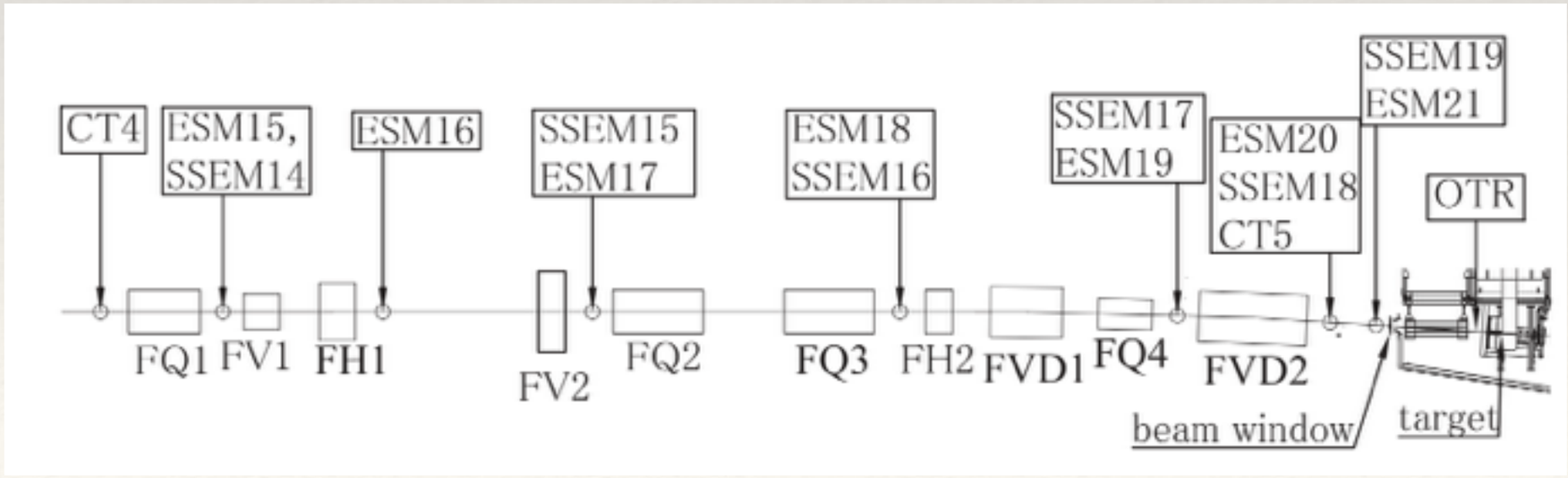
Discussion for T2K Beam Monitors at 750 kW and Above

Current Beam Monitors

- Current beam monitors are:
  - 5 current transformer monitors (CT)
  - 21 electrostatic monitors (ESM)
  - 19 segmented secondary emission monitors (SSEM)
  - 50 ionization chamber beam loss monitors (BLM)
  - 1 optical transition radiation monitor (OTR) 60 cm upstream of target
- Layout of the final focus section:

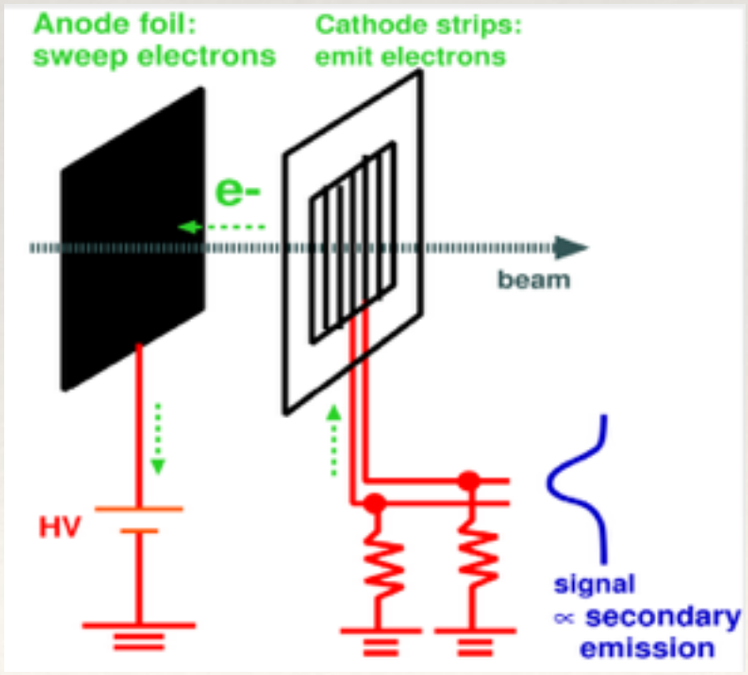


Beam Profile Monitors

SSEMs

3 5 micron thick foils per SSEM

Located throughout the primary beamline - induced beam losses are a concern in addition to damage to the monitor

