WP4
The Hyper-Kamiokande Experiment

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On behalf of the JENNIFER-WP4

Queen Mary University of London
September 23, 2016

EU grant n.644294

A Multi-purpose Experiment

Comprehensive study of ν oscillation

- CPV
- Mass hierarchy with beam+atmosph. ν
  octant
- Test of exotic scenarios

Nucleon decay discovery potential

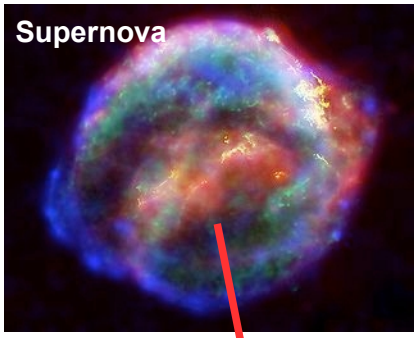
- All visible modes including p and p→
  can be advanced beyond SK.
- Reaching yrs sensitivity

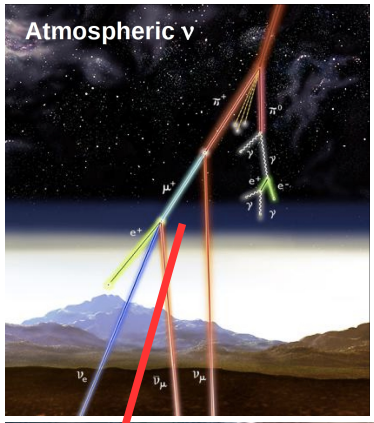
Unique Astrophysics

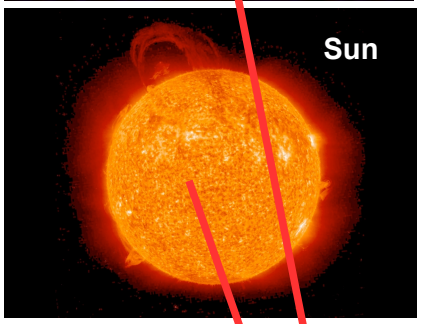
- Precision measurement of solar ν
- High statistics Supernova ν with pointing
  capability and energy info.
- Supernova relic ν (non-burst)
  observation is also possible

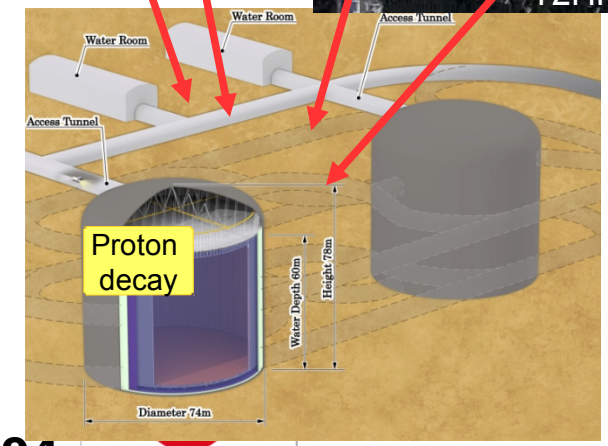
Earth core's chemical composition

Etc.









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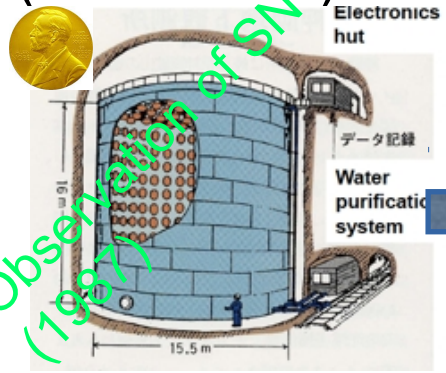
Kamiokande Evolution

- Increasing interests and achievements in neutrino physics in the last decades.
- Three generations of large Water Cherenkov in Kamioka.
- **Tank design for Hyper-Kamiokande optimized** .

