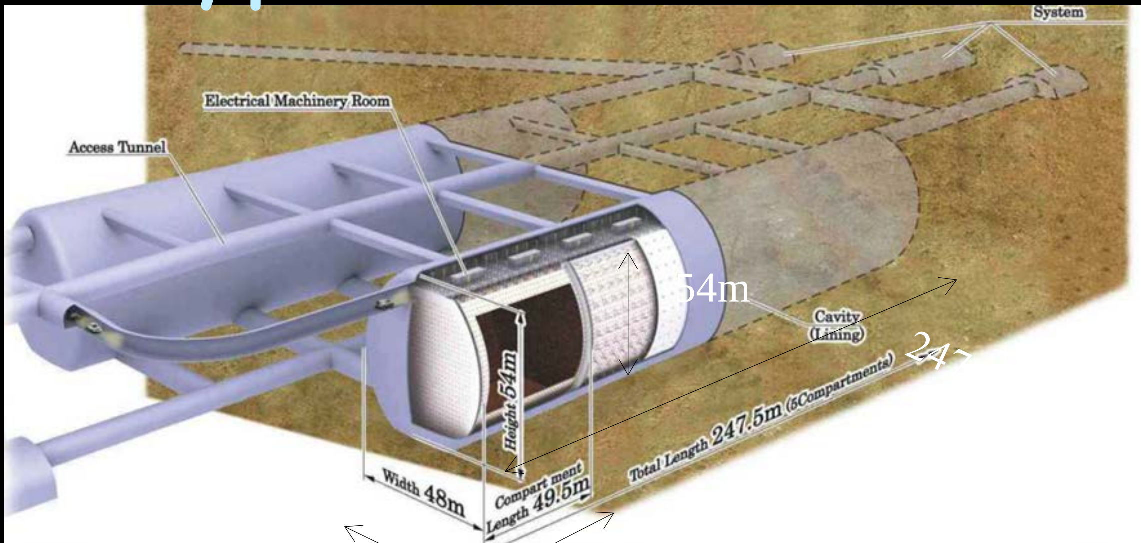


Natural extension of the technique being proven by the success of T2K:

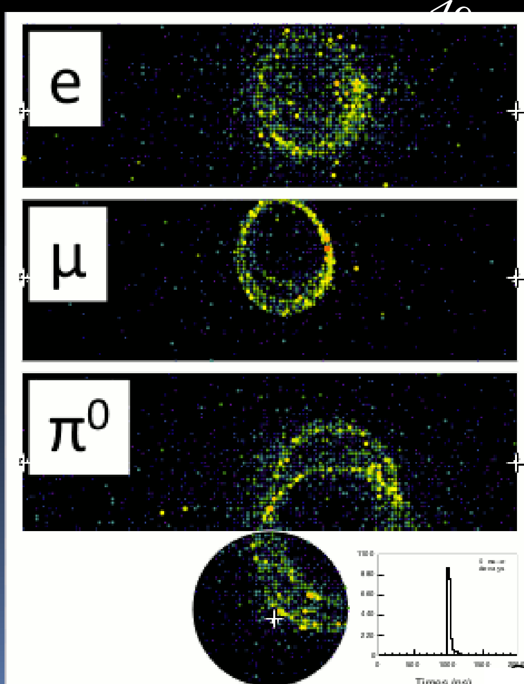
- Use J-PARC beam
- Hyper-K at 295km as Super-K
- Off-axis narrow-band beam
- Eν~0.6 GeV



Hyper-Kamiokande Detector



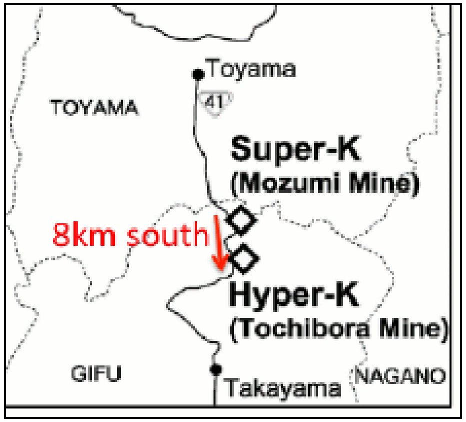
- International working group:
  - 12 Countries, 67 Inst., 240 people
- 2 open meetings per year since 2012
- International Board formed



- Water Cherenkov, proved technology & scalability:
  - Excellent PID at sub-GeV region >99%
  - Large mass → statistics always critical for any measurements.

Total Volume	0.99 Megaton
Inner Volume	0.74 Mton
Fiducial Volume	0.56 Mton (0.056 Mton × 10 compartments)
Outer Volume	0.20 Mton
Photo-sensors	99,000 20"Φ PMTs for Inner Detector (ID) (20% photo-coverage) 25,000 8"Φ PMTs for Outer Detector (OD)
Tanks	2 tanks, with egg-shape cross section 48m (w) × 50m (t) × 250 m (l)

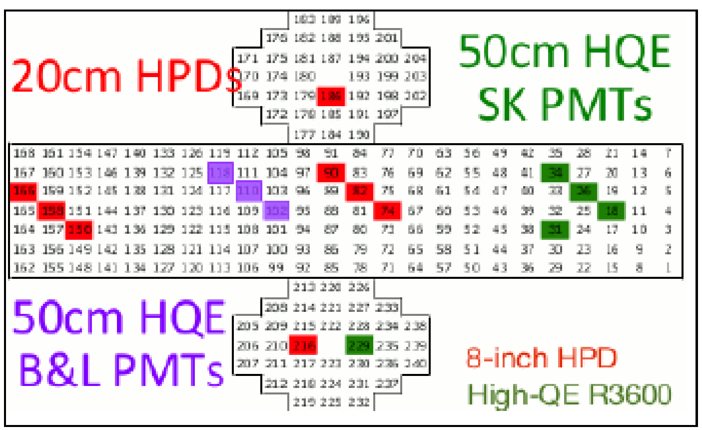
Cavern and Detector R&D

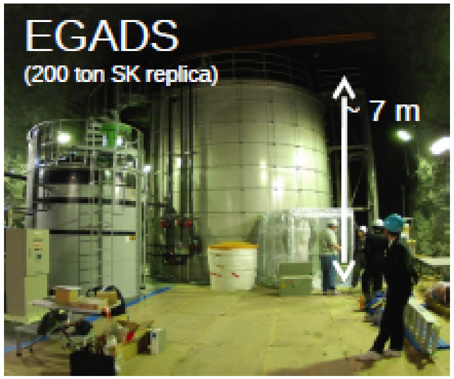


Two candidate sites (2.5° off-axis, 295 km baseline)

