The TRIUMF Neutrino Program – T2K

Dean Karlen
University of Victoria and TRIUMF

TRIUMF 50th Anniversary Science Symposium – July 17, 2018

Neutrinos at TRIUMF (T2K)

Under his leadership, Akira Konaka started the T2K effort in Canada in 2001

- unable to be here today…

"Letter of Intent" for a new project in Japan (June 2001)

The JHF-Kamioka neutrino project

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“JHF-Kamioka neutrino project” (2001)

From the document:

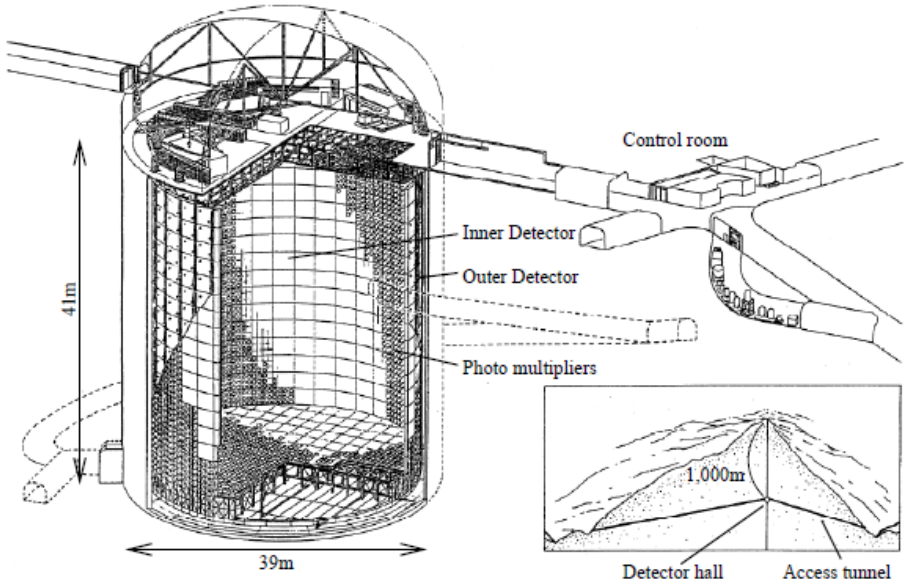


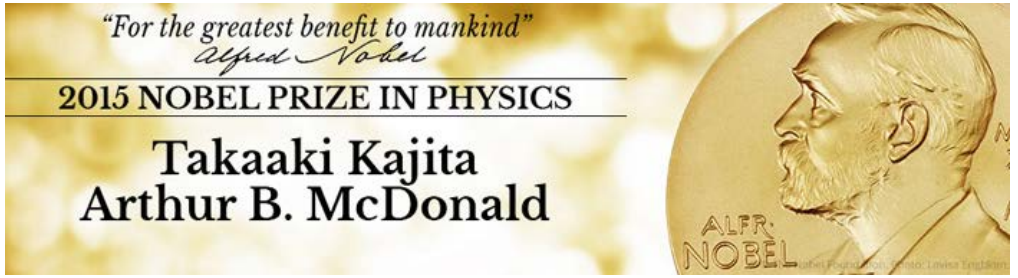
Figure 7: A schematic view of the Super-Kamiokande Detector.

Figure 1: Baseline of the JHF-Kamioka neutrino project

It concludes with:

The first phase experiment is planned to start in 2007.

Scientific motivation



In decades prior, experiments detected neutrinos from natural sources at lower than expected rates:

- neutrinos produced from cosmic rays striking our atmosphere
- neutrinos produced in the nuclear reactions that power the sun

The mystery was solved at the turn of the century with measurements by Super Kamiokande and the Sudbury Neutrino Observatory that firmly established that neutrinos "oscillate" (change their flavour)

These experiments only sensitive to 2 of the possible 3 types of oscillation

- Could measure the third type with reactor and accelerator neutrinos
- With accelerator neutrinos, matter/anti-matter differences can be explored

Building a Canadian team (2001 – 2003)

The “JHF-nu” project represented a great opportunity for Canadian physicists to make the next discoveries in neutrino oscillation

- much work to build the experiment – a large Canadian team was needed

Akira convinced several TRIUMF scientists to participate in the project, forming a nucleus with which he attracted several additional scientists from across Canada

- TRIUMF organized November 2001 retreat to discuss opportunities with the spokesperson and KEK-DG, also attracting leaders from other countries

20 Canadian scientists signed the pre-collaboration LOI 2003

The JHF-nu proposal approved by Japan Gov’t in December 2003

Letter requesting Canadian participation

We are very pleased to announce that the funding for the neutrino project at J-PARC has been approved by the Japanese Government at the end of December, 2003. Six hundred million Yen is allocated for FY2004, starting from April 2004, as the first year budget for the proposed 5-year construction period. Although the Governmental proposal of the FY2004 budget has to be approved formally by the Congress in March, 2004, no major amendment is anticipated as has been the case for the past several decades. Therefore, the start of the neutrino project at J-PARC in FY 2004 is secured.

A total amount of the 5-year budget we are requesting for the construction of the neutrino beam line, experimental hall, and detector is about 16 billion Yen which covers basic components of the beam line elements and minimum requirements for the neutrino detectors. To achieve the best performance of the neutrino beam line and the neutrino detectors so that they can fully exploit the high-intensity beam to be provided by J-PARC, Canadian intellectual and financial inputs are both essentially important. Your active commitment to the J-PARC neutrino project is highly welcome.

HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION
KEK

January 27, 2004

Dear Dr. Kosaka,

We are very pleased to announce that the funding for the neutrino project at J-PARC has been approved by the Japanese Government at the end of December, 2003. Six hundred million Yen is allocated for FY2004, starting from April 2004, as the first year budget for the proposed 5-year construction period. Although the Governmental proposal of the FY2004 budget has to be approved formally by the Congress in March, 2004, no major amendment is anticipated as has been the case for the past several decades. Therefore, the start of the neutrino project at J-PARC in FY 2004 is secured.

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Sincerely yours,

Yoji Totsuka
Director General
High Energy Accelerator Research Organization

Visit to J-PARC

Designing the experiment

Neutrino beamline

- the JHF proton accelerator, approved in 2001, already under construction → urgent to incorporate extraction for neutrino production (with help from TRIUMF)
- design deliberately misdirects the beam axis a few degrees away from the far detector (as proposed by TRIUMF group) – much improved beam properties

Near detectors

- rough concept of an “unsophisticated” detectors to measure properties of the neutrino beam, before oscillation takes place