Kamiokande (1983-1996)



3kton

Observation of SN1987A (1987)

Super-Kamiokande (1996-)

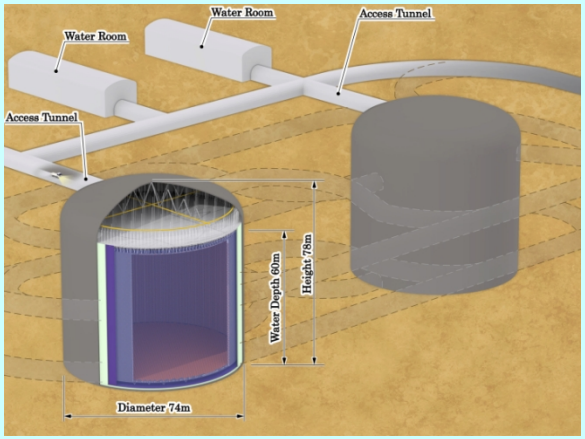
50kton

Discovery of neutrino oscillation (1998)

Observation of electron neutrino appearance (w/ beam, T2K, 2013)

x17

Hyper-Kamiokande (2026-)



0.52Mton=520kton

(380kton fiducial)

x10

(x20 fiducial mass)

arXiv:1109.3262
arXiv:1309.0184
PTEP 2015, 053C02

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Proto-Collaboration

Gifu University (Japan)
High Energy Accelerator Research Organization (KEK) (Japan)
Kobe University (Japan)
Kyoto University (Japan)
Miyagi University of Education (Japan)
Nagoya University (Japan)
Okayama University (Japan)
Osaka City University (Japan)
Tohoku University (Japan)
Tokai University (Japan)
University of Tokyo, Earthquake Research Institute (Japan)
University of Tokyo, Institute for Cosmic Ray Research, Kamioka Observatory (Japan)
University of Tokyo, Institute for Cosmic Ray Research, Research Center for Cosmic Neutrinos (Japan)
University of Tokyo (Japan)
University of Tokyo, Institute for the Physics and Mathematics of the Universe (Japan)
Tokyo Institute of Technology (Japan)
Boston University (USA)
Chonnam National University (Korea)
Dongshin University (Korea)
Duke University (USA)
Imperial College London (UK)
Institute for Particle Physics Phenomenology, Durham University (UK)
INFN and Dipartimento Interateneo di Fisica di Bari (Italy)
INFN-LNF (Italy)
INFN and Università di Napoli (Italy)
INFN and Università di Padova (Italy)
INFN Roma (Italy)
Institute for Nuclear Research (Russia)
Iowa State University (USA)

IRFU, CEA Saclay (France)
Laboratoire Leprince-Ringuet, Ecole Polytechnique (France)
Lancaster University (UK)
Los Alamos National Laboratory (USA)
Louisiana State University (USA)
National Centre for Nuclear Research (Poland)
Pontificia Universidade Catolica do Rio de Janeiro (Brazil)
Queen Mary, University of London (UK)
Royal Holloway University of London (UK)
Seoul National University (Korea)
Seoyeong University (Korea)
State University of New York at Stony Brook (USA)
STFC Rutherford Appleton Laboratory (UK)
Sungkyunkwan University (Korea)
The California State University Dominguez Hills (USA)
TRIUMF (Canada)
University Autonoma Madrid (Spain)
University of British Columbia (Canada)
University of California, Davis (USA)
University of California, Irvine (USA)
University of Edinburgh (UK)
University of Geneva (Switzerland)
University of Hawaii (USA)
University of Liverpool (UK)
University of Oxford (UK)
University of Pittsburgh (USA)
University of Regina (Canada)
University of Rochester (USA)
Universidade de Sao Paulo (Brazil)
University of Sheffield (UK)
University of Toronto (Canada)
University of Warsaw (Poland)
University of Warwick (UK)
University of Washington (USA)
University of Winnipeg (Canada)
Virginia Tech (USA)
Wroclaw University (Poland)
York University (Canada)