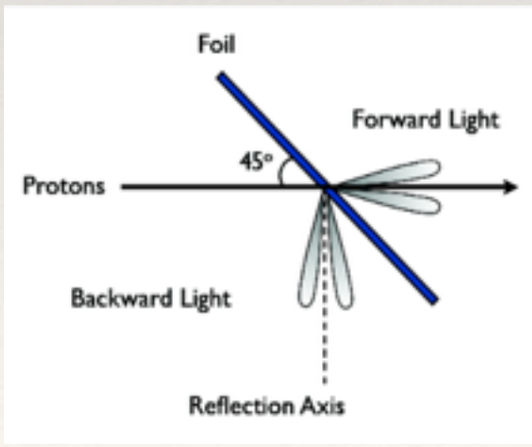


OTR

50 micron thick Ti 15V-3Cr-3Sn-3Al alloy foil (15% V, 3% Cr, 3% Al, 3% Sn)

Instantaneous beam power limitation comes from the thermal stress -> can operate up to 1 MW if rep rate is 1 Hz

60 cm upstream of the target - induced beam loss from OTR foil is not relevant for the primary beam line



Beam Properties

- 8 bunches in a spill
- Bunch width in time of ~15 ns
- Bunch separation is 580 ns
- RMS in transverse directions is ~1-10 mm throughout the beamline
- At 750 kW expect ~2.5e13 protons per bunch
- Monitors should be able to survive ~1e22 POT