Far detector

- already in place and operational

Beamline contributions

Kicker designs

- Mike Barnes, Gary Wait

Neutrino beamline optics

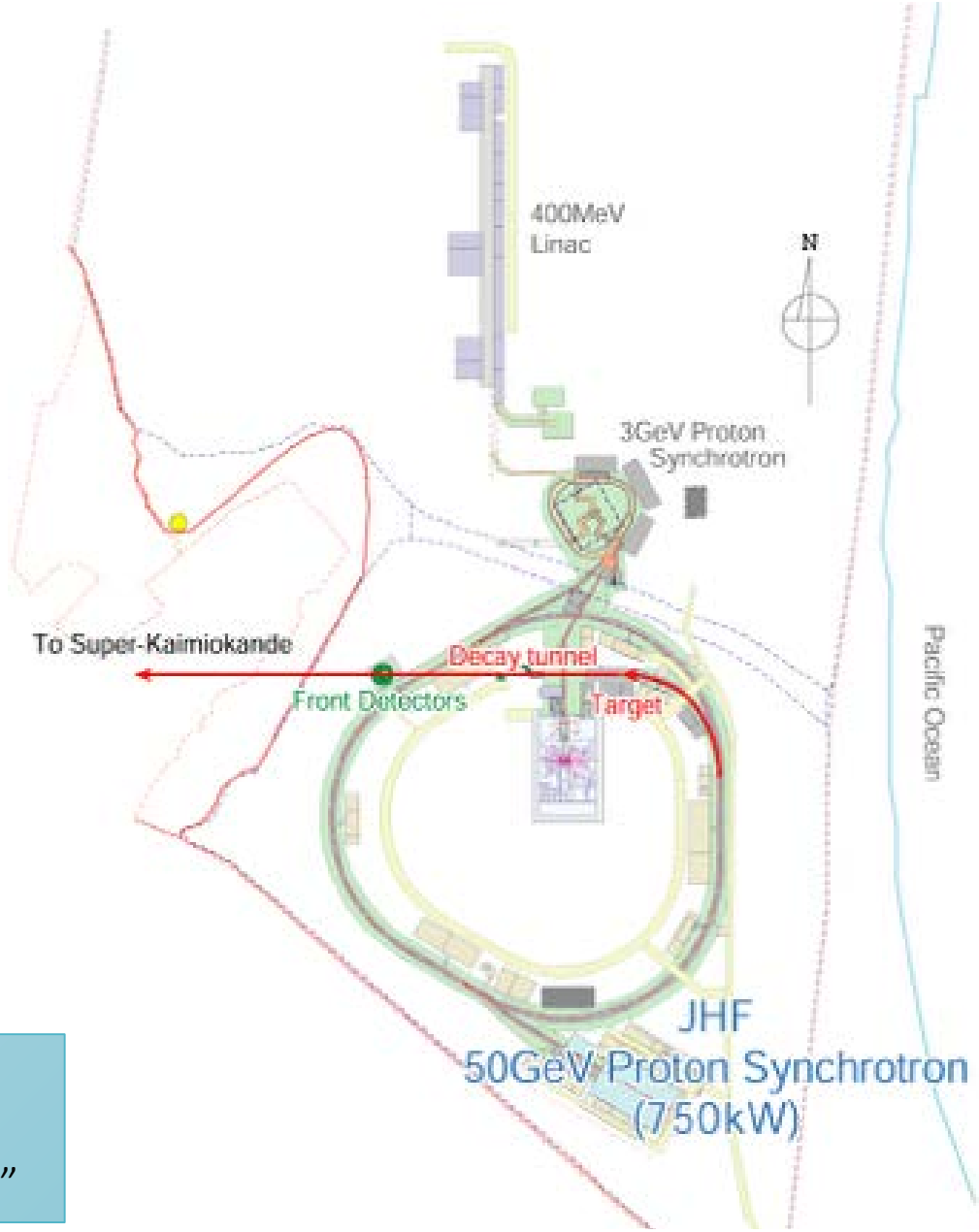
- Jaap Doornbos

Hot cell

- Clive Mark, Mike Gallop, Chad Fisher, Ewart Blackmore

Technical advisory committee

- Ewart Blackmore (chair), Clive Mark

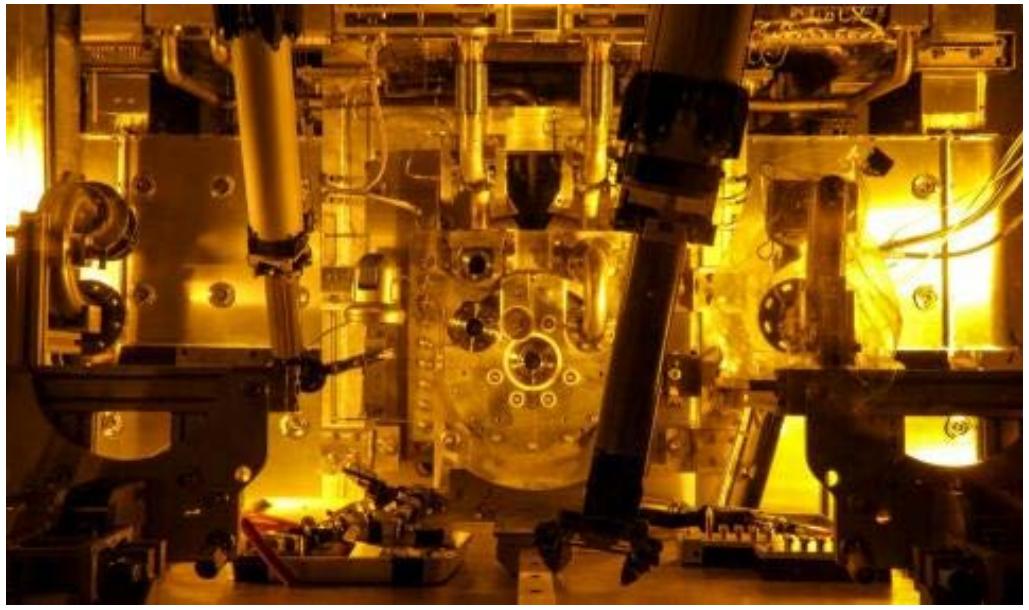


Former T2K spokesperson (Takashi Kobayashi):
"Without the collaboration with TRIUMF, the T2K beam facility would not have been completed."

Hot cell – emergency target repair

In 2015, a leak in the helium cooling system for the target threatened to shutdown the T2K experiment

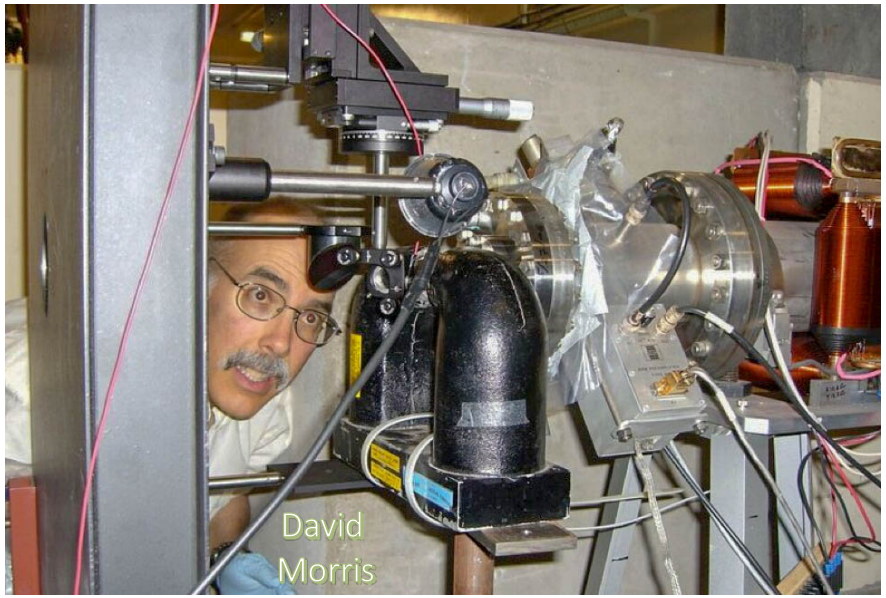
- Highly radioactive environment – impossible to access directly
- Chad Fisher and Isaac Earle called in to do the repair in the hot cell