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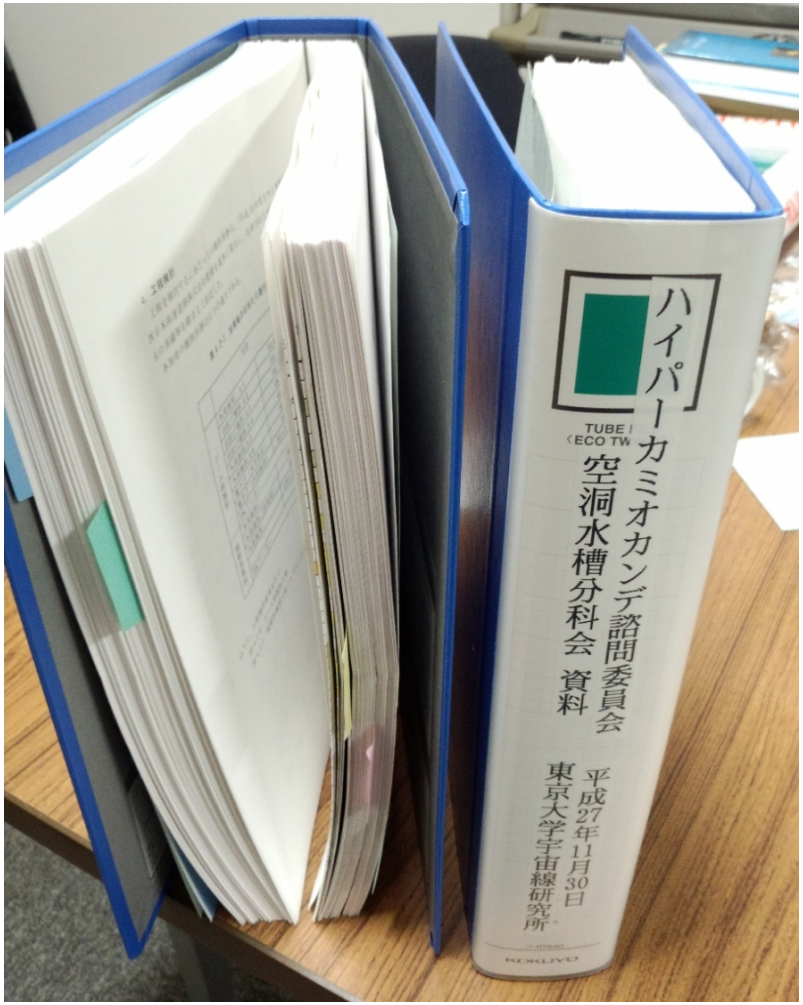
Hyper-K Design Report

KEK Preprint 2016-21
ICRR-Report-701-2016-1

Hyper-Kamiokande

DesignReport
Version2(DatedFebruary7,2016)



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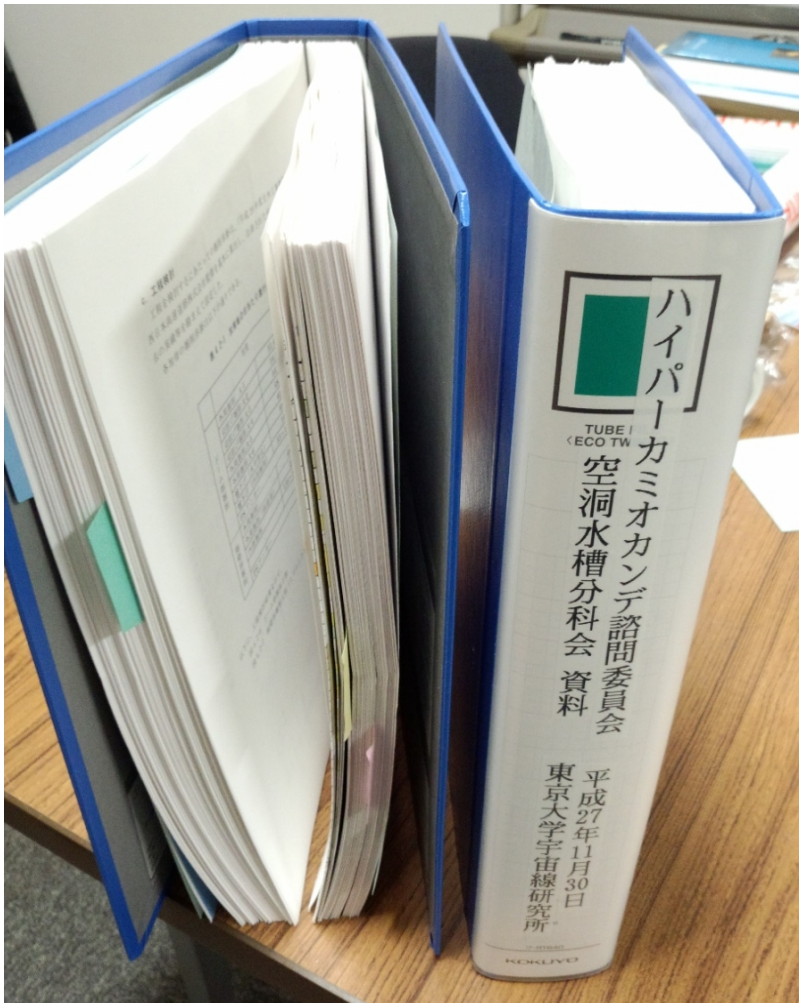
Design Report