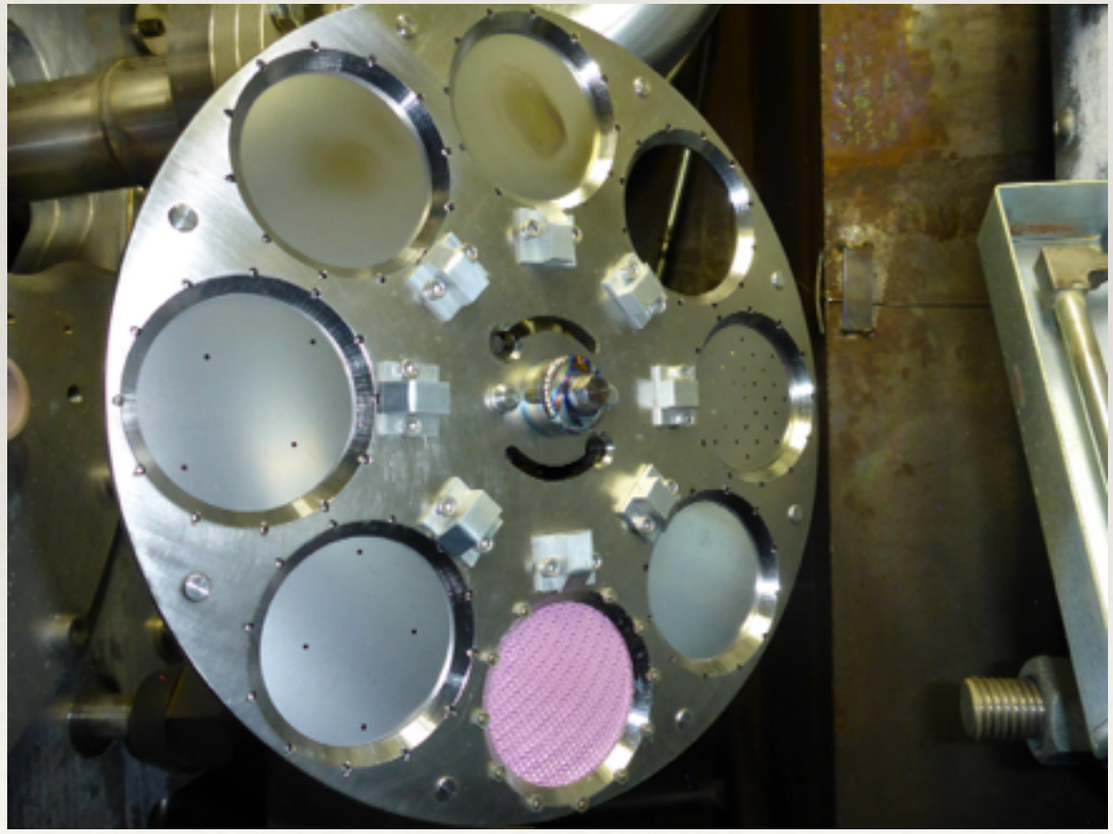
Monitor Operation at High Power

- Expect CT, BLM and ESM operation without major problems at higher power
- Will profile monitors be able to operate at high power?
  - No clear degradation of the SSEM signal seen yet

OTR disk was replaced with 6.6e20 POT integrated on two foils

Visible darkening of Ti alloy where the beam impinges the foil

It was observed that this foil damage can bias the beam width and position measurements



High Power Profile Monitor Options

- OTR upgrades (not much thought in this area so far):
  - Larger foil disc = more spare Ti foils
