The T2K Neutrino Beamline

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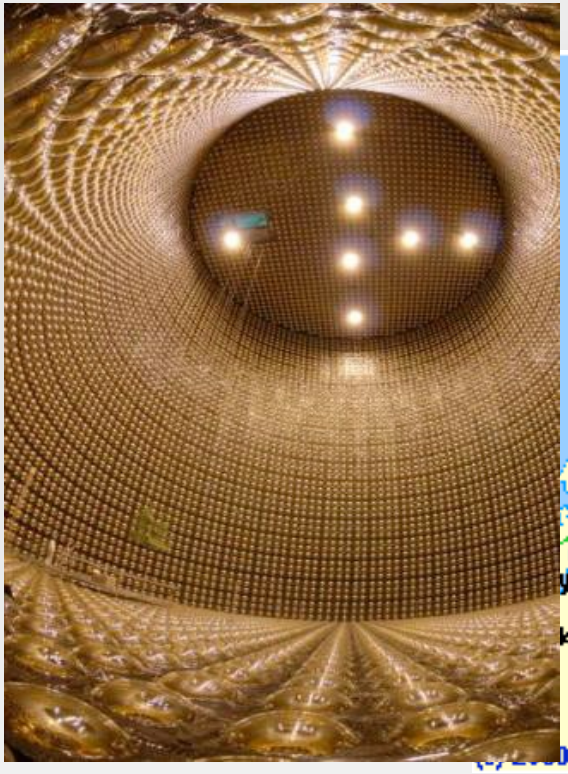
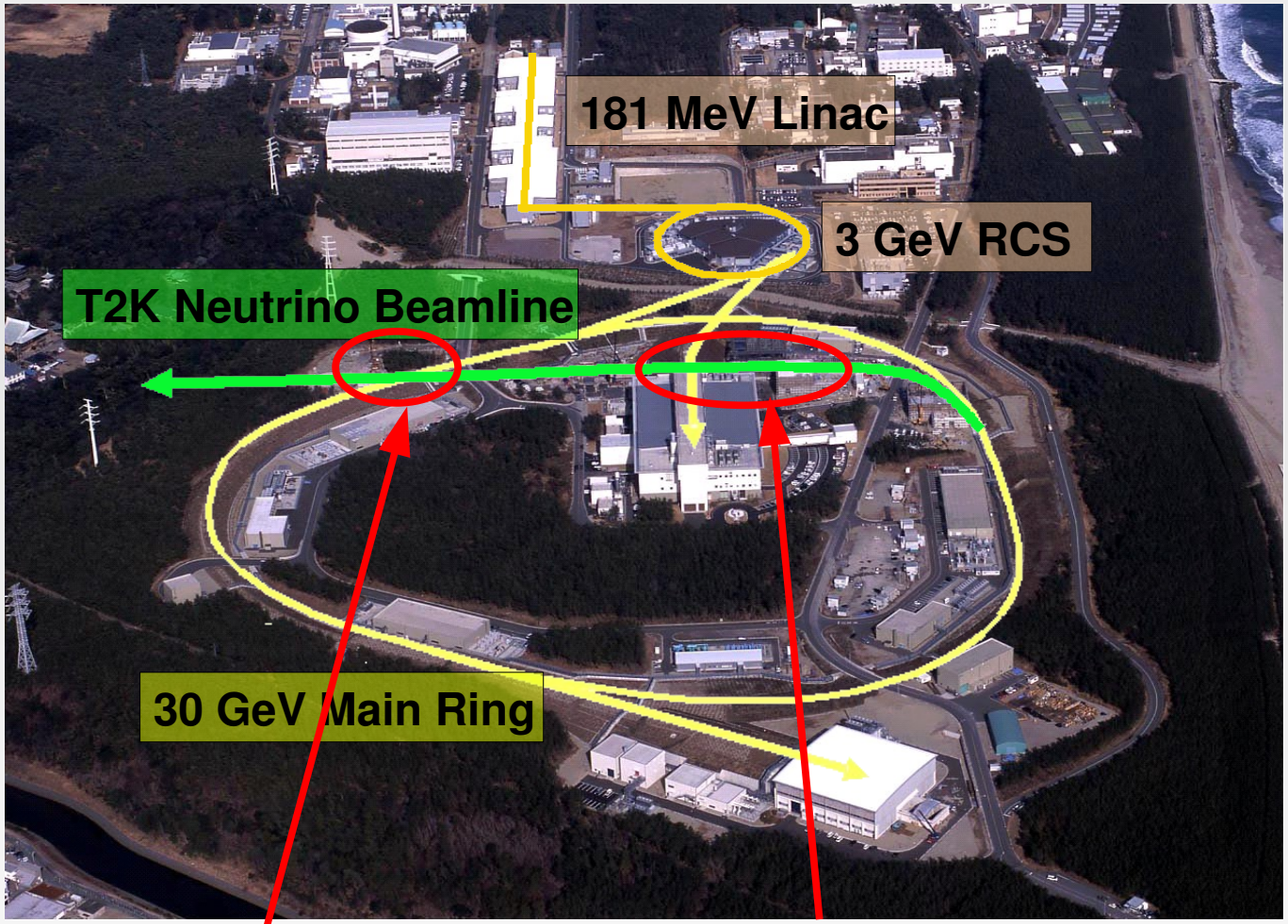
T2K Experiment



- Neutrino beam produced at J-PARC using 30 GeV proton synchrotron
- Far detector is Super-K 50 kton water Cherenkov detector
- Near detector at 280 m downstream neutrino production target is currently being built
- Detectors located 2.5 degrees off-axis – narrower energy distribution with peak at oscillation maximum (~700 MeV)