- JENNIFER members contributed and lead both the overall and sections of the 300 pages of the Design Report.
- The JENNIFER support is mentioned in the acknowledgements.
- It constitutes the seedcorn of the future Technical Design Report.
- It was submitted to the Hyper-K Advisory Committee (January 2016) and successfully passed the review.



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Tasks

Task 4.1: Water Cherenkov Detector [INFN, NCBJ, QMUL, RAL, KEK].

Task 4.2: High-Pressure TPC [CEA, INFN, KEK, QMUL, RAL]

Task 4.3: Beam [RAL, KEK]

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Deliverables

Task 4.1:

- Updated sensitivity studies for Hyper-K using a new WC detector around 2km (month 24);
- Photosensors performance study (month 36);
- Tests with the 1kton WC prototype (month 48)

Task 4.2:

- Simulation with accurate gas properties (month 48)

Task 4.3: Beam [RAL, KEK]

- Beam target design for 750kW operations (month 36);
- Beam target proposal for MW beam (month 48).

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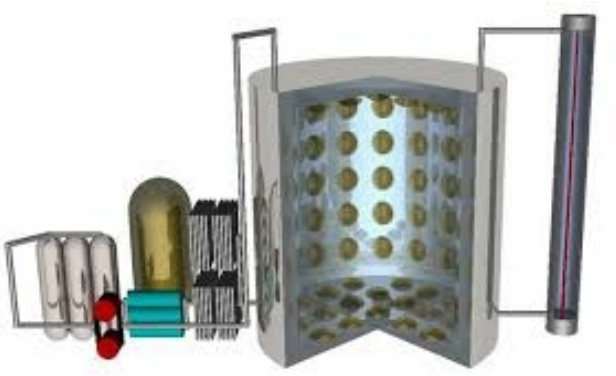
Water Cherenkov “Prototypes”

- Several Water Cherenkov detectors in the world.
- We are working together with the Super-Kamiokande and EGADS collaboration on several items for Hyper-K. We can use those Water Cherenkov (WC) as “prototypes”.