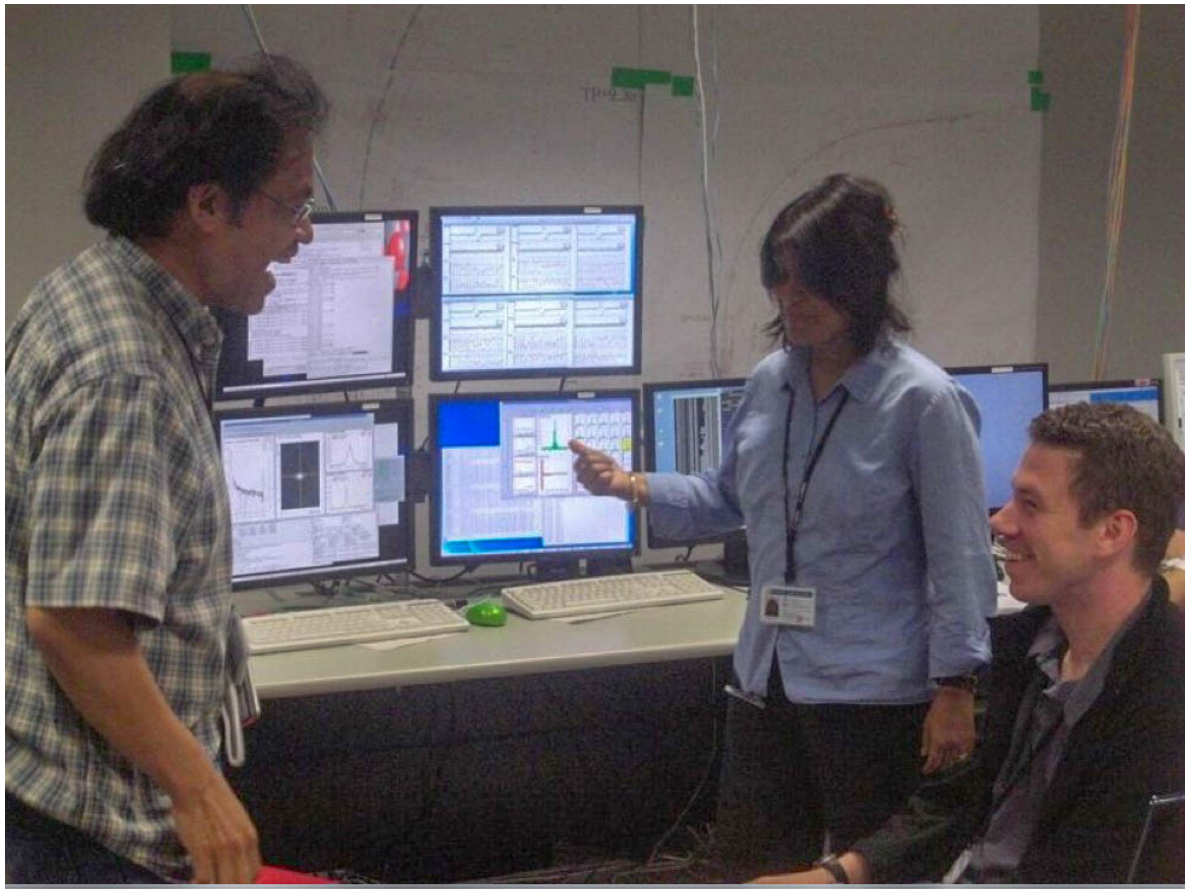
Optical Transition Radiation Detector

TRIUMF proposed to use OTR system to accurately measure position/size of beam striking target

- Once approved, Toronto/York Universities took lead. Tested concept at NRC Ottawa.



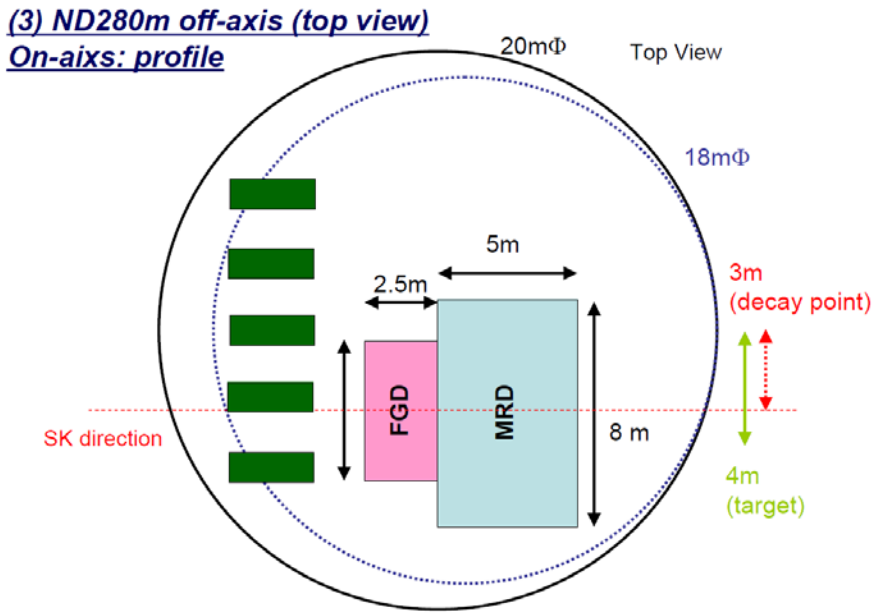
OTR system a success…

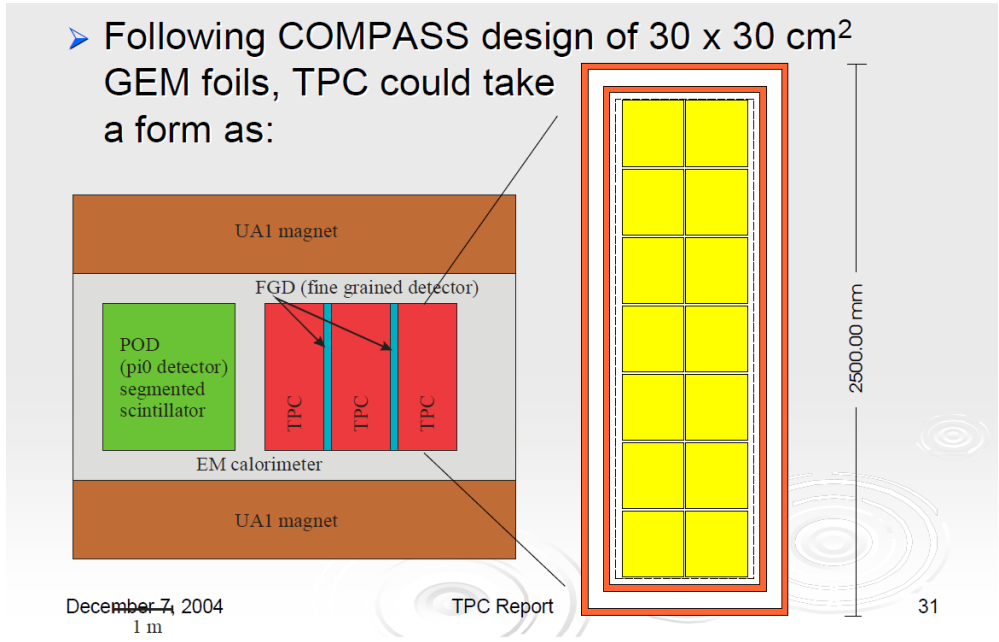


Near detector

While the accelerator and far detectors were primarily the responsibility of Japanese groups, the near detector was to be built by foreign groups