  - Graphite foil?
- Carbon fiber SSEM monitor
- Beam induced fluorescence monitor
  - Choose over ionization profile monitor due to very large space charge in T2K beam
  - Preliminary investigation into the suitability for the T2K beam line has been done

Potential Fluorescing Gasses

- Based on the measurements made at the CERN PS (NIMA 492 (2002) 74–90), we consider two options for the gas:

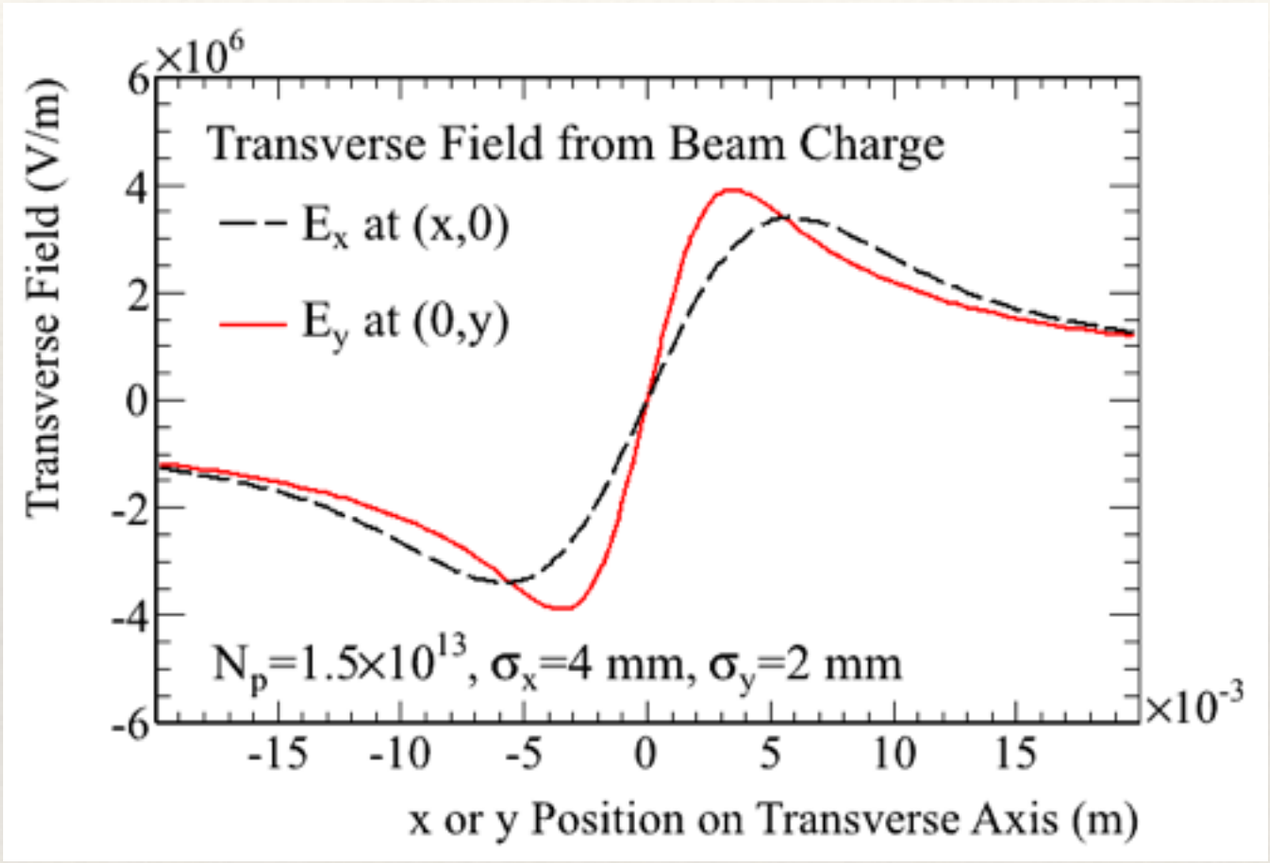
	N	Xe
Molecular mass	28	131
keV deposited / photon	3.6	46
lifetime (ns)	58	6 and 52 (~equal)
spectrum	peak at 391 nm from N	broad from 370-500 nm