Super-Kamioka (~50kton), Kamioka



EGADS (~200t), Kamioka

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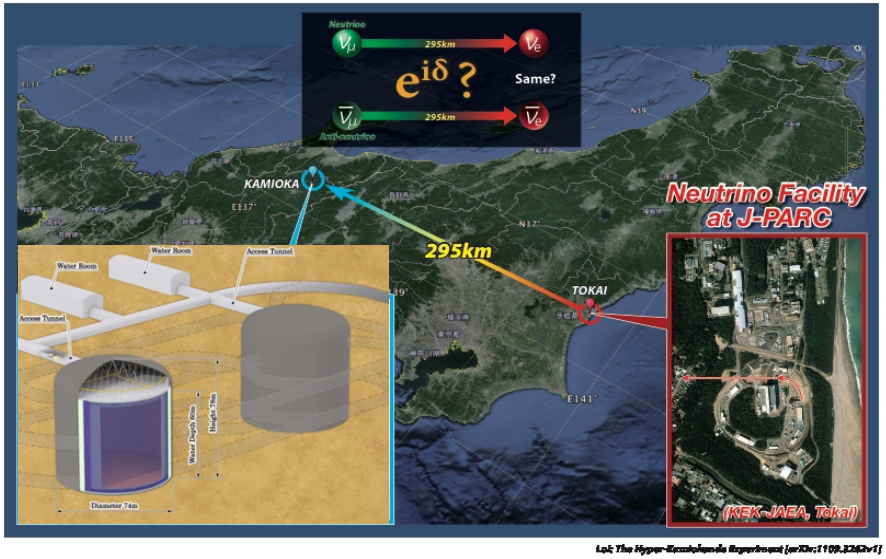
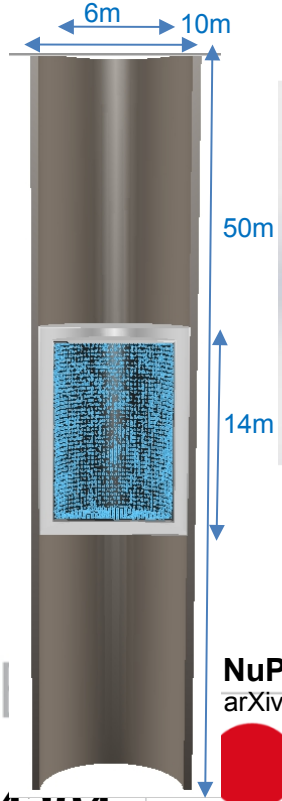
Tokai to Hyper-Kamiokande

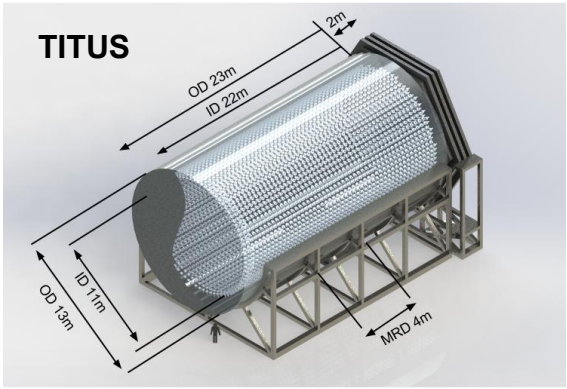


Use upgraded J-PARC neutrino beam line (same as T2K) with expected beam power > 1.3MW, 2.5° off-axis angle, narrow-band beam at ~600MeV.

Near ND280 detector will be upgraded to continue for Hyper-K;

Intermediate (at ~1,2 km) WC detector is needed and aimed to be added. Two proposals that are currently forming a unique collaboration.





arXiv:1606.08114 [physics.ins-det]

NuPRISM
arXiv:1412.3086 [physics.ins-det]

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WC Detector Work (Task 4.1)

- Hyper-Kamiokande and the intermediate detector are Water Cherenkov (WC) detectors.
- We are working on:
  - PMTs and electronics (next slide)
  - DAQ (next talk)
  - Calibration (next talk)
- Our contributions will be used in both the Hyper-Kamiokande and intermediate detectors.
- Super-K and EGADS are our “prototypes” for the calibration work.

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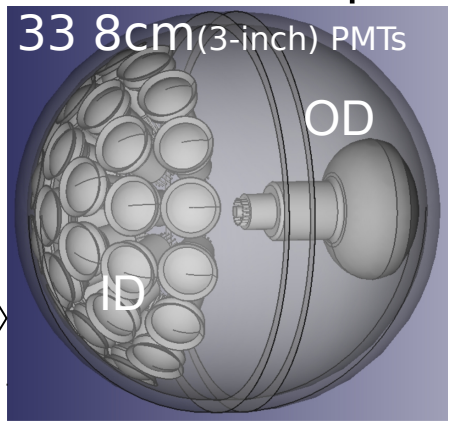
Multi-Channel Optical Module