- Tochibora mine:
  - ~8km South from Super-K
  - Construction feasible with existing techniques
  - Overburden~650m(~1755m.w.e.). SK: ~2700m.w.e.
- Mozumi mine (same as Super-K)
  - Deeper than Tochibora (~700-850m)
  - Recent geological survey
  - Construction procedures being established

- All aspects of the tank design (water tak liner, compartments, etc.) are under way.
- Testing photosensor candidates in EGADS tank in Kamioka mine.

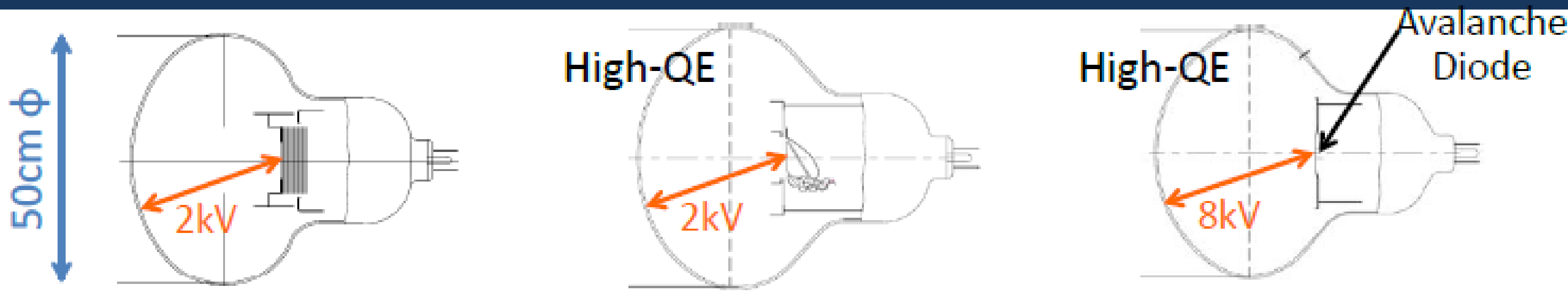




Three photosensors candidates:

- SK PMTs
- High QE PMTs
  - box-line dynode
- High QE hybrid photodetector
  - avalance diode instead of metallic dynode

Hyper-K photodetector candidates



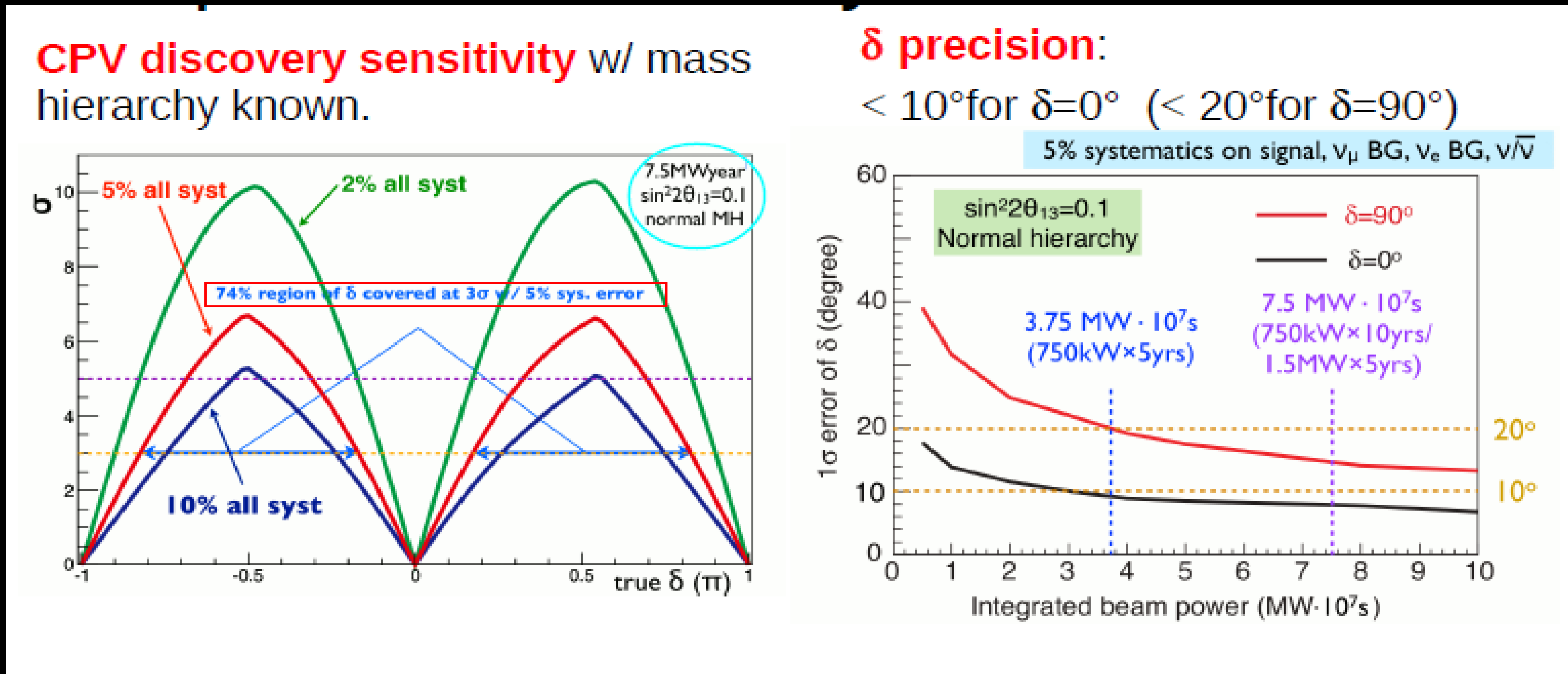
20″ PMT (Venetian-Blind dynode)	20″ Improved PMT (Box&Line dynode)	20″ HPD (Hybrid Photodetector)