- The design evolved dramatically in 2004
- Canada group given responsibility for most critical elements (TPC+FGD)





Time projection chambers (TPCs)

Completed TPC R&D at UVic/TRIUMF for the International Linear Collider gave us a head start…

Highly ambitious schedule:

- 2005: Design/build/test prototype (proof of principle/funding)
- 2006-8: Design/construction of final systems
- 2009: Install in Japan

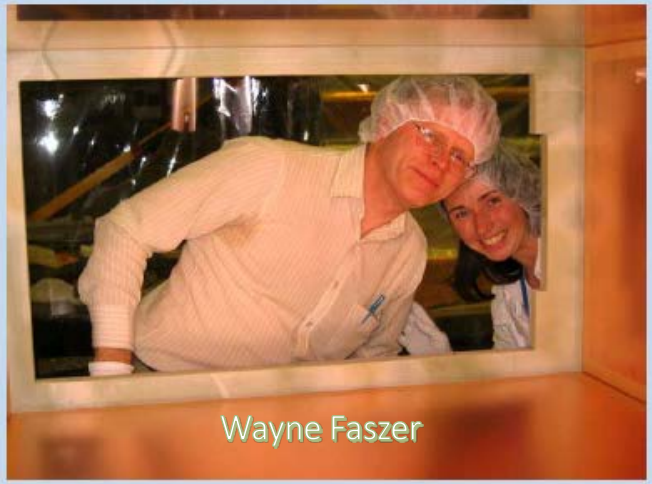
TPC prototype: 2005

Prototype worked, with results in time for funding review (Jan 11)!

Met performance specifications!

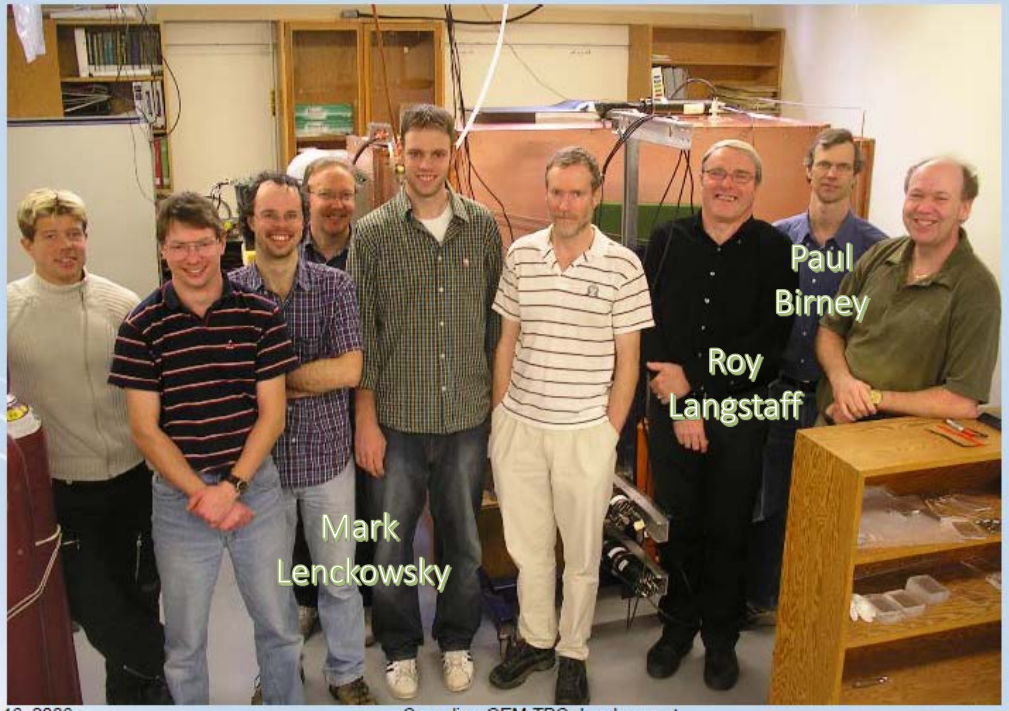
Funding for 3 fullsize TPCs approved in April 2006

- Hard work!



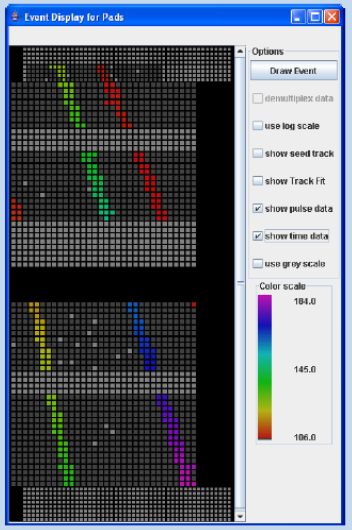
TPC shipped to Victoria

- brought over by ferry on December 20



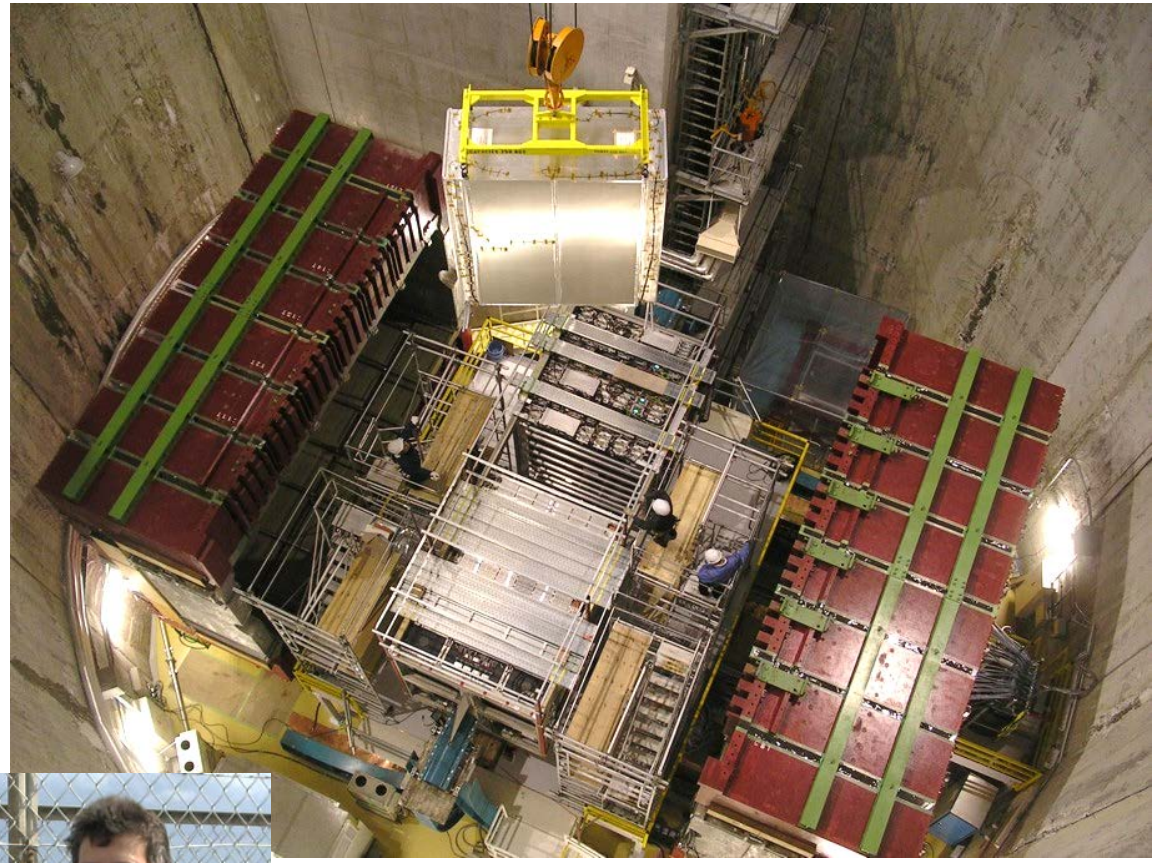
January 16, 2006 Canadian GEM TPC development 47