- Working concept from KM3NeT but:
  - peripheral Inner Detector/Outer Detector.
  - lower pressure tolerance required.
  - ultrapure water.
- Large fiducial volume by directional sensitivity cut and less dead area.
- No geomagnetism compensation.
- Many PMTs and readout channels.
- Acrylic pressure vessel:
  - low radioactive background
  - high optical transmittance
  - contain radon from PMT glass
  - pressure vessel for protection of PMTs and electronics.
  - same vessel and electronics for Inner and Outer (veto)Detector

Based on KM3NET optical module

1 of concepts



20cm PMT for OD

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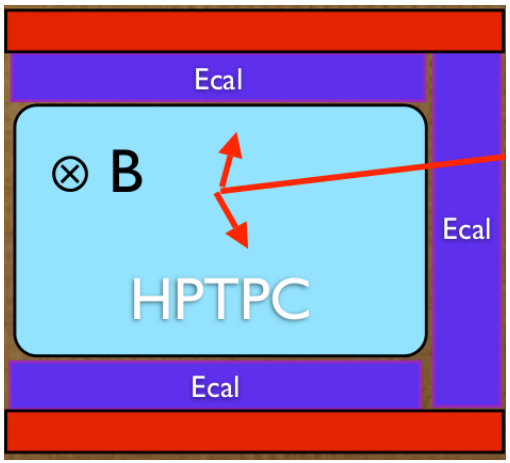
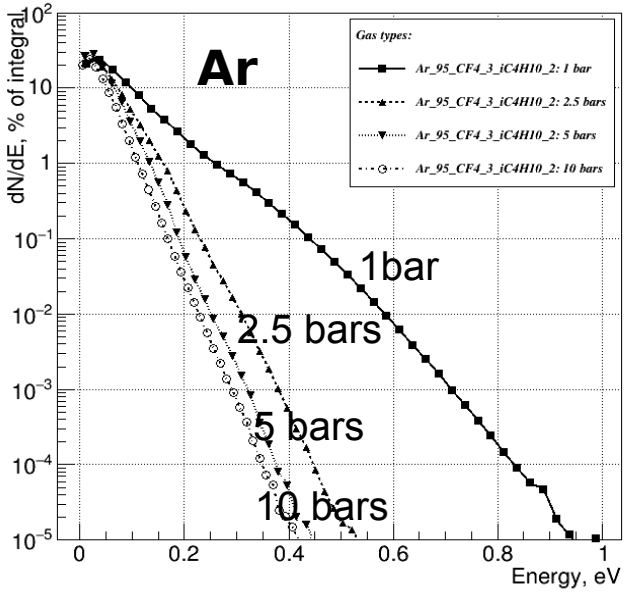
High Pressure TPC (Task 4.2)



- Aim: Reduce the systematic errors affecting the measurements at Hyper-Kamiokande addressing low energy protons and pions, not possible otherwise.
- It can constitute an upgrade of ND280 for Hyper-Kamiokande.

- Simulation of gas properties started.
- Measurement of gas properties planned and preparations are progressing.
- Optimization of detector design in progress to reach 2% error on neutrino interactions.