	20″ PMT	New 20″ PMT	20″ HPD
Gain	1×10^7	1×10^7	$10^4 \sim 10^5$*
C.E.	80%	93%	95%
T.T.S. (FWHM)	5.5ns	2.7ns	0.75ns*
P/V ratio@1p.e.	1.7	≥2.5	>3

* w/o Preamp

Estimated values (New 20″ PMT and 20″ HPD)

Expected Sensitivity to CP Violation



- Assuming 5% nominal systematics and 0.750MW/y (3y ν-beam and 7y anti–νbeam), 74% region of δ can be covered at 3σ
- It corresponds to a precision of < 10° for δ=0°.

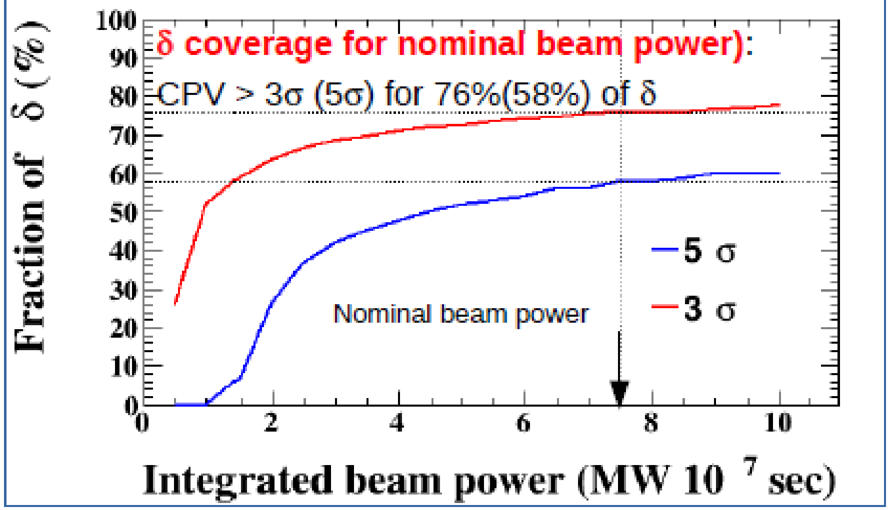
δ_{CP} Sensitivity

Appearance	Signal		Background					Total
	$\nu_\mu \to \nu_e$	$\bar{\nu}_\mu \to \bar{\nu}_e$	ν_μ	$\bar{\nu}_\mu$	ν_e	$\bar{\nu}_e$	NC	
ν mode	3016	28	11	0	503	20	172	3750
$\bar{\nu}$ mode	396	2110	4	5	222	265	265	3397

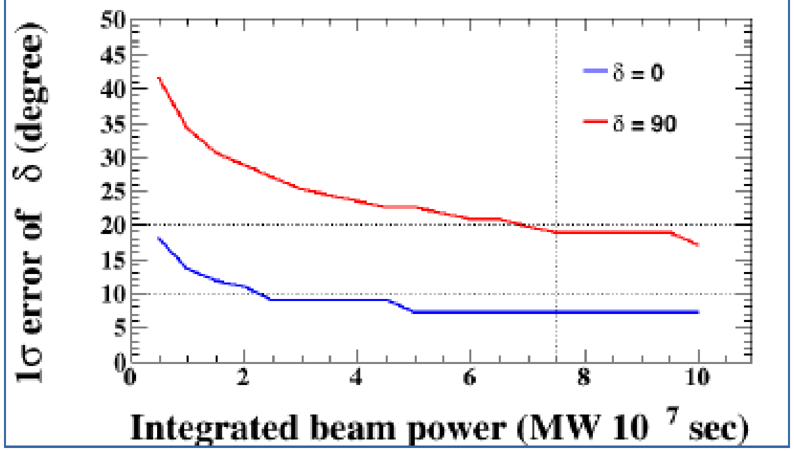
Disappearance	ν_μ	$\bar{\nu}_\mu$	ν_e	$\bar{\nu}_e$	NC	$\nu_\mu \to \nu_e$	Total
ν mode	17225	1088	11	1	999	49	19372
$\bar{\nu}$ mode	10066	15597	7	7	1281	6	26964

Large expected number of events. NH, $\sin^2 2\theta_{13}$ = 0,1 and δ_{CP} = 0

Fractional region of δ(%) for CPV ($\sin\delta \neq 0$) > 3,5 σ



1σ uncertainty of δ as a function of the beam power: < 19°(6°) for δ = 90°(0°)

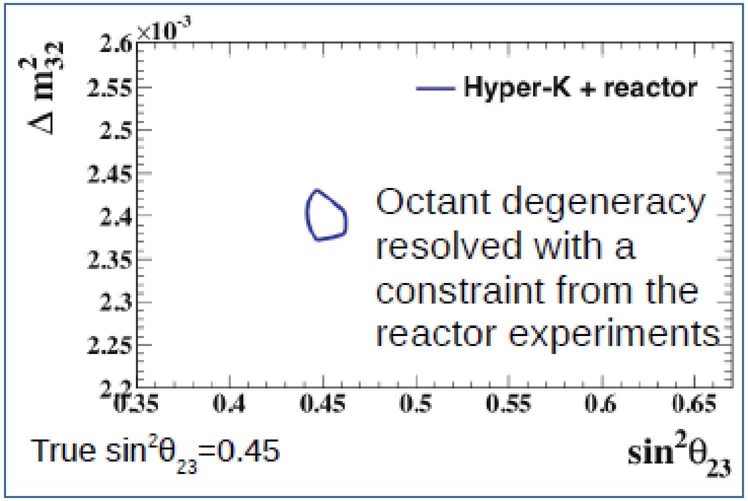


Mass Hierarchy, Mixing Angles

Beam Physics

- $\sin^2 2\theta_{23}$ and Δm^2_{23} determined from oscillation beam analysis
- Octant resolution w/ reactor θ_{13}: ~3σ wrong octant rejection for $\sin^2\theta_{23}$<0.46 or >0.56