More light from N_2

Ionized Xe is less affected by beam space charge since it is more massive and has a short lifetime component

T2K Beam Space Charge

- Calculated the electric field for a single bunch with 1.5e13 protons, 4 mm x 2 mm transverse RMS:

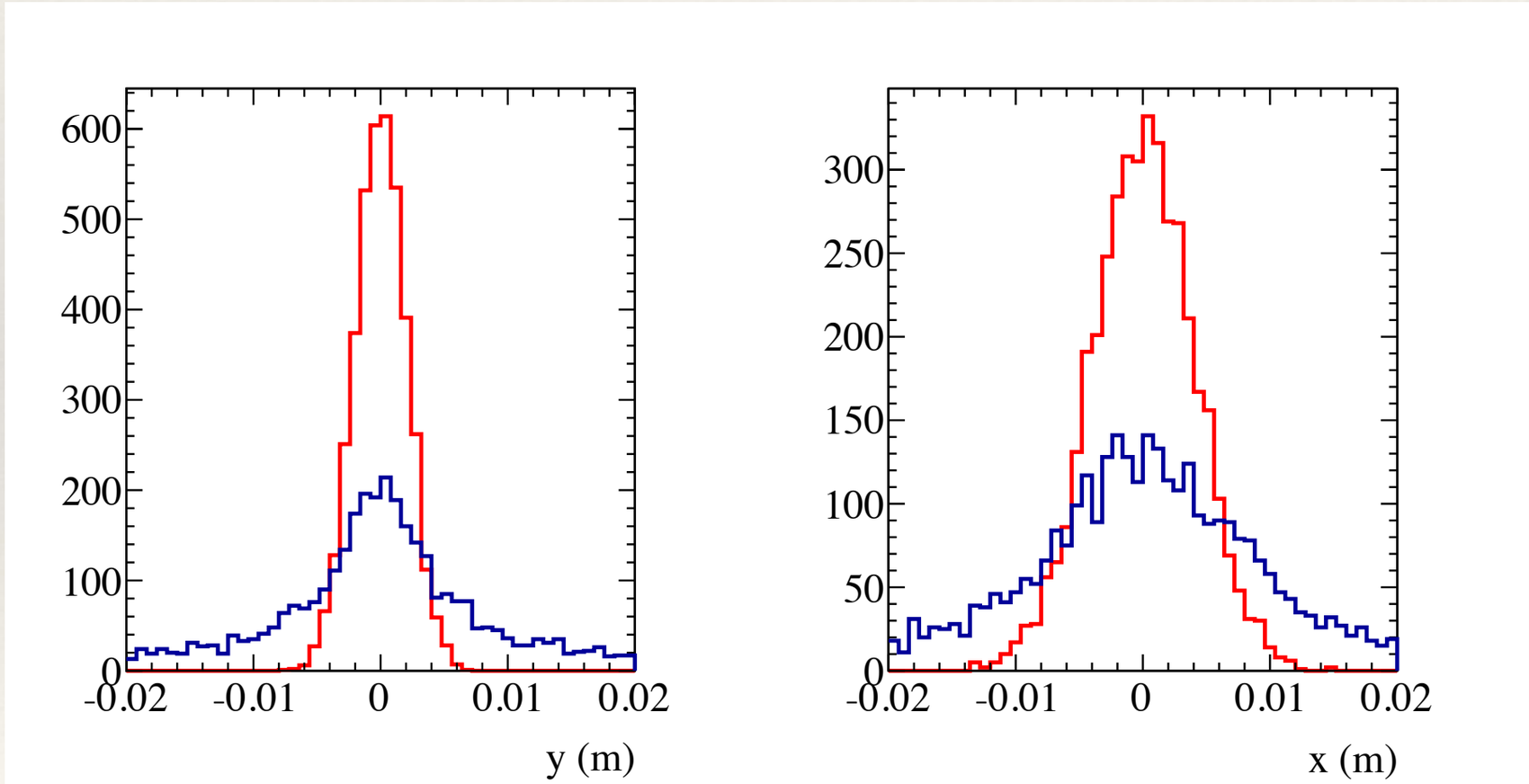


- If the fluorescent light is produced by an ionized molecule, it can drift in the beam field before the light is produced, distorting the profile

Beam Profile Distortion N_2

Simulated the profile distortion for nitrogen assuming all light is coming ionized molecules