J-PARC Accelerator Complex

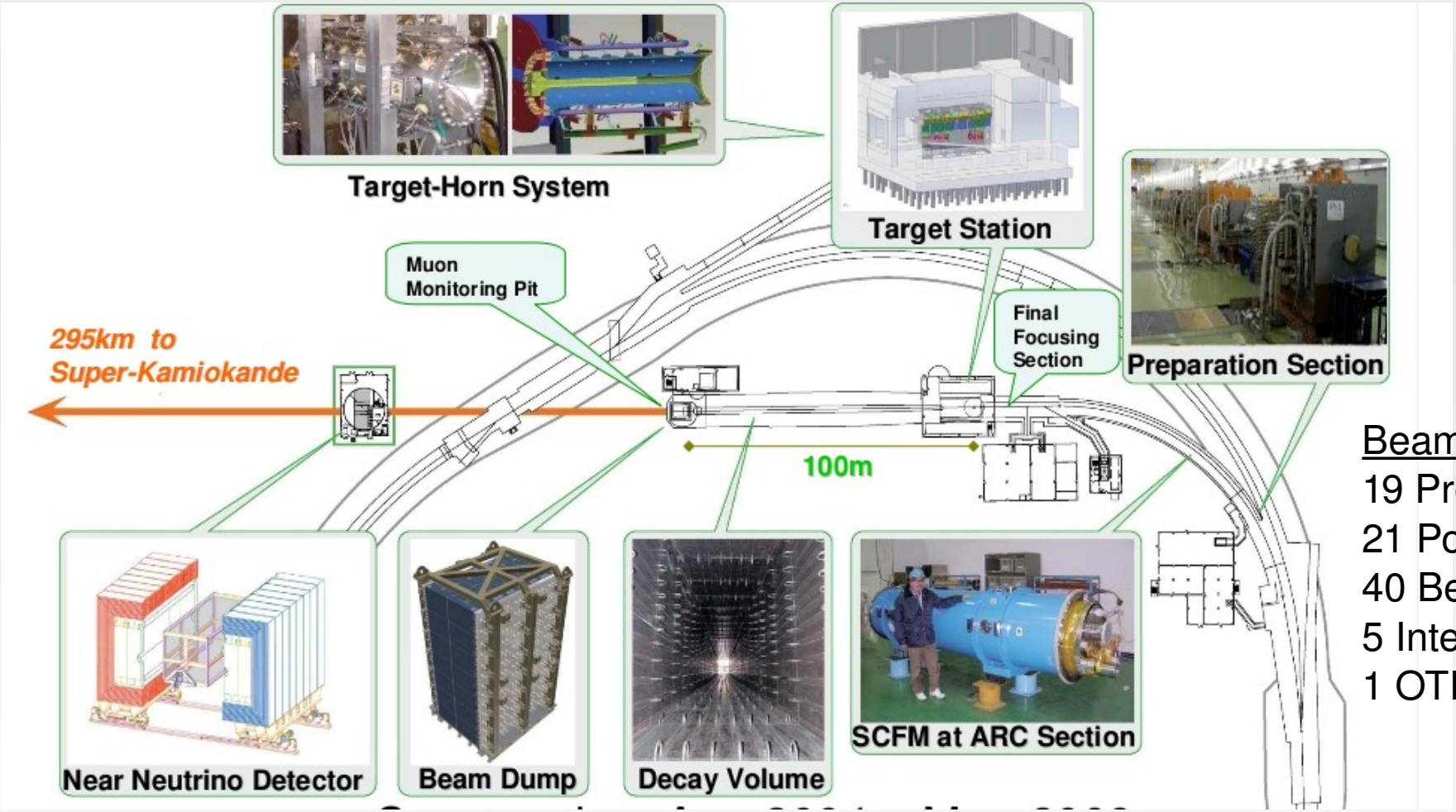


280 m on-axis and off-axis neutrino detectors

Neutrino target hall, decay volume, muon detector

- Accelerator Complex Schedule:
  - Linac, RCS – 2007
  - Main Ring – 2008
  - Neutrino – 2009
- Accelerator Design/Performance
  - Design goal of 750 kW
  - Will be achieved at 30 GeV
  - 4x10^11 p single shot mode for beamline commissioning (0.3 kW at 6 sec. Period)
  - Details on continuous/high power beam configurations on later slide

T2K Beamline



<u>Beamline Monitors</u>

19 Profile
21 Position
40 Beam loss
5 Intesity
1 OTR

Status and Goals for Commissioning

- Major goal for spring 2009 commissioning was passing a Japanese government inspection for radiation safety (inspection was passed)
- Additional goals included:
  - Studies of neutrino beamline tunings
  - Study performance of beamline components
- Constraint - minimize radioactivation of beamline areas to allow for summer work
- Status of beamline for commissioning:
  - All magnets fully operational
  - All beamline monitors and muon monitor functioning
  - First horn installed
  - One module for INGRID (280 m on-axis detector) installed
  - GPS and triggering at Super-K operational
- Two spring commissioning runs – April 23rd-28th, May 22nd-28th.

Beamline Components

Beamline Magnets

Superconducting Magnets

- Located in the arc section of the beamline
- 28 magnets each producing both dipole (2.59 T) and quadrapole (18.6 T/m) fields
- Operational current of 4.36 kA, T_{max}<5 K
- 2 hour recovery from normal quench

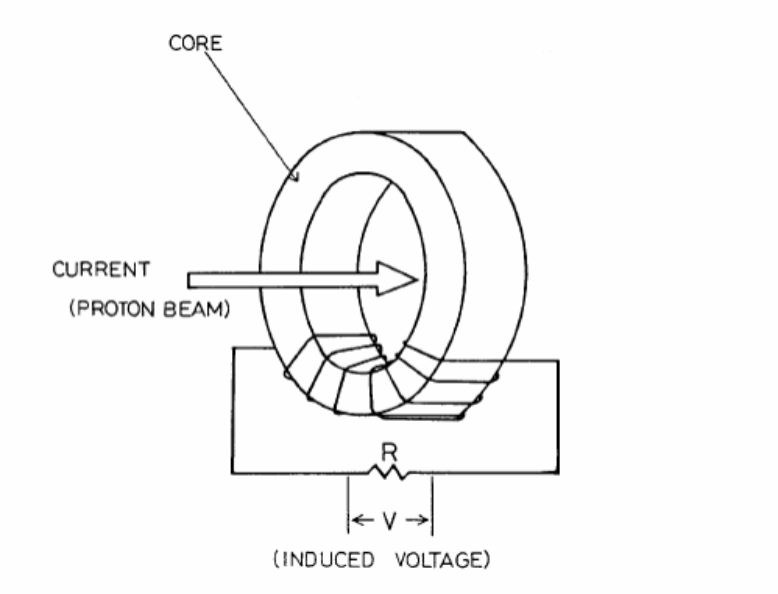
Normal Conducting Magnets

- Located in the preparation and final focusing sections of the beamline
- Operate in the 1-10 kG range

CT and Beam Loss Monitors

Current Transformer (CT) Monitors

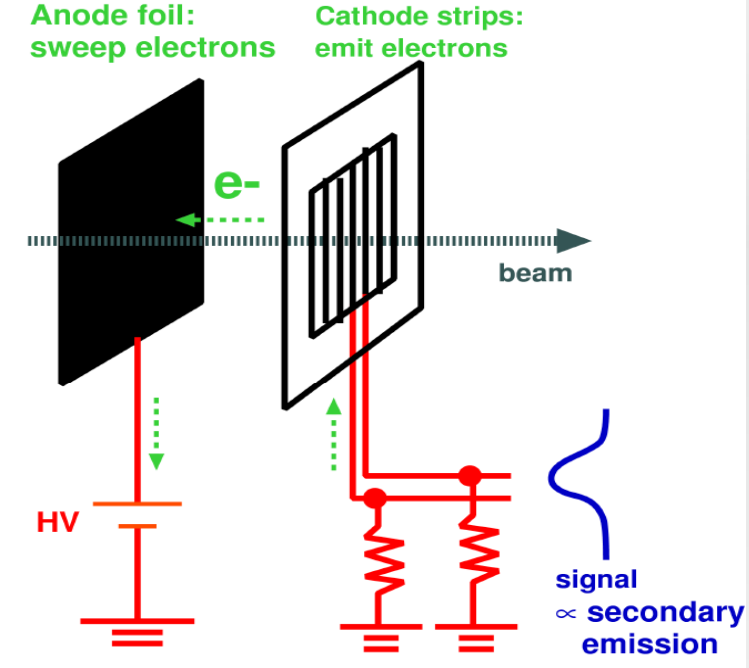
- 5 monitors spaced throughout the T2K beamline
- Linear response up to 90A
- Flat response in 1 kHz-60 MHz range



Beam Loss Monitors

- 40 Gas filled proportional counters
- Can observe a wide range of beam loss
- TLD badges placed near BLMs for calibration during commissioning