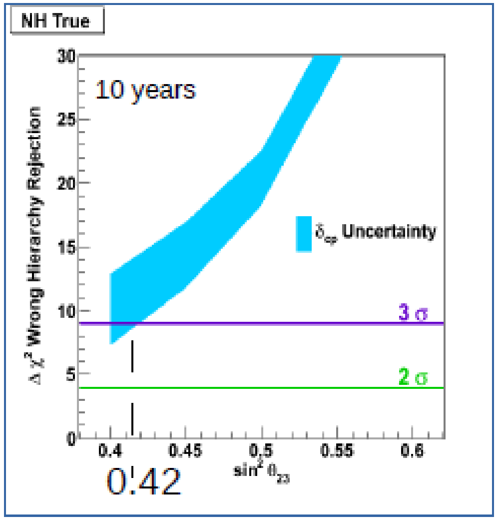
True $\sin^2\theta_{23}$	1σ err $\sin^2\theta_{23}$	1σ err Δm^2_{23} (eV^2)
0.45	0.006	1.4
0.50	0.015	1.4
0.55	0.009	1.5

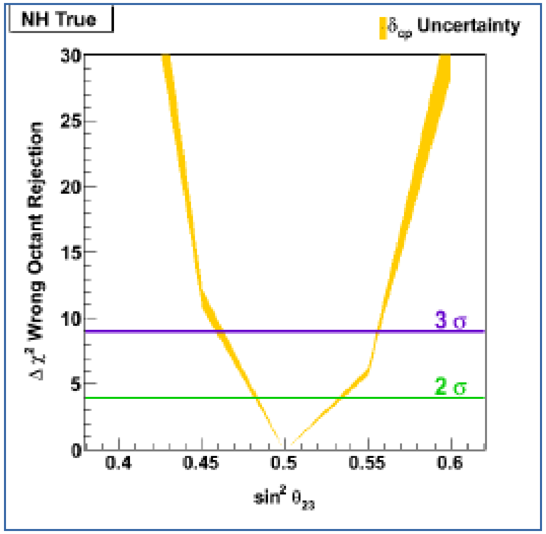


Atmospheric neutrinos

Use atmospherics for 3σ mass hierarchy determination and also θ_{23} octant determination.