coloured according to arrival time



TPCs completed at TRIUMF 2008-2009

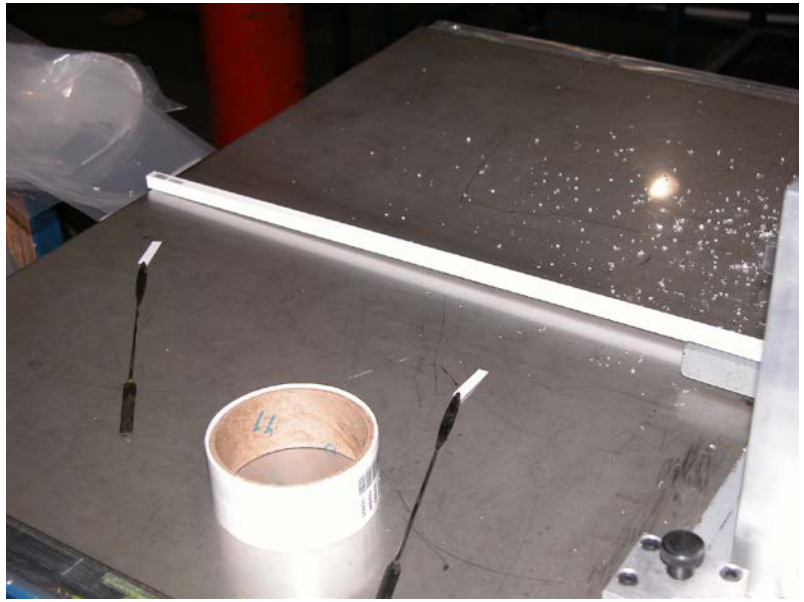
TPCs shipped to Japan 2009

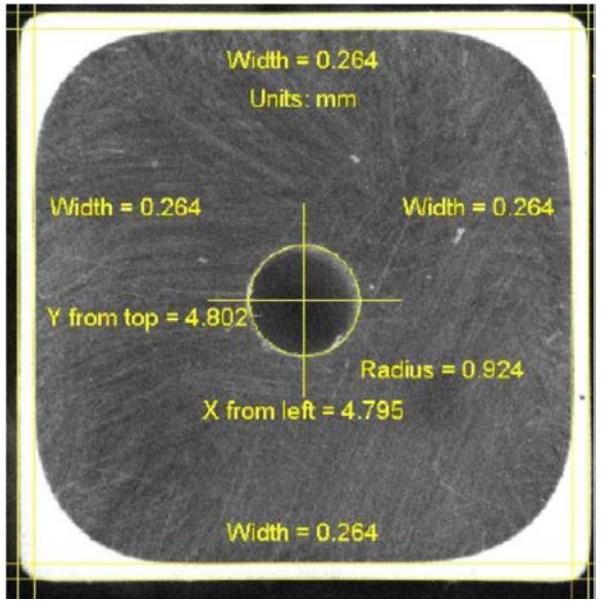


Fine grained detectors (FGDs)

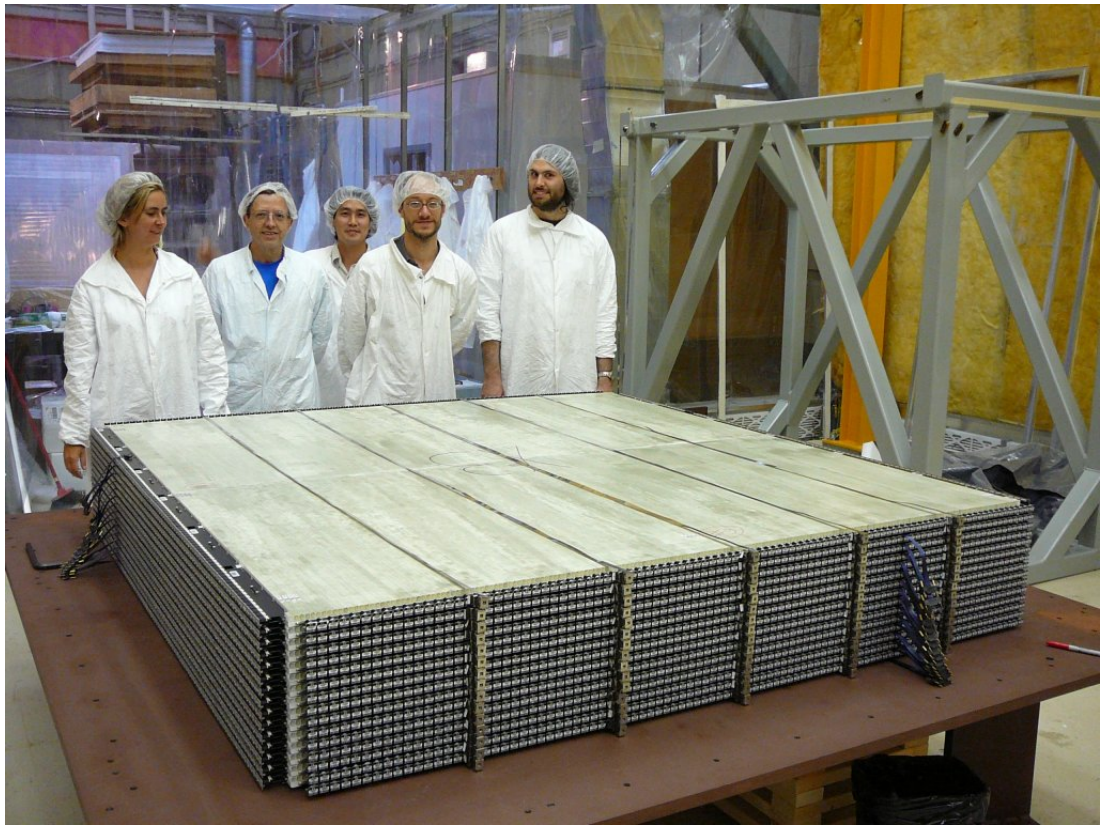
11,900 scintillator bars: 1 cm x 1 cm x 186 cm (total length: 22 km)

- co-extruded with TiO2 coating at Celco Plastics in Surrey in 2006
- glued into panels of 192 bars at TRIUMF, fibres inserted into each bar
- readout with miniature “silicon photo-multipliers” (SiPM) - now called MPPCs





Fine grained detectors (FGDs)