Drift electron velocity distribution



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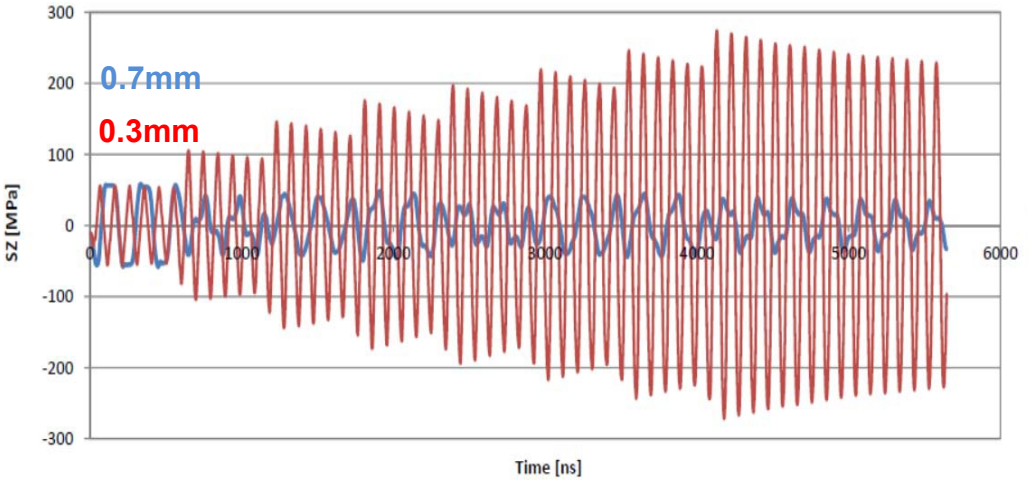
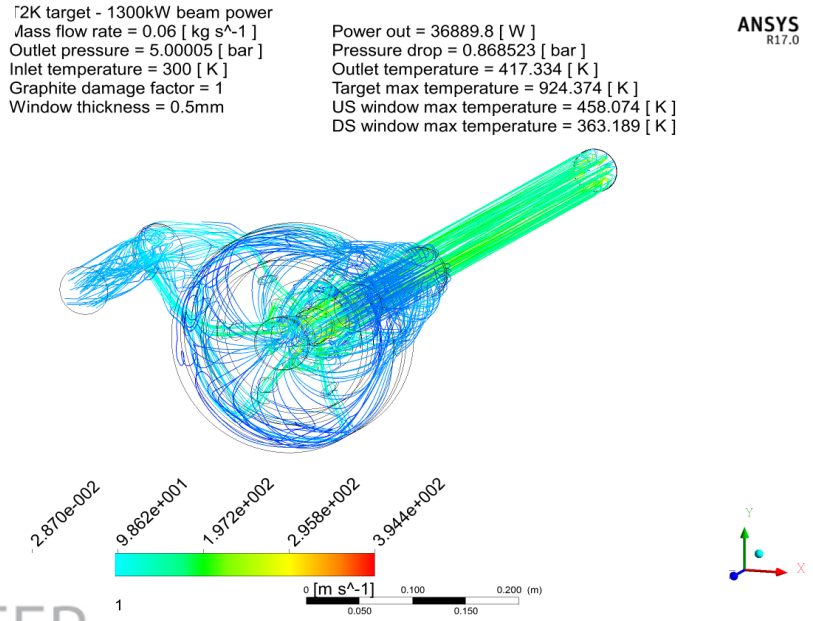
Target and Beam Window (Task 4.3)



KEK approved a $80M Upgrade up to 1.3MW beam power.

New beam window studies for 1.3MW are underway.

Z(beam direction) stress as function of time at window centre (max stress point) @ 1.3MW



Studies of the current target design operating at increased flow rate and pressure are in progress.

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Secondments

WP	Days total	Months	Planned	Fraction	Started secondmts	Fraction started	Planned in 4 years
WP1	259	8,6	19	45,4%	17	89,5%	65
WP2	2078	69,3	107	64,7%	94	87,9%	227
WP3	943	31,4	51	61,6%	45	88,2%	113
WP4	381	12,7	53	24,0%	32	60,4%	98
WP5	41	1,4	5	27,3%	2	40,0%	10
Total	**3702**	**123,4**	**235**	52,5%	190	80,9%	513

Fraction of started 60% secondments is higher than the the fraction of "completed units" 24%.

WC Prototype is now SK. We will increase our secondments to Kamioka.

Considerable increase expected in the rest of the project due to shifts at installation of calibration in Super-K.

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Conclusions

All Tasks are proceeding well and according to plan.

- Task 4.1:
  - Demostrated importance of intermediate detector.
  - We are working on several items related to WC detectors useful for both Hyper-Kamiokande and the intermediate detector.
  - We use Super-Kamiokande to test our calibration.
  - All our items are reported in the Technical Report.
- Task 4.2:
  - The HPTPC is a possible candidate for ND280 update.
  - Work focussed on the detector simulation.
- Task 4.3:
  - Working on material radiation and optimization for 1.3MW beampower.

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