arXiv:1109.3262

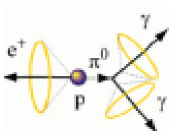


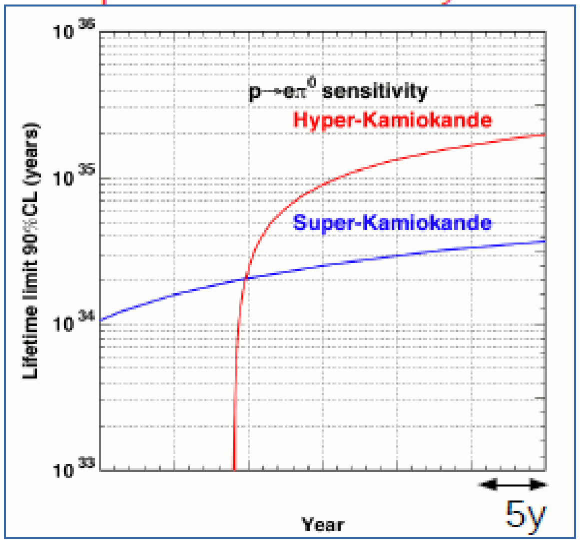


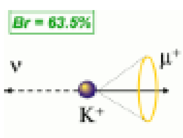
Proton Decay

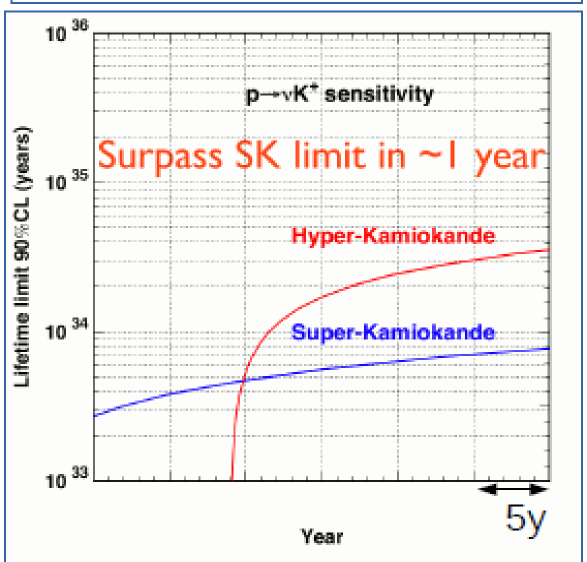
arXiv:1109.3262

Surpass SK limit in ~1 year

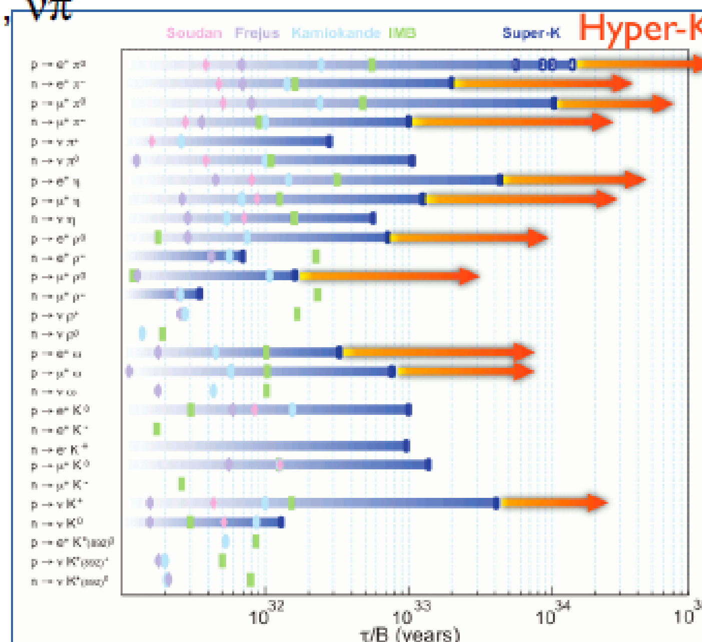








- 10 times better sensitivity than Super-K
- Hyper-K surpasses SK limits in ~1y
- Hyper-K is sensitive in every single mode
  - $p\to e^+\pi^0$: 1.3×10^{35} y at 90% CL
  - $p\to\bar{\nu}K^+$: 2.5×10^{34} y at 90% CL
  - Note: limits with old reconstruction
  - Many other modes:
    - $p(n\to e,\mu)+(\pi,\rho,\omega,\eta)$; 10^{14}-10^{35}
    - K^0 modes
    - $\nu\pi^0$, $\nu\pi^+$
    - ….



Astrophysical Neutrinos

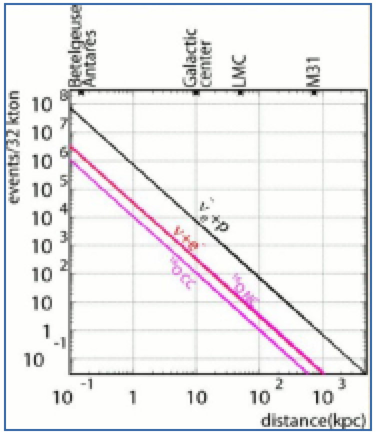
arXiv:1109.3262

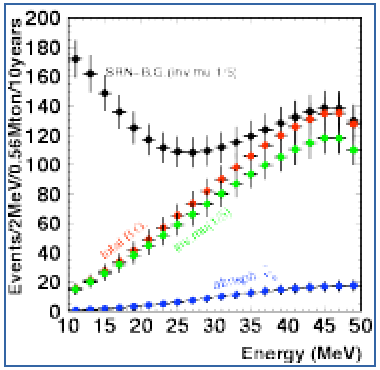
More physics topics can be investigated by Hyper-Kamiokande:

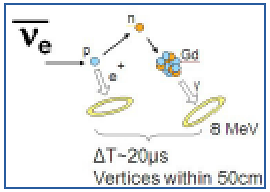
•Solar Neutrinos: ^{8}B 200 ν's / day from Sun → day/night asymmetry of the solar neutrinos flux can be precisely measured at HK (<1%).

• 200k ν's from Supernova at Galactic center (10kpc)
→ time variation & energy can be measured with high statistics. Important data to cross check explosion models