Position and Profile Monitors

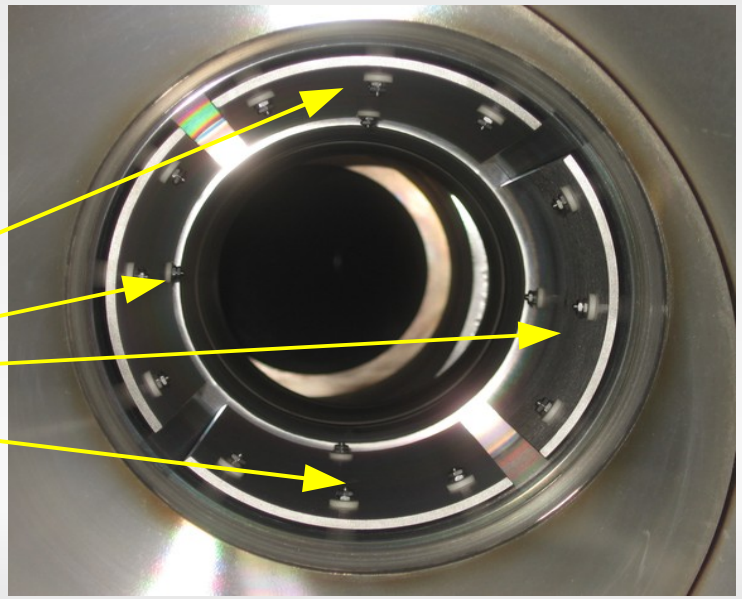


Segmented Secondary Emission Profile Monitor (SSEM)

- 19 monitors throughout beamline
- Current induced by beam incident on cathode strips
- Each monitor has X and Y oriented strips
- Expected uncertainty of 0.2 mm or less
- Will be pulled out for high intensity running

ElectroStatic Beam Position Monitor (ESM)

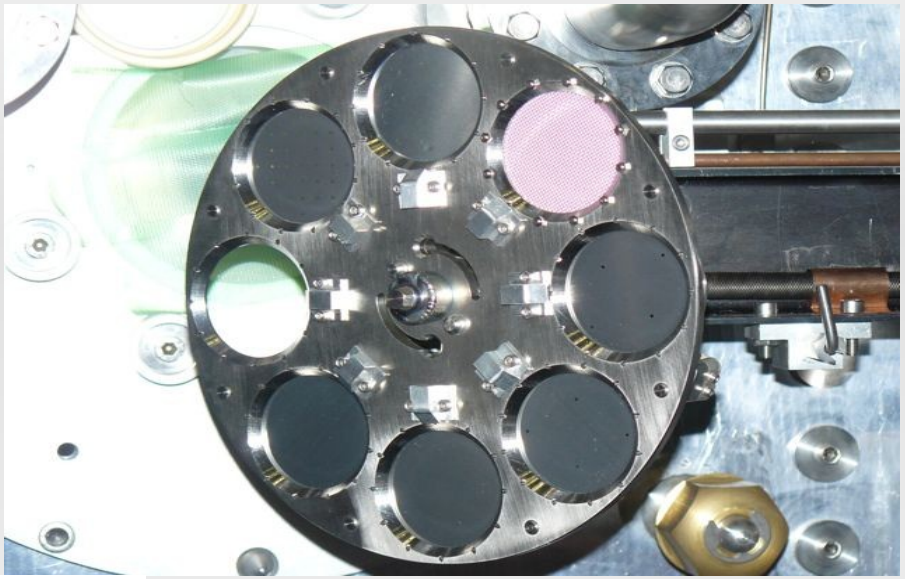
- 21 monitors located near SSEMs
- Nondestructive measurement
- Four electrodes measure beam field
- Find beam position by comparing signal sizes
- Design resolution of 0.5 mm

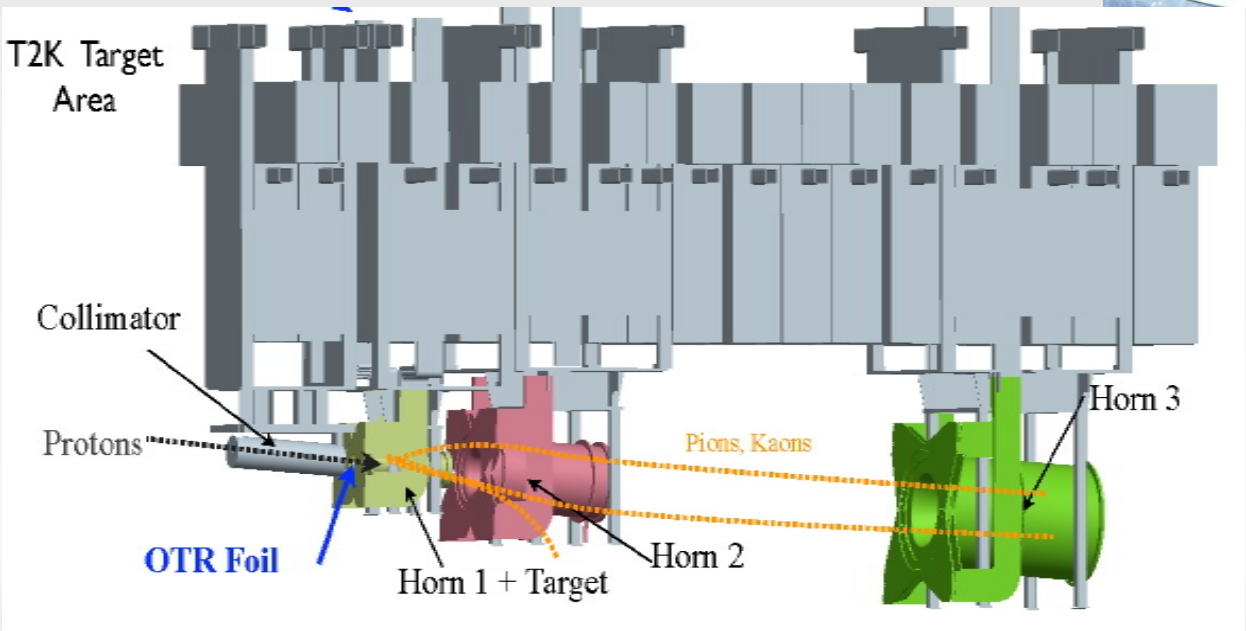


OTR and Horns

Optical Transition Radiation Monitor

- Beam crosses foil to produce optical transition radiation or fluorescent light
- Light is imaged using system of parabolic mirrors and camera
- Image shows profile of proton beam
- Located 280 mm upstream of target



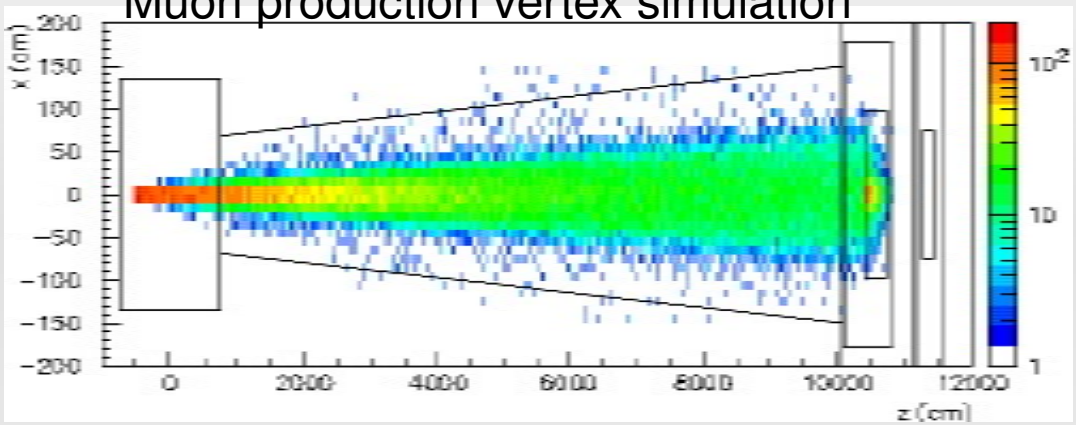


Target + Magnetic Horns

- Helium cooled graphite target
- Three magnetic horns focus the hadrons produced at the target
- Nominal currents of 320 kA
- For commissioning only first horn at 273 kA