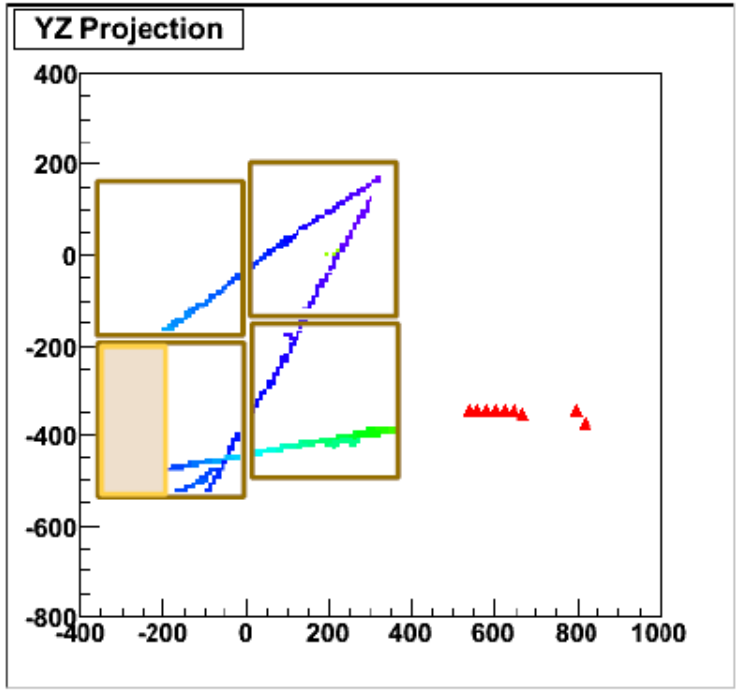


Fine grained detectors (FGDs)

TRIUMF Staff

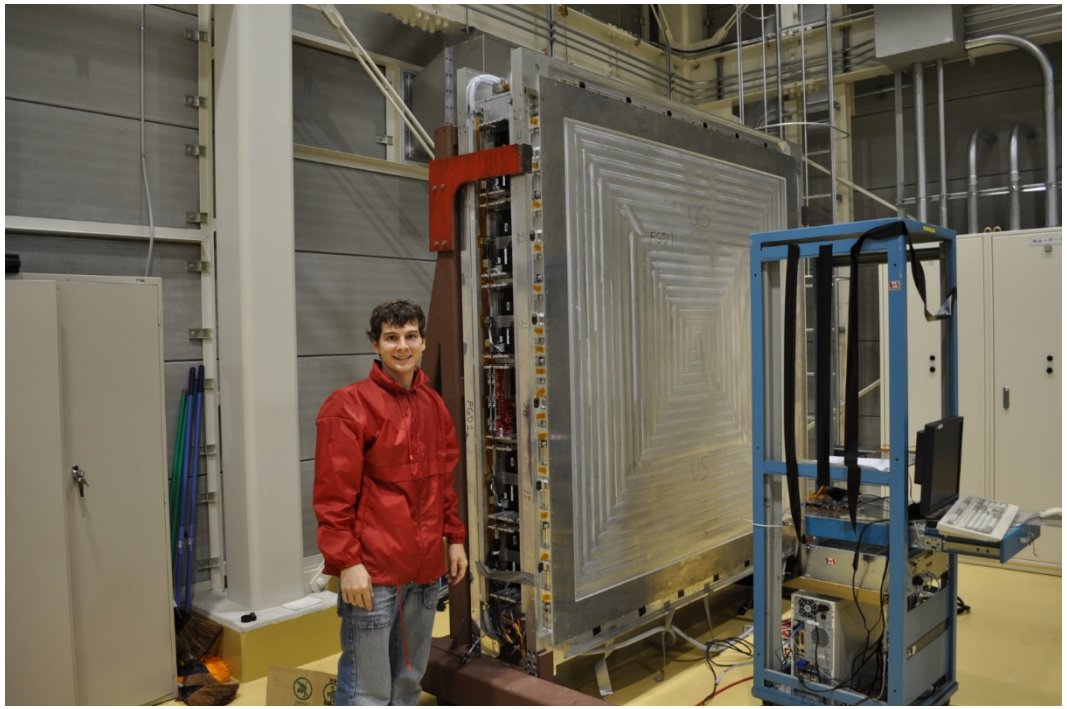
Pierre Amaudruz	Naimat Khan	Konstantin Olchanski
Daryl Bishop	Chapman Lim	Chris Pearson
Wayne Faszer	Thomas Lindner	Renee Poutissou
Peter Gumplinger	Philip Liu	Fabrice Retiere
Rich Helmer	Andy Miller	Peter Vincent
Robert Henderson	David Morris	Stan Yen

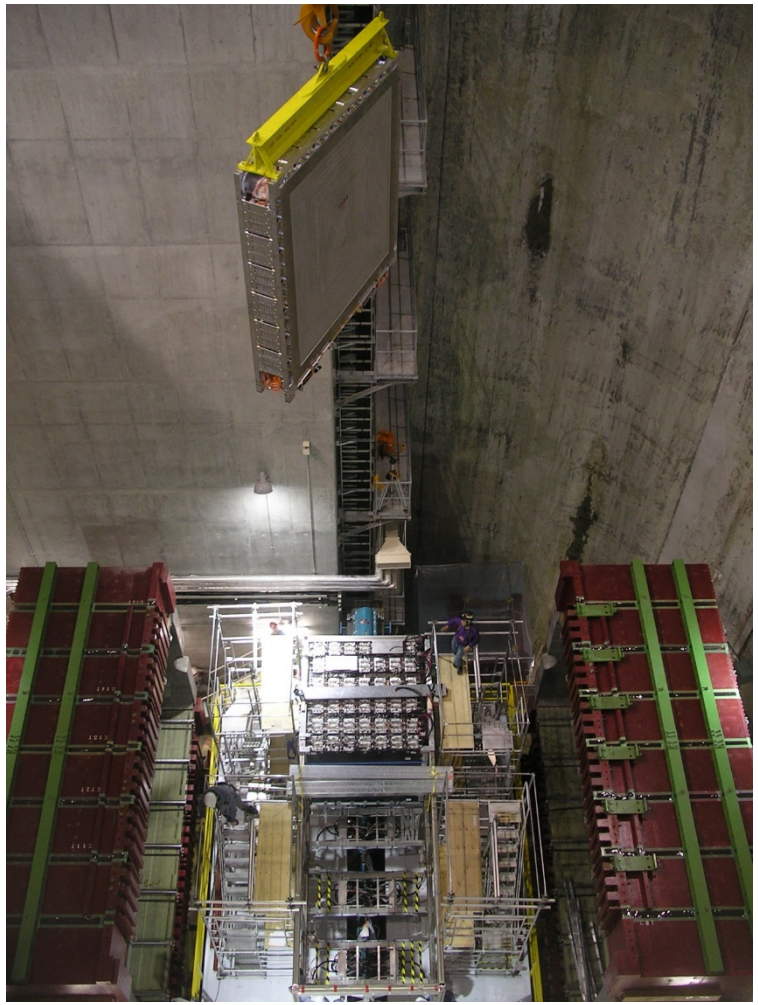
Test of TPC and FGD in M11 (2008)



FGDs shipped to Japan (2009)