•Supernova relic neutrinos → possible G_d-doping of Hyper-K

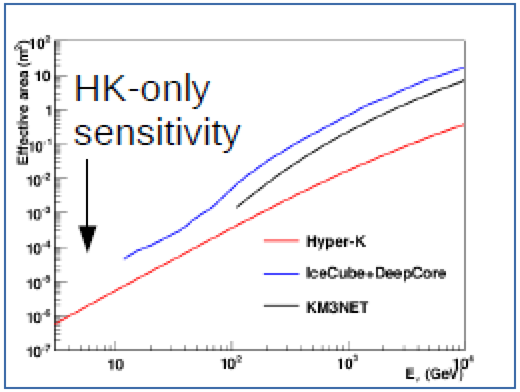




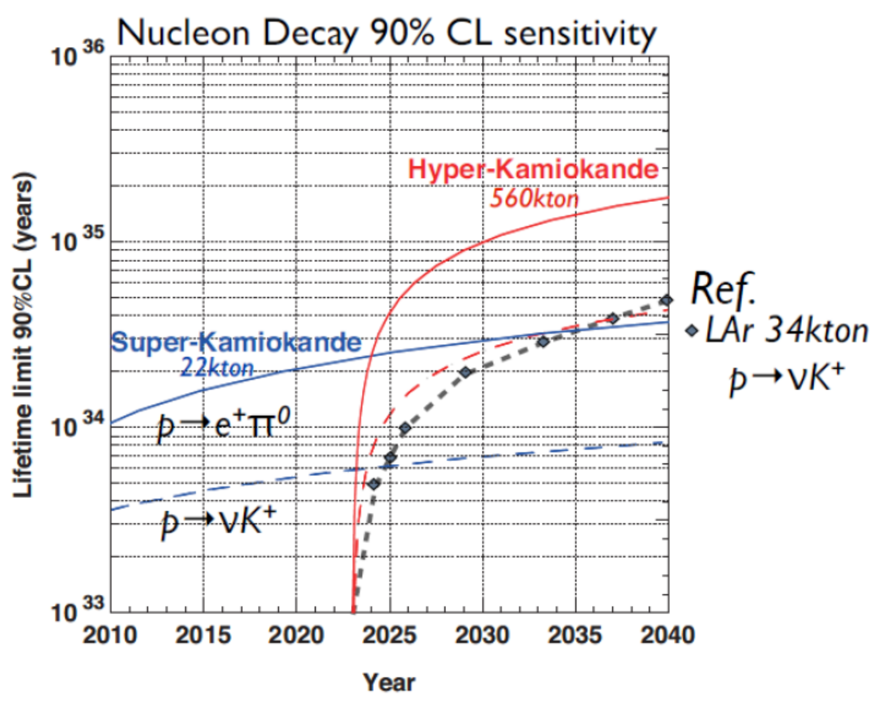


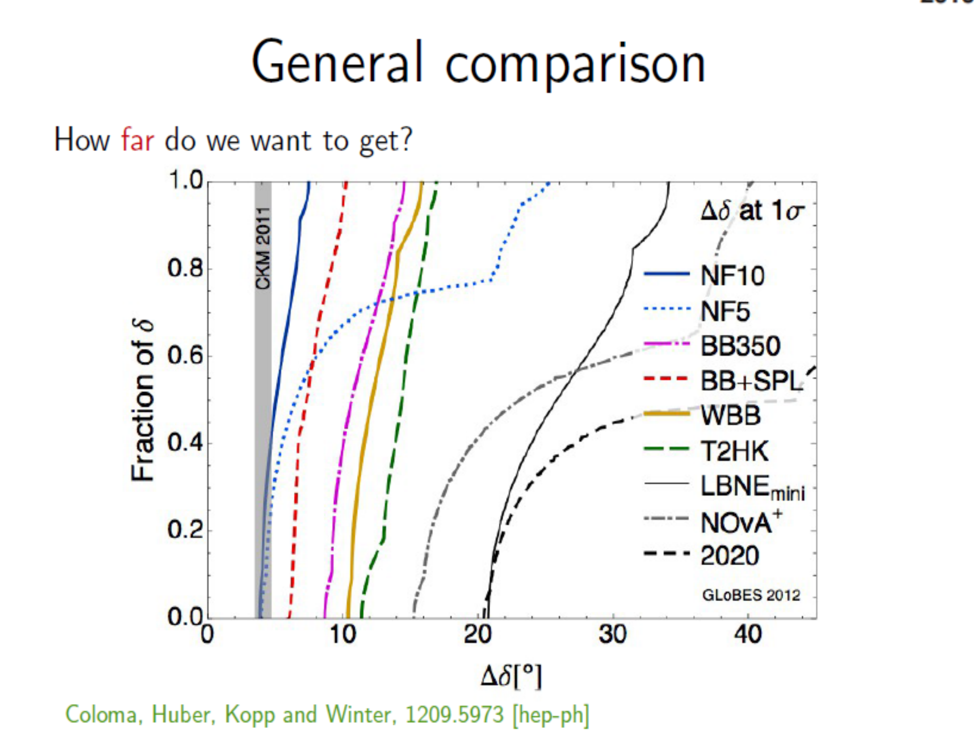
•Indirect Searches for Dark Matter (low-energy best sensitivtiy): 1) search for excess of neutrinos from the center of the Earth, Sun and galactic centre as compared to atmospheric neutrino background 2) Search for diffuse signal from Milky Way halo.

•Search for transient astrophysical phenomena: solar flares, GRBs, etc.



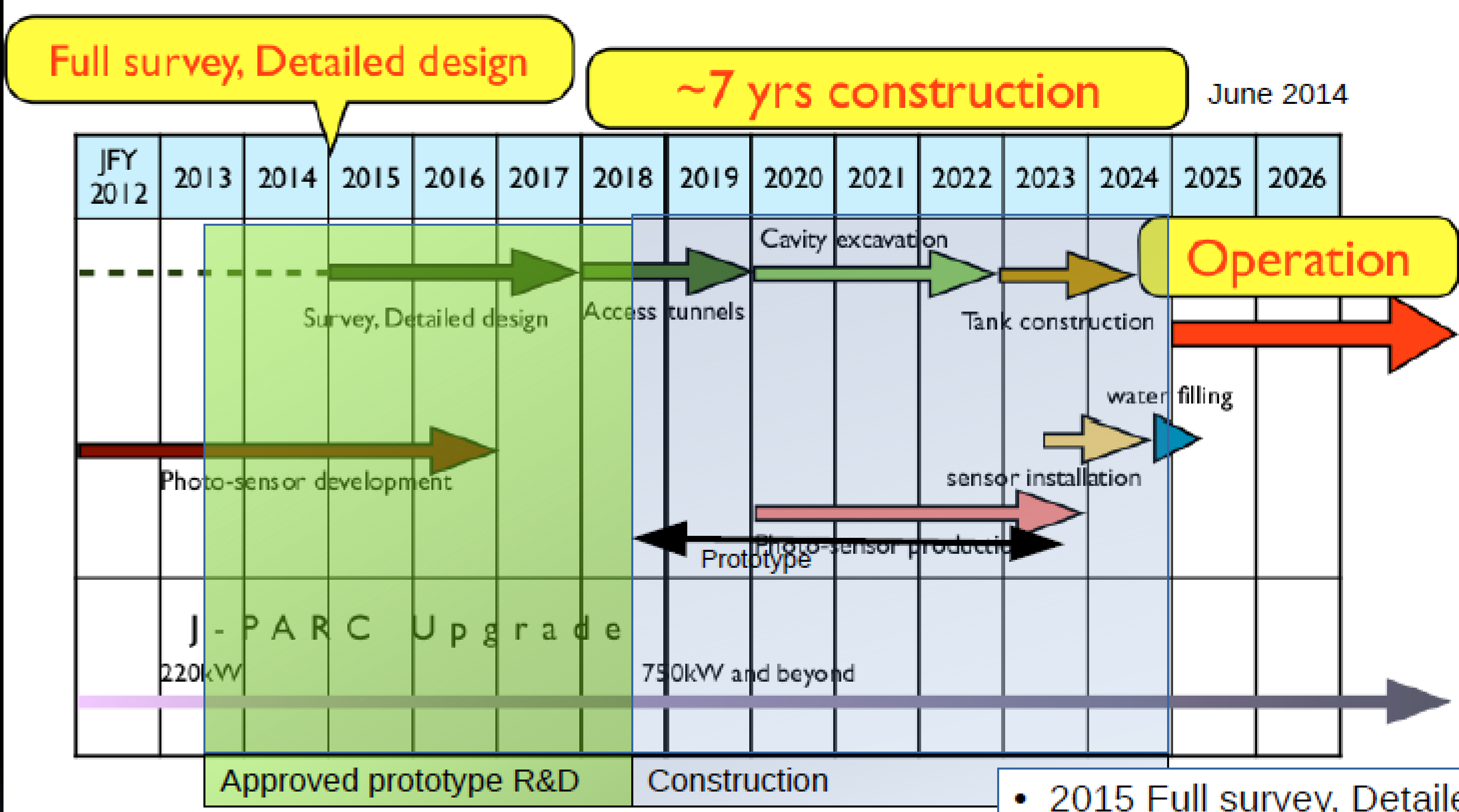
Qualche confronto…





Hyper-K Schedule

LOI April 2014 (PTEP)