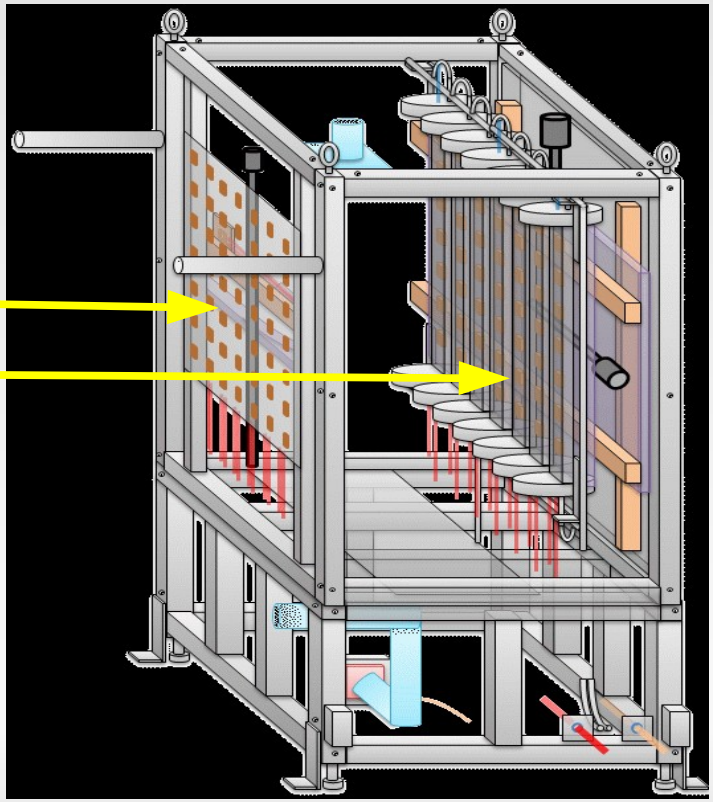
Decay Volume and Muon Monitor

Muon production vertex simulation



Decay Volume and Beam Dump

- ~100 m decay volume after target station
- Water cooled graphite block beam dump at end of decay volume



MUMON Muon Monitor

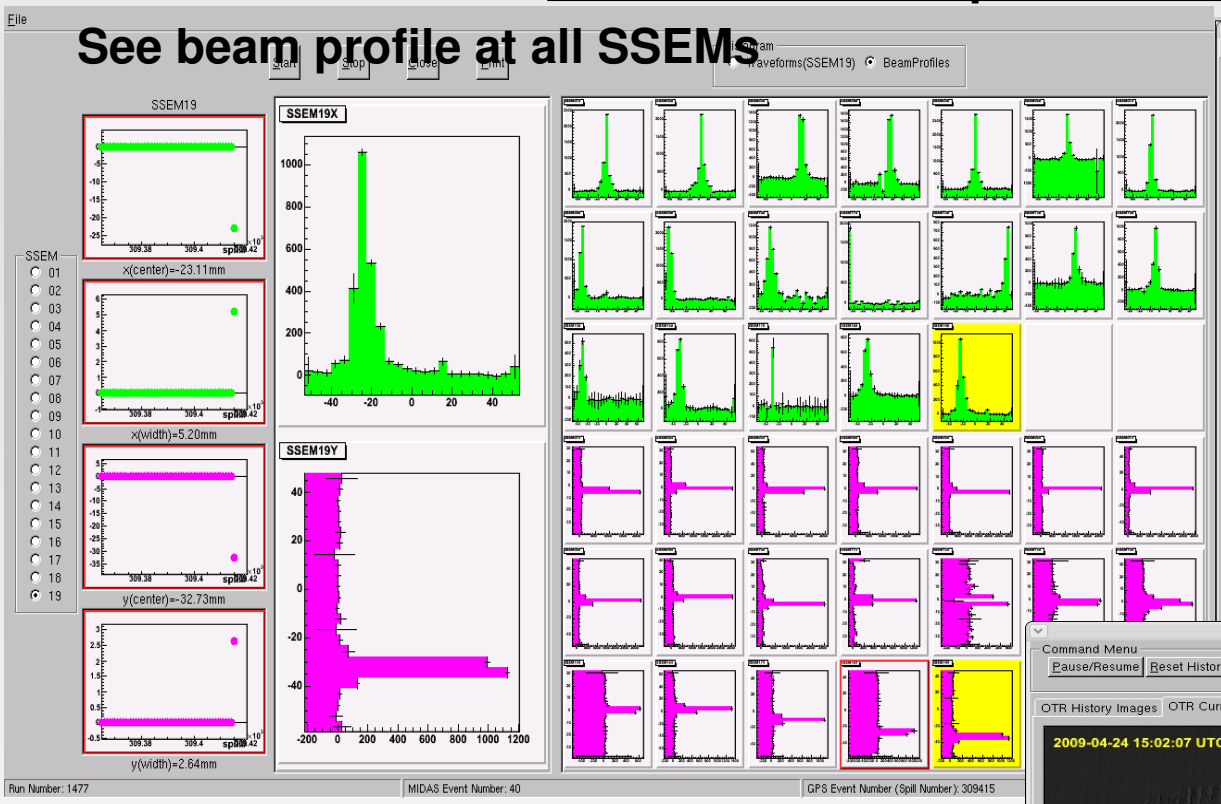
- Located downstream of beam dump
- Silicon PIN photodiodes
- Ionization chamber
- Measures secondary muons from pion decays
- >5 GeV muons make it through beam dump (looking at tail of distribution)
- Determine beam position and direction along with SSEM, ESM and OTR