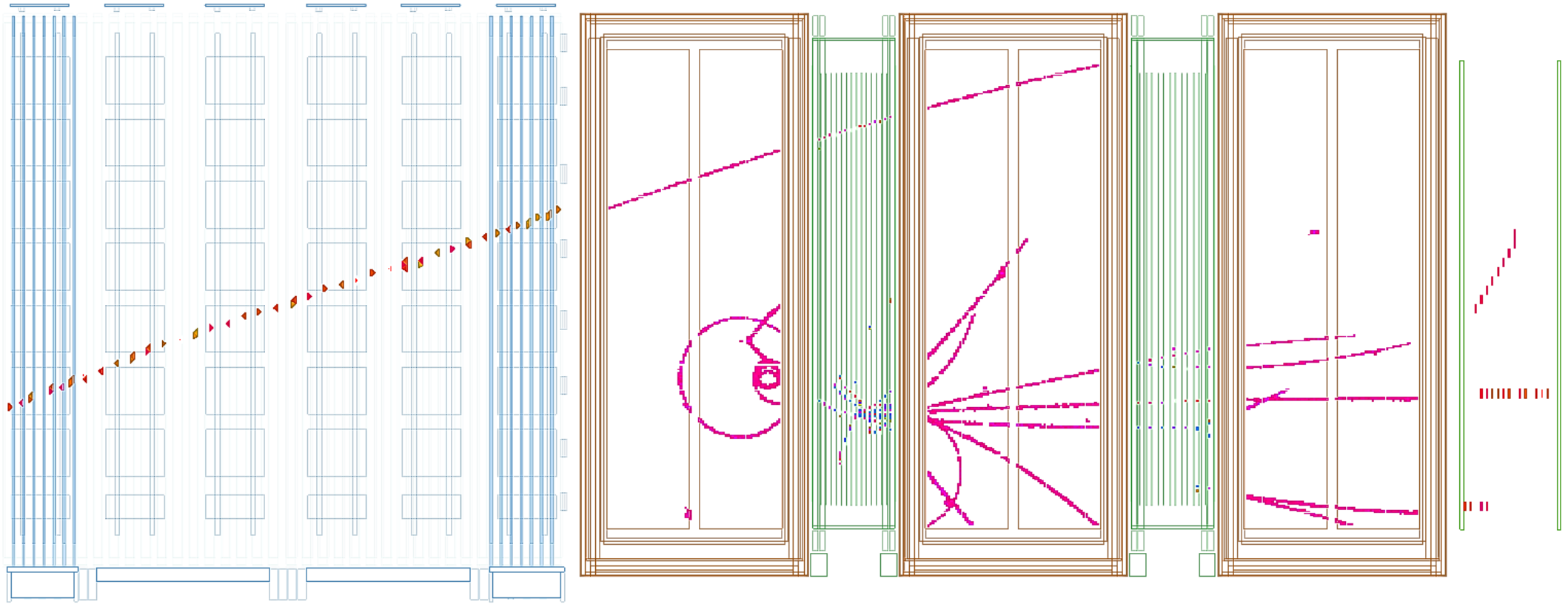
installed prior to TPCs





Near detector ready for first data

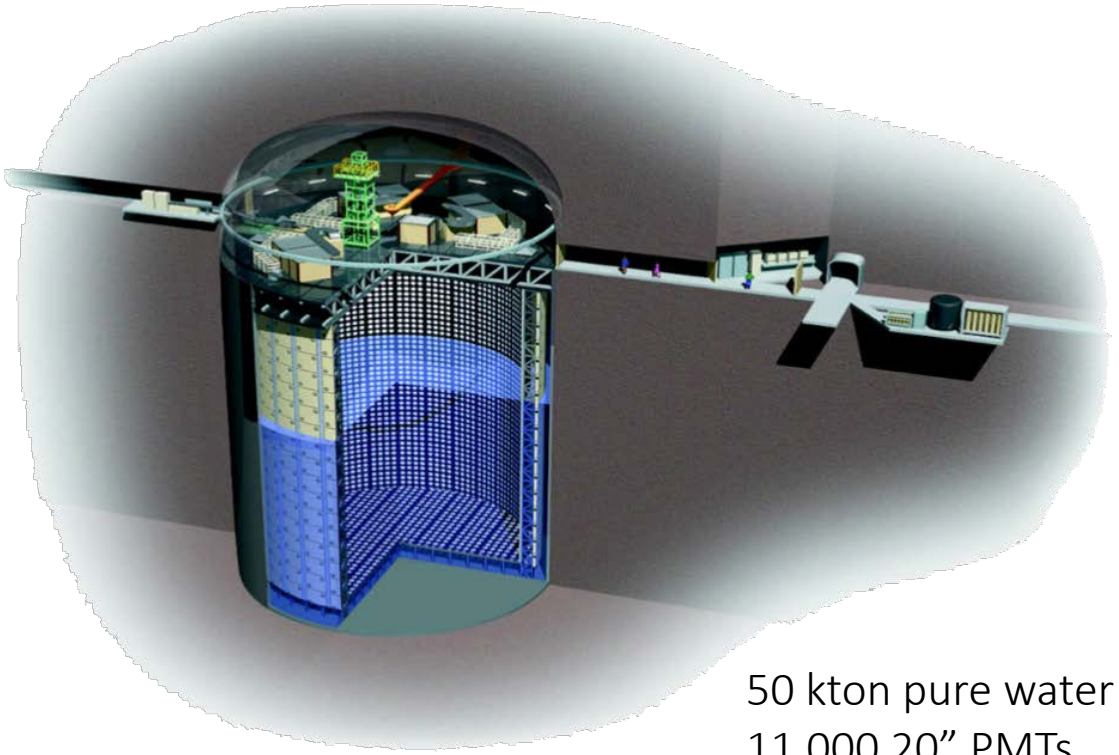
First T2K physics run, January 2010



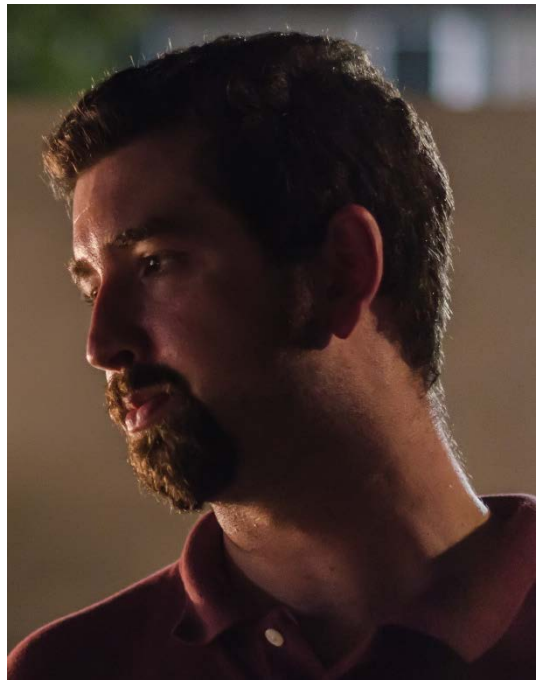
Far detector: Super-Kamiokande (SK)