- 2015 Full survey, Detailed design
- 2018 Excavation, Constructioon
- 2025 Operation

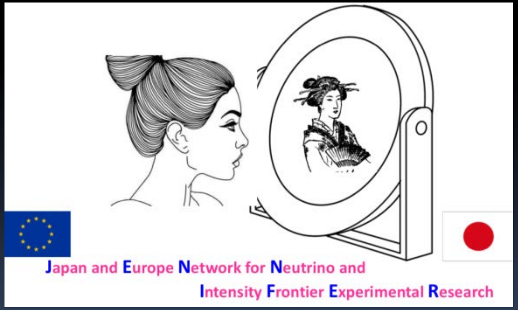
Proposal submission early 2016 → Approval JFY-2017

Funding ….

- **Cavern and Detector (WC) R&D funded in JAPAN (> 2M)**
- Awarded RISE grant in H2020 **JENNIFER** (secondments in Japan)
- A first funding request approved in **UK (2014-2017)**
- Submitted funding requests in Canada, Switezrland and Spain

JENNIFER (EU) (Starting date: April 1 2015)

● Horizon2020 EU RISE grant (call: H2020-MSCA-RISE-2014) awarded to fund secondments to Japan for 4 years for T2K, **Hyper-K**, BELLE2



● Japanese partners: KEK, University of Tokyo.

● PI: INFN (Antonio Passeri).

EU Institutes in T2K/HK: INFN (Italy), Barcelona, Saclay, **QMUL & RAL**, Warsaw

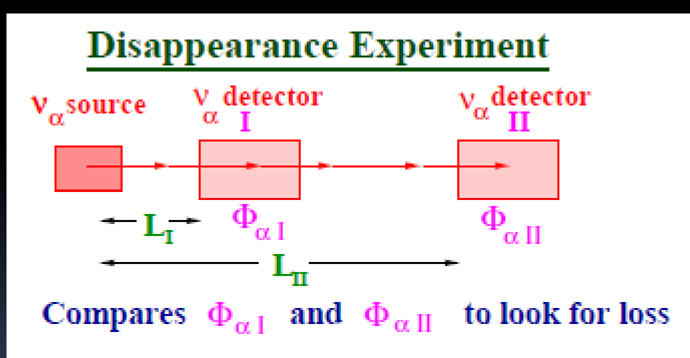
Schedule

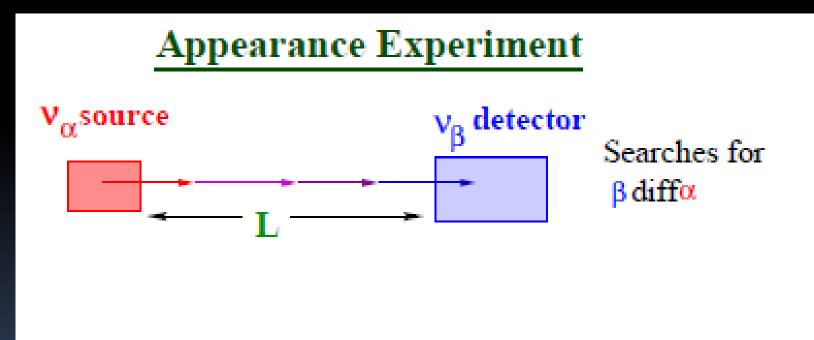
- 29-31 gennaio 2015 (HyperK (P58) open Meeting)
  - ICCR-KEK MOU Syemposium Press release
  - Launch the Hyper-K proto collaboration
- Luglio-agosto 2015 (Toward JFY2017 budget request)
  - TDR Draft (including Detector design, Excavation, Budget,Cost sharing,Near Detector design,Request to JPARC)
- Ottobre 2015
  - International Review of the TDR
  - (second round beginning 2016)
- Gennaio 2016
  - Start negotiation of budget request (MEXT)
- 2016-2017
  - Masterplan2017, Roadmap2017
- 2018 -> Inizio HyperK

Backup

Goal di fisica (Proposal 2001)

- Misure di θ_{13} :
  - Direct detection of neutrino flavour mixing in "appearance" mode
- Misura di precisione di θ_{23}, Δm^2_{23}
  - θ_{23} = 45° ± 5° (T2K puo' distinguere l'ottante)
- X-sections di interazioni neutrino nella regione del GeV @ ND280
- Ricerche esotiche : Neutrini Sterili ed effetti sub-leading





$$P_{\mu\to\mu} \approx 1 - \sin^2 2\theta_{23} \sin^2\left(\frac{\Delta m^2_{31} L}{4E}\right)$$
+ (subleading terms)

$$P_{\mu\to e} \approx \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin^2\left(\frac{\Delta m^2_{31} L}{4E}\right)$$
+ (CPV term) + (matter term) + ...