Assume 3e13 protons, 4 mm x 2 mm beam RMS, 15 ns RMS bunch length

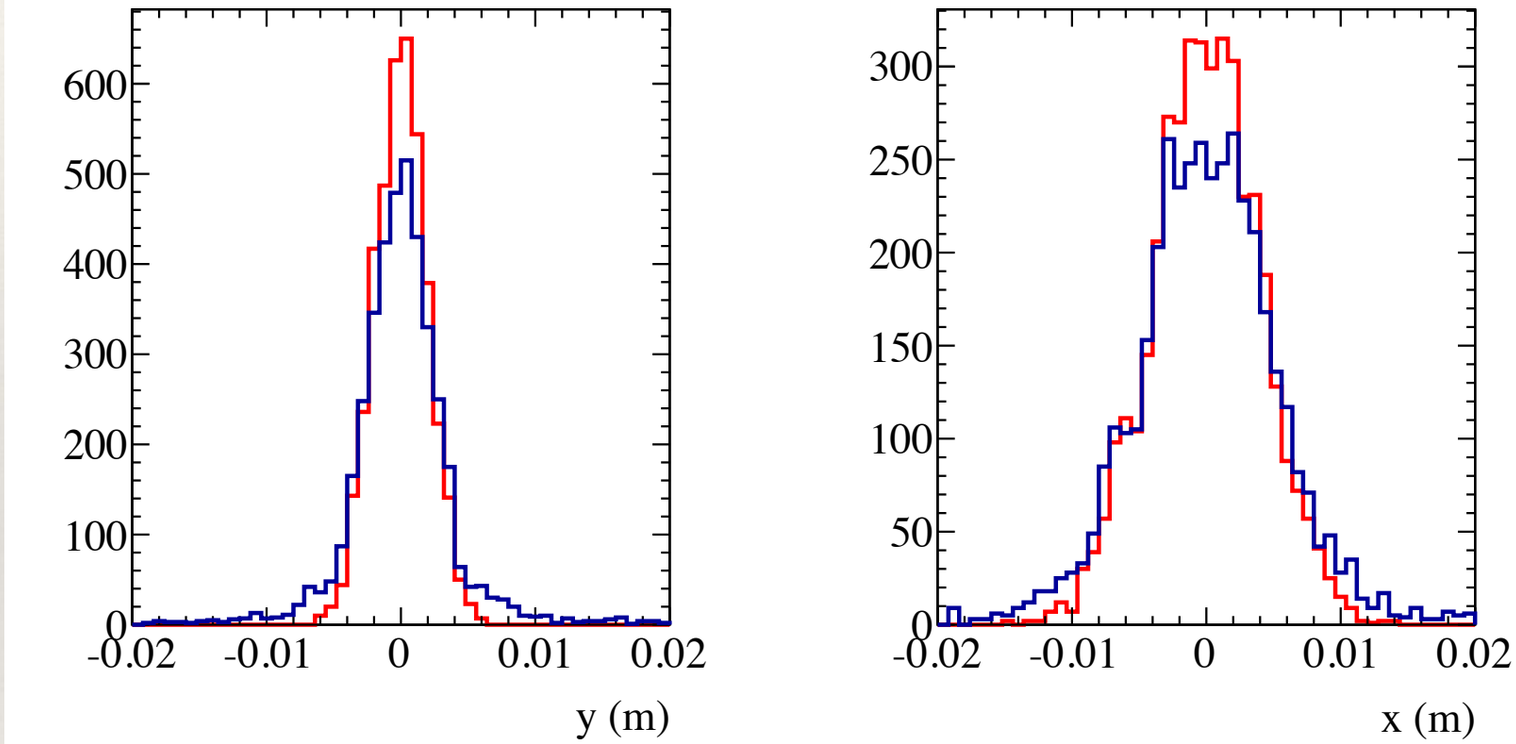


Beam profile

Fluorescent light profile

Beam Profile Distortion Xe

Same simulation as previous slide but with ionized Xe



Beam profile

Fluorescent light profile

Almost no distortion of the beam profile

It would seem that Xe is the preferred gas, but it does produce 1 order of magnitude less light for equivalent beam losses

Still Use N_2?

- We could correct for the profile distortion from N2+ if we know the arrival time of the photons (since the bunch length is significantly shorter than the decay time, 15 ns vs 58 ns)
- Would need a light detection system with very good timing resolution
- Considering and MPPC array rather than a camera+image intensifier (trade off spatial resolution for timing resolution)
- Could do full waveform readout
- This fall, we will place some MPPCs near the beam line to test their performance:
  - Beam induced noise rate
  - Dark noise rate with exposure to radiation
  - Gain with exposure to radiation

Beamline Vacuum and Gas System

- The residual gas pressure in the T2K beam line is 3e-6 Pa
- We need 2-3 orders of magnitude more gas to have ~few thousand photons per spill
- How to do this?
  - Y. Hashimoto from the J-PARC accelerator group has designed a gas jet system that achieves 5e-4 local pressure will maintaining 1e-8 Pa in the nearby beam line

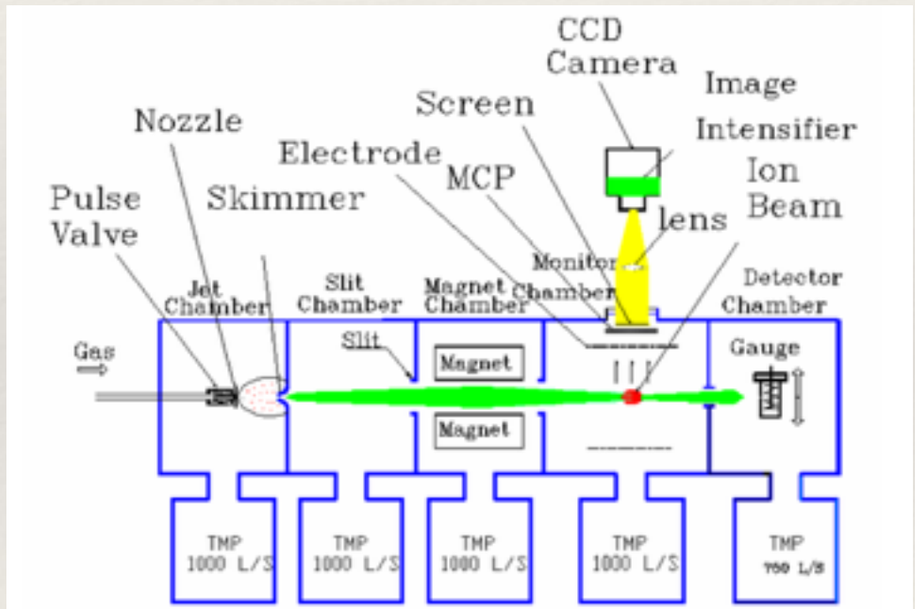


Figure 1: Schematic view of the sheet beam profile monitor

- May be overkill for an extraction line. Looking for a simpler, cheaper, more compact solution.

Summary

- We are concerned about the operation of beam profile monitors at high power
  - Even now, all but the most downstream SSEM is removed during continuos beam operation
- Considering options for upgraded or alternative beam profile monitors
  - SSEM or OTR monitors may be improved with new foil materials
  - It appears that a BIF monitor could work in the T2K beamline
    - Now starting to investigate the light detection and gas injection/vacuum systems
  - Open to any suggestions and opportunities for collaboration

Extra Slides