TRIUMF (and some University groups) joined the SK collaboration

- introduced new data analysis method; significantly better performance



50 kton pure water
11,000 20” PMTs



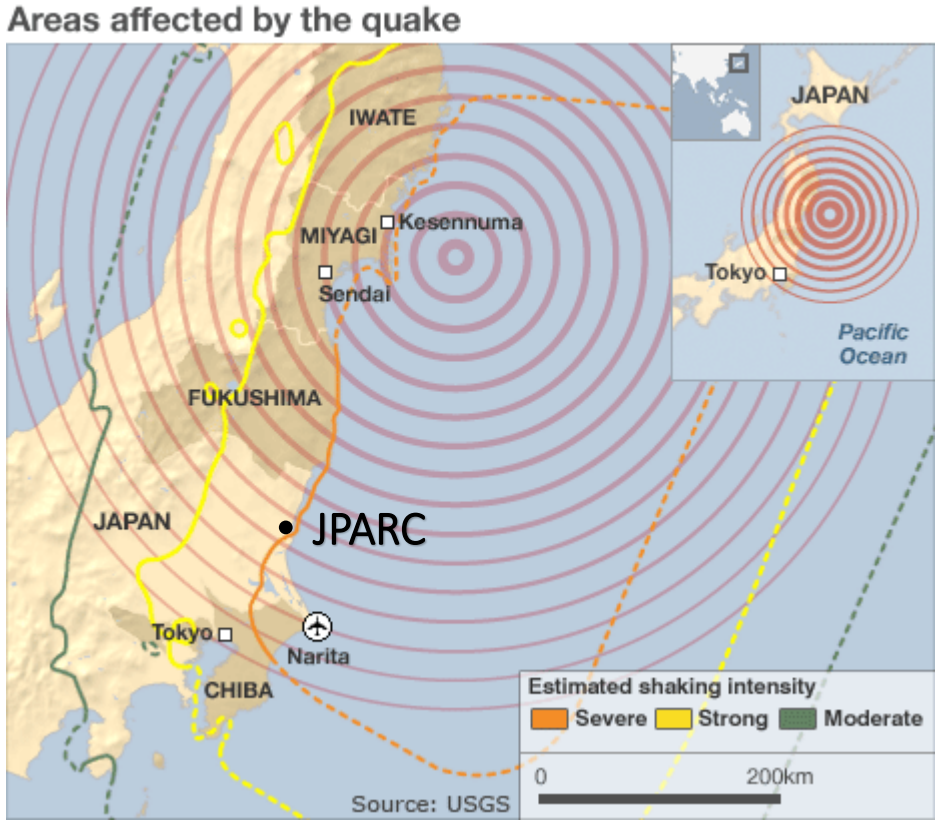
March 11, 2011

The first results from T2K were to be announced at a special seminar scheduled for 3:00 PM at the Japanese laboratory, KEK

At 2:46 PM – magnitude 9 earthquake struck, followed by devastating tsunami waves

No injuries nor tsunami damage at the JPARC lab

No damage to SK



Structural damage

Severe road damage on site

Little building damage

Accelerator not severely damaged

- Returned to operation by end 2011

T2K – a scientific success

Data collected by T2K showed that all 3 types of oscillation occurs!

Awarded the 2016 Breakthrough Prize in Fundamental Physics

- "For the fundamental discovery and exploration of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the standard model of particle physics."
- shared with 5 collaborations

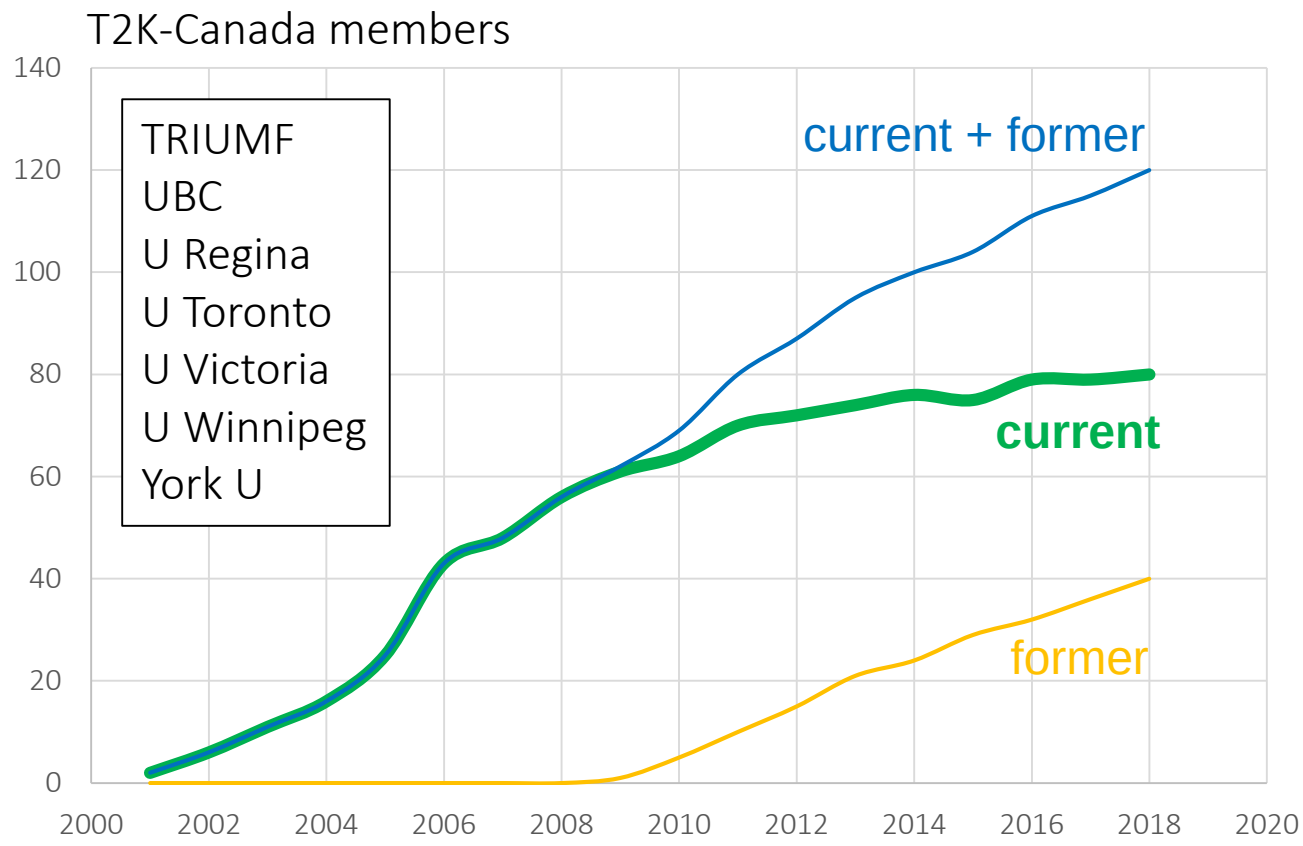
T2K-Canada: a TRIUMF success story

Only with TRIUMF, could a large group be established and accomplish so much in such a short time

- excellent technical resources
- highly knowledgeable and enthusiastic staff

A great training ground for students and postdocs

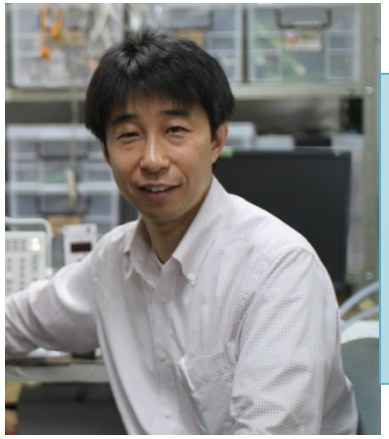
- many now hold faculty positions



Closing words from T2K spokespersons

Former T2K spokesperson (Takashi Kobayashi):

"Long and extremely fruitful collaboration with TRIUMF has been essential for the success of T2K experiment. We really appreciate essential contribution from TRIUMF on many aspects of T2K experiment and we would like to continue and further strengthen our collaboration toward the next generation experiment, Hyper-Kamiokande."



Current T2K spokesperson (Tsuyoshi Nakaya):

"In T2K, we really trust TRIUMF to design the beamline and to construct the key components of near detectors: FGD and TPC. In addition, as true friends, we enjoyed running the T2K experiment successfully with discovery of muon-neutrino to electron-neutrino oscillation"