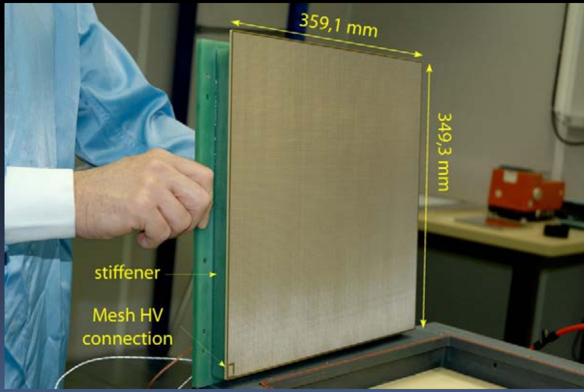
TPC: contributo INFN

Prima TPC di grandi dimensioni basata su rivelatori micro-pattern come tracciatore

Perchè una TPC basata su rivelatori micro-pattern come tracciatore:

- Risoluzione spaziale eccellente (≈0.3mm) in un ampio volume
- Contrariamente alle TPC tradizionali, la risoluzione non dipende dalla direzione delle traccie: molte traccie da CCQE sono a largo angolo.
- Leggerezza, indispensabile per i secondari di bassa energia
- Identificazione per dE/dx (risoluzione ≈ 10%)
- Buona risoluzione in impulso <10% @1GeV/c

La TPC durante l'installazione



MM

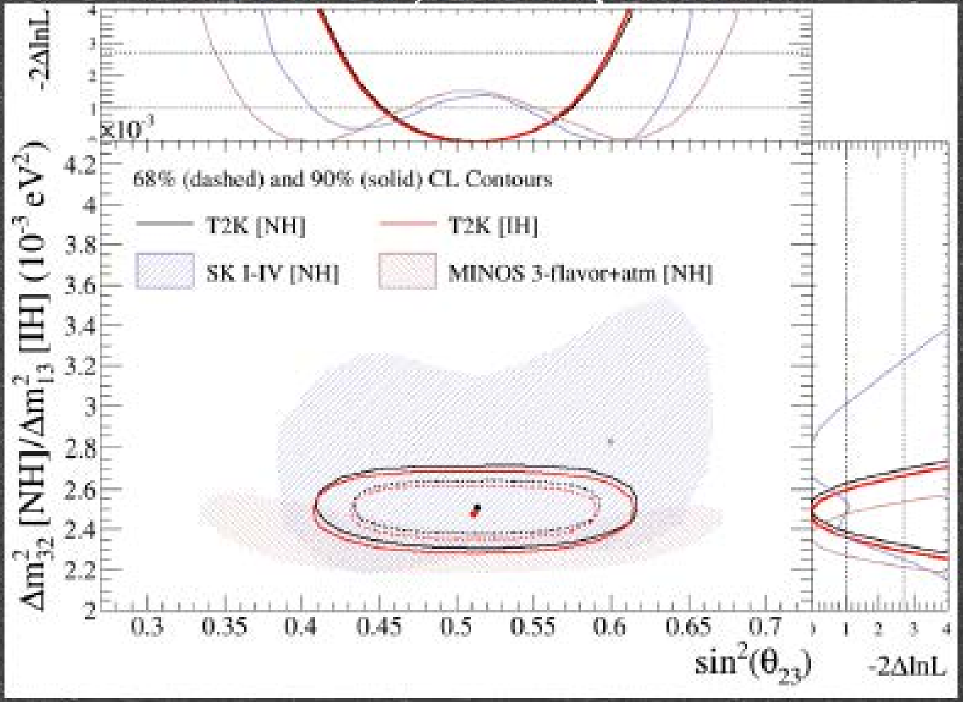
Le TPC dei progetti futuri (Alice,ILC) prevedono MPGD Readout

T2K Highlights 2013-2014

ν_μ disappearance analysis

T2K

PRL. 112, 181801 (2014)



- For the first time the mixing angle θ_{23} is better constrained by an accelerator experiment than by atmospheric neutrinos
- $\sin^2(\theta_{23}) = 0.514 \pm 0.055$ (NH) → 10% uncertainty corresponding to an uncertainty of 3° on the angle

UK HK Funding status (STFC)

- "Bridging funds"
  - ➢ Jan 2014-March 2015
  - ➢ Calibration HW: ~£11k
  - ➢ Travel funds: ~£40k
  - ➢ Limited support from STFC/RAL engineers (DAQ)

- "Project funds"
  - ➢ October 2014 (retroactive) – September 2017
  - ➢ Currently finalizing the costs with STFC
  - ➢We decreased our travel request thanks to EU funds
  - ➢ Awarded almost all we asked for. It's mainly personnel: postdocs and STFC/RAL engineer costs for DAQ and beam.
  - ➢ Construction grant to follow this one.

ICRR-KEK/IPNS MOU

ハイパーカミオカンデ計画の推進についての覚書

東京大学宇宙線研究所および高エネルギー加速器研究機構素粒子原子核研究所は、次世代核子崩壊・ニュートリノ実験「ハイパーカミオカンデ」計画の実現が、物理学及び天文学の発展に重要な意義をもたらすことを認識し、ハイパーカミオカンデ研究者グループの研究方針を踏まえつつ、協力して計画を推進する。また計画推進体制や予算措置を含む、計画推進に必要な事項について、適宜連絡協議する。

この合意は、平成２６年１２月ZZ日から２年間有効とし、２者間の協議により更新できるものとする。

平成２６年１２月ZZ日

東京大学宇宙線研究所長
梶田隆章

高エネルギー加速器研究機構
素粒子原子核研究所長
山内正則

Memorandum of Understanding of
The cooperation in the Hyper-Kamiokande project

The Institute for Cosmic Ray Research of the University of Tokyo and the Institute of Particle and Nuclear Studies of the High Energy Accelerator Research Organization have reached agreement regarding cooperation in promoting the advanced nucleon decay and neutrino experiment program, Hyper-Kamiokande, by understanding that the program would make significant progress in a wide range of fields in physics and astronomy. It is also agreed to review and develop the program in its comprehensive aspects including promoting organization and budget measures.

This agreement is effective for two years from December XX, 2014 and is able to be updated upon the discussion between the two organizations.

December XX, 2014

Takaaki KAJITA
Director
Institute for Cosmic Ray Research,
The University of Tokyo

Masanori YAMAUCHI
Director
Institute of Particle and Nuclear Studies,
High Energy Accelerator Research
Organization