Commissioning Experiences/Highlights

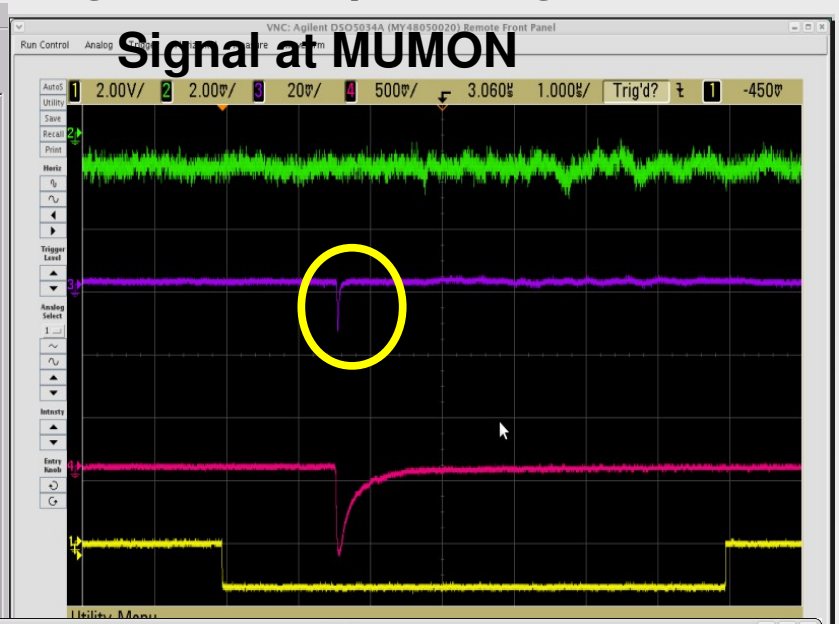
Commissioning Firsts

First beam with super conducting and NC dipole magnets

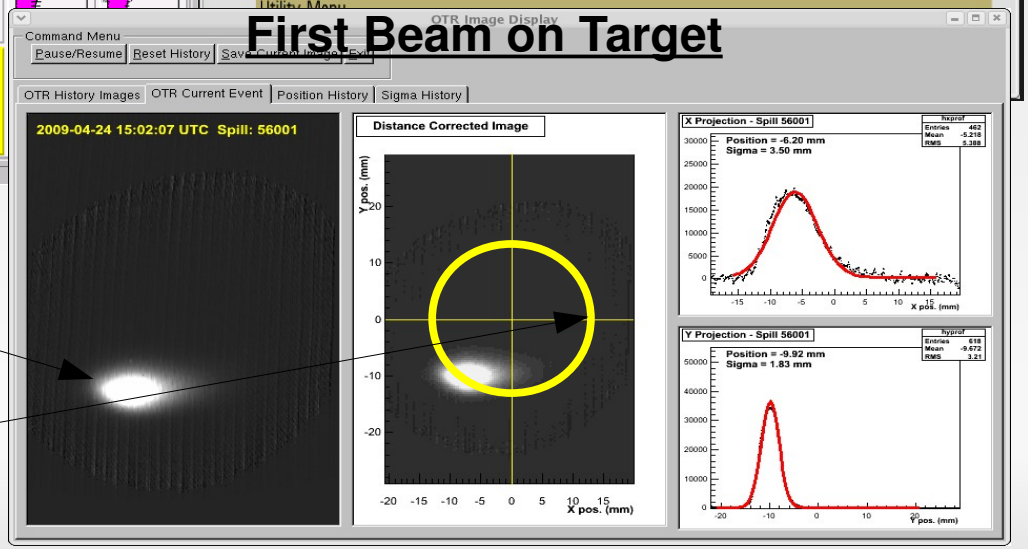
See beam profile at all SSEMs



Signal at MUMON



First Beam on Target



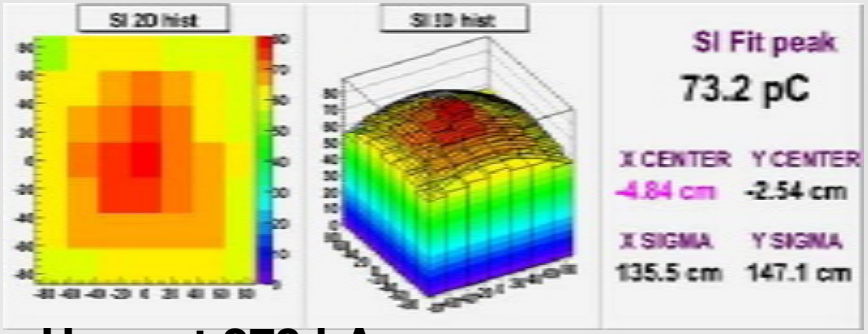
As seen by fluorescent foil

Approximate target outline

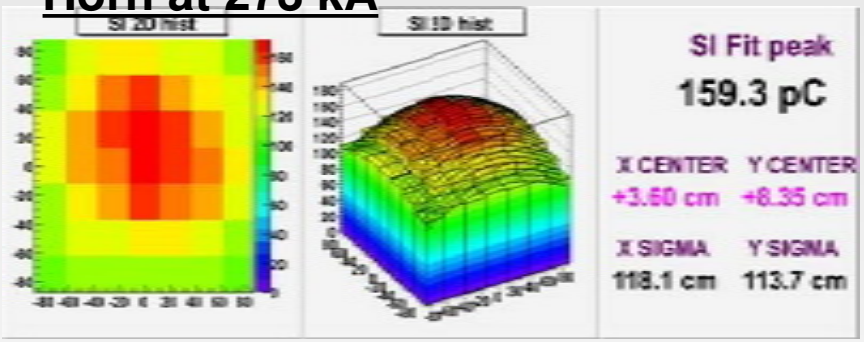
MUMON and Emulsion Studies

MUMON SI Profiles

Horn off

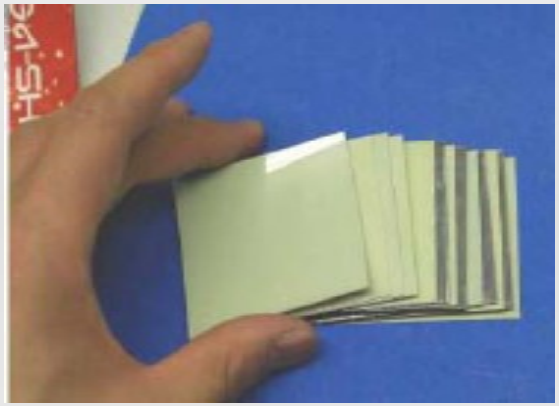


Horn at 273 kA



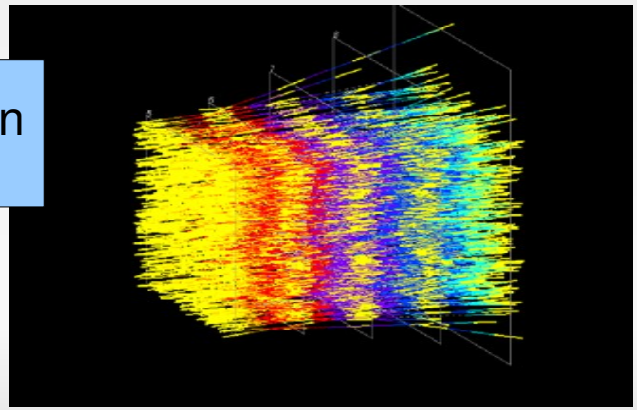
- See peaks in MUMON
- Positions correlate well with profile monitors
- Total charge increases with Horn 1 focusing

Emulsion Plates Downstream of MUMON

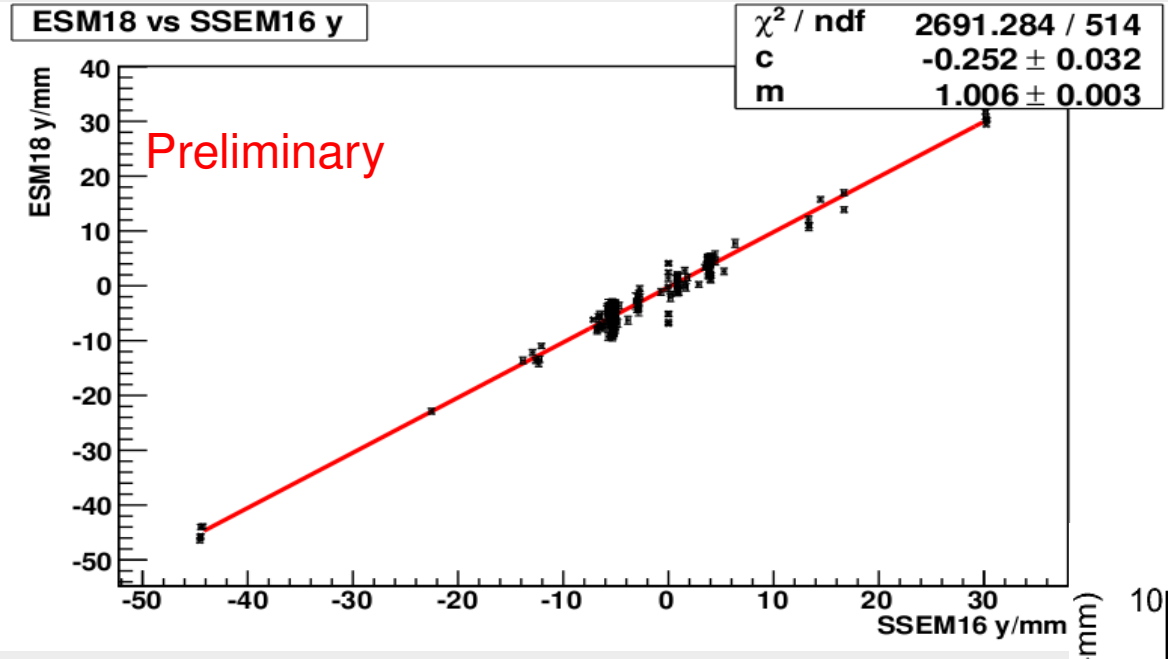


- Placed emulsion plates immediately behind MUMON to verify muon
- Can separate mu/e to get muon flux
- Inserted for three separate spills
- Analysis is ongoing

Emulsion data

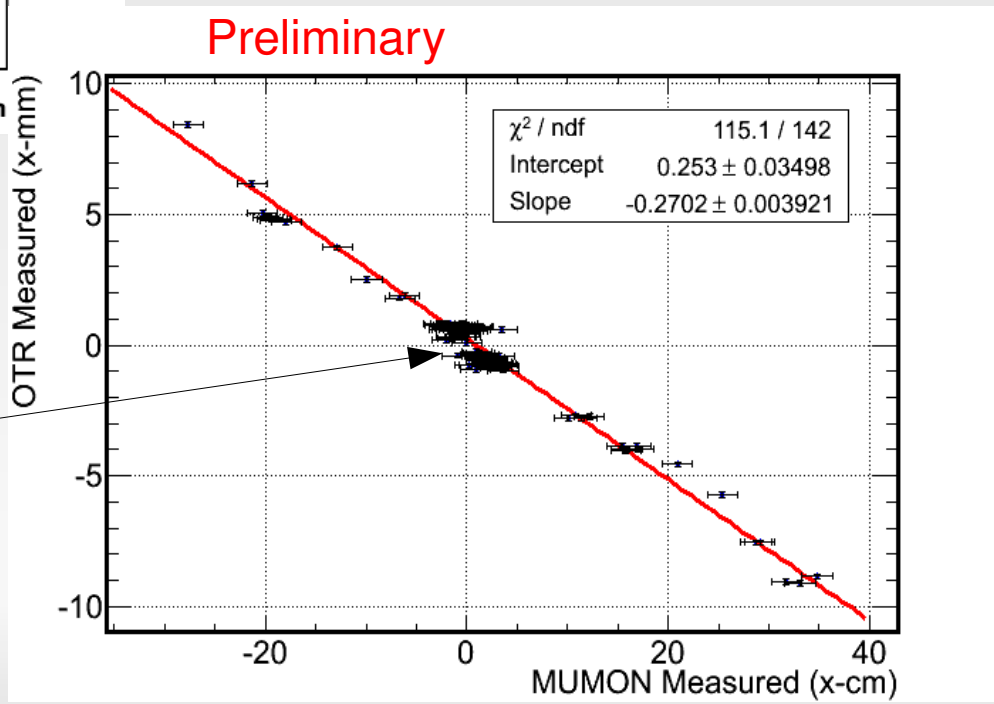


Preliminary Alignment Studies



Preliminary studies of monitor correlations show no major surprises

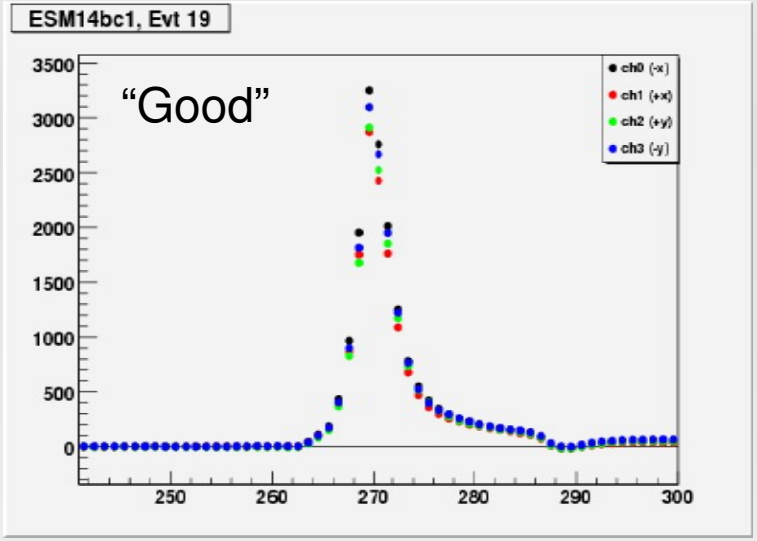
Detailed studies ongoing

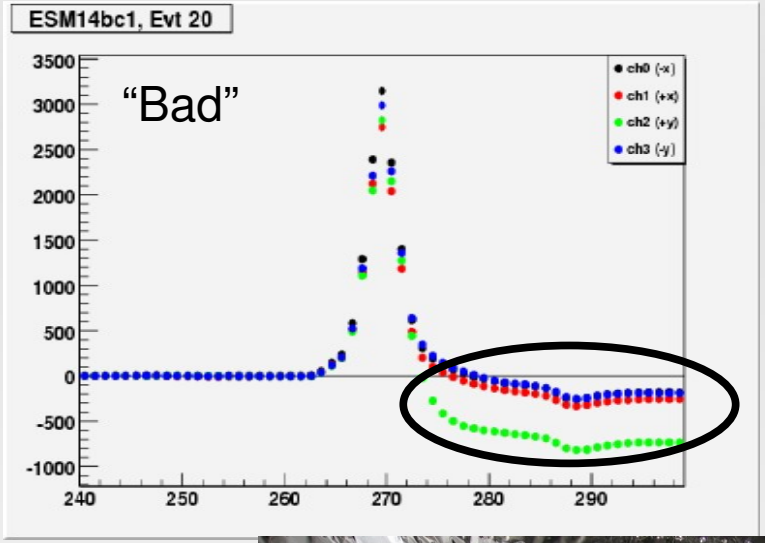


See good agreement for beam position at center of target as measured by OTR and MUMON

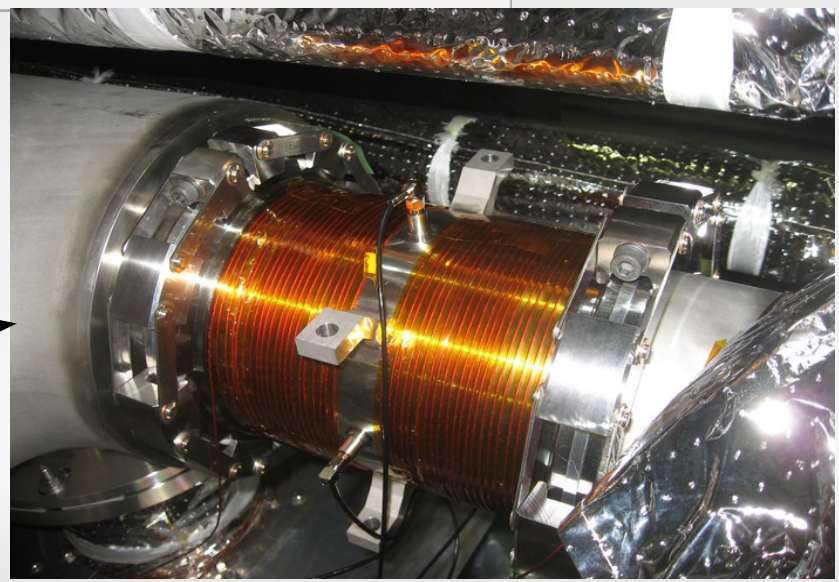
ESM and SE Electrons

- Anomalous waveforms seen for ESMs during commissioning





- Only seen when SSEMs are inserted
- Best hypothesis – due to secondary emission electrons from the SSEMs
- Hardware fix under investigation – wrap solenoid around the ESM to steer away electrons



Summary of Accomplishments

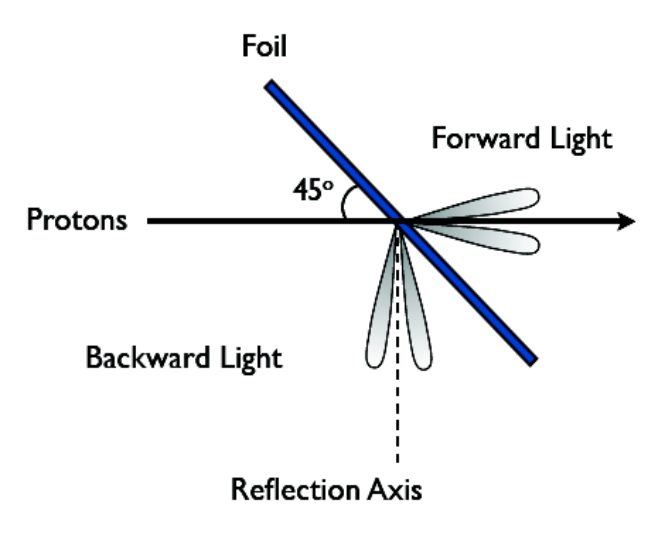
- Stability of the extraction beam orbit from Main Ring is confirmed
- Combined function superconduncting magnets work as expected
- Beam is transported to center of T2K target with no significant beam loss
- Beam tuned to within 3 mm w.r.t the design orbit
- Functionality of the beamline monitors confirmed
- Neutrino production and pion focusing by the horn confirmed by MUMON signal
- Stable beam during continuous operation within 1 mrad as measured by MUMON
- Intentional quench of 4 superconducting magnets, recovery in 2 hrs
- Additional beam configurations:
  - Power: 1.13 kW operation for 30 seconds (6sec/cycle, 2 bunches, 7.1×10^{11} protons/bunch)
  - Duration: 0.14 kW operation for 40 minutes (6sec/cycle, 1 bunch, 1.7×10^{11} protons/bunch)

Moving Forward

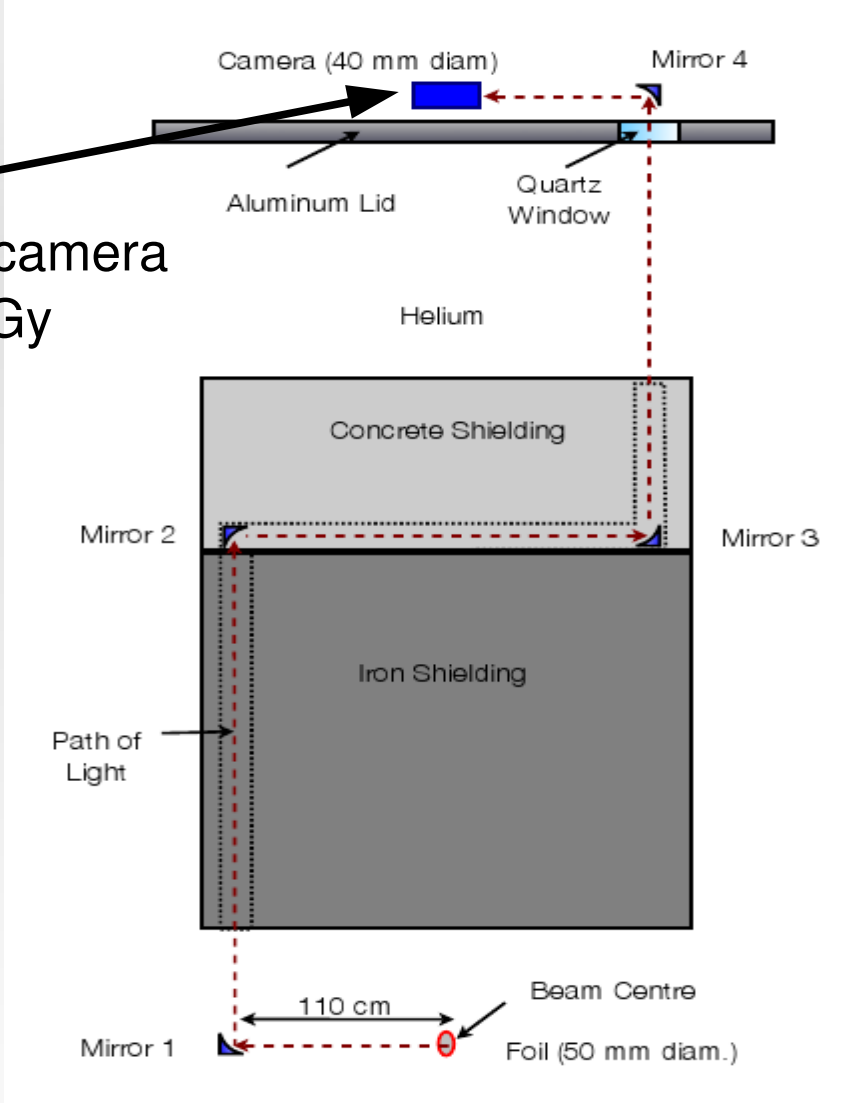
- Next beam commissioning run begins later this year
  - In June, accelerator team already achieved 6 bunch operation
- Preparation for multi-bunch and 100 kW operation
- Horn 2 recently installed and Horn 3 will be installed soon
- On-axis (INGRID) detector at 280 m installation is ongoing and will be complete before next round of commissioning
  - Goal of direct confirmation of neutrino production
- Be ready for physics run by December 2009!

Extra Slides

OTR Detector

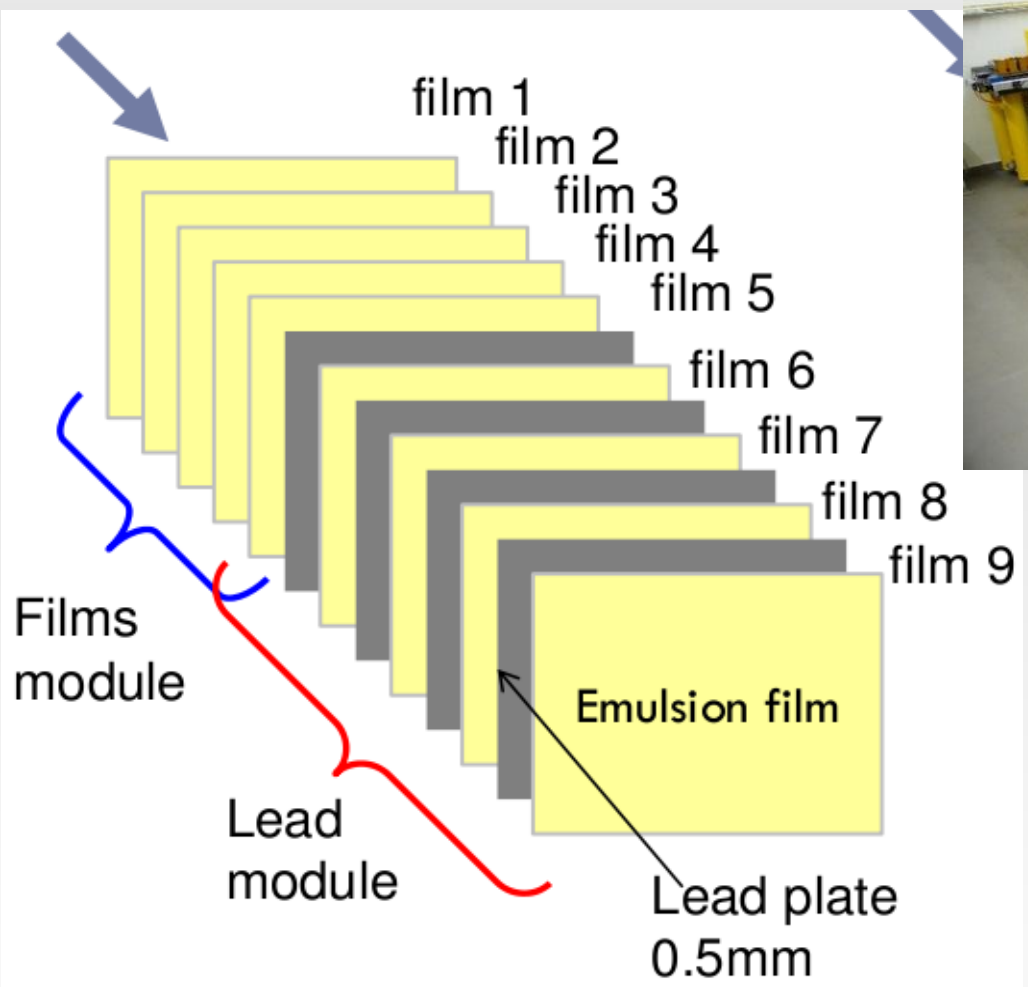


Rad-hard camera
up to 10 kGy



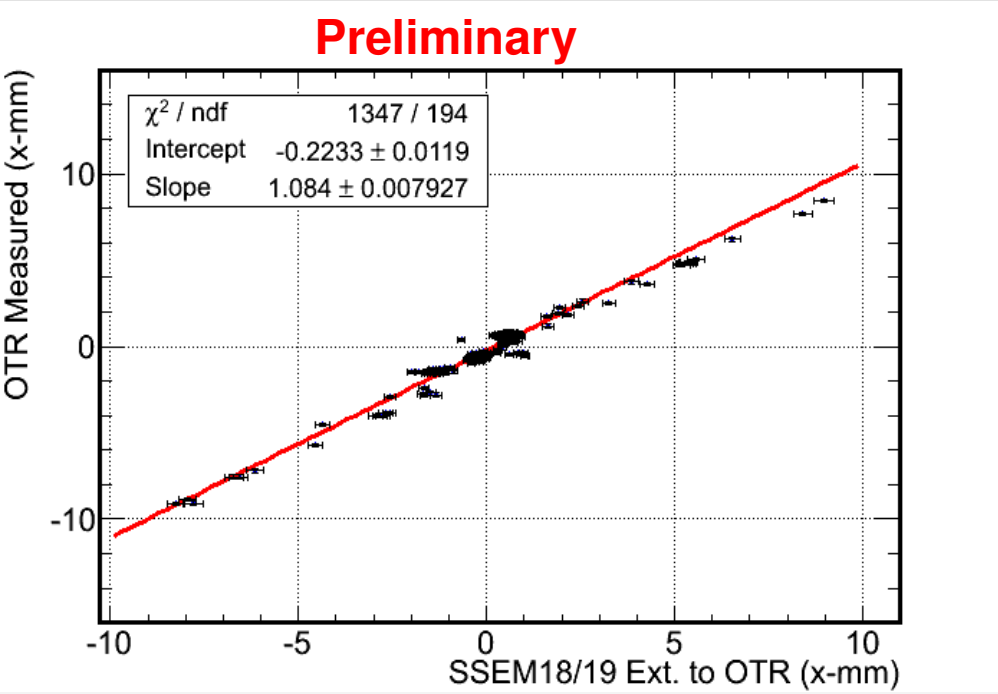
- Use optical transition radiation to monitor beam near target
- Produced when particles moves between media with different dielectric constants – radiates difference in E field

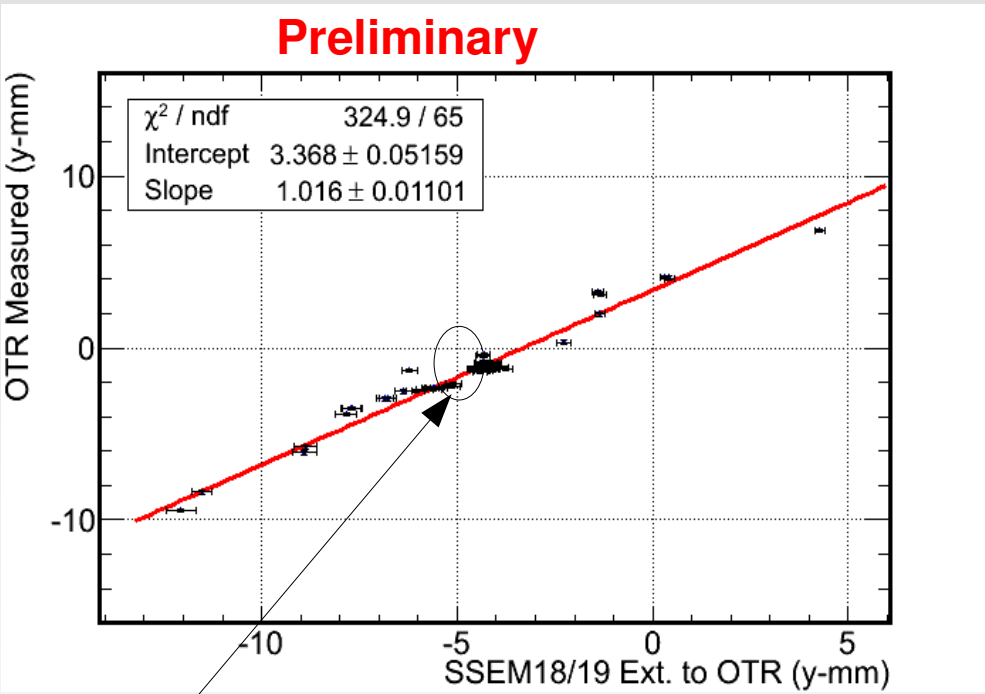
Emulsion Details



Emulsion scanning at LHEP Bern

SSEM vs OTR Correlations





Offset understood as difference in alignment coordinate systems