UCANS V (13th May 2015) @ INFN LNL, Italy

Development of a linac-based neutron source for BNCT with beryllium three-layer neutron target system

T. Nakamoto on behalf of iBNCT project

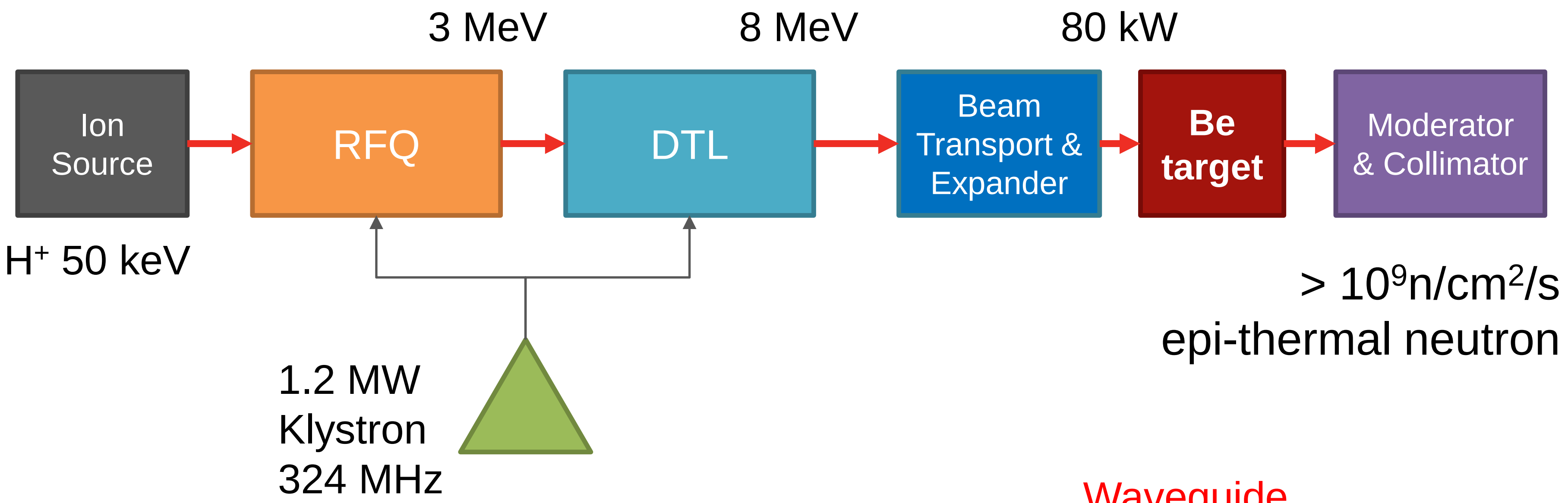
Latest Status

- UCANS IV: M. Yoshioka presented
  - Principle of BNCT
  - Installation of RFQ & DTL
- What’s new
  - Installation of RF system and beam transport
  - RF conditioning
  - First beam
  - Installation of TMCS
  - High intensity ECR ion source
  - Upgrade of beam diagnostics for high intensity beam
  - Miscellaneous issue of RFQ and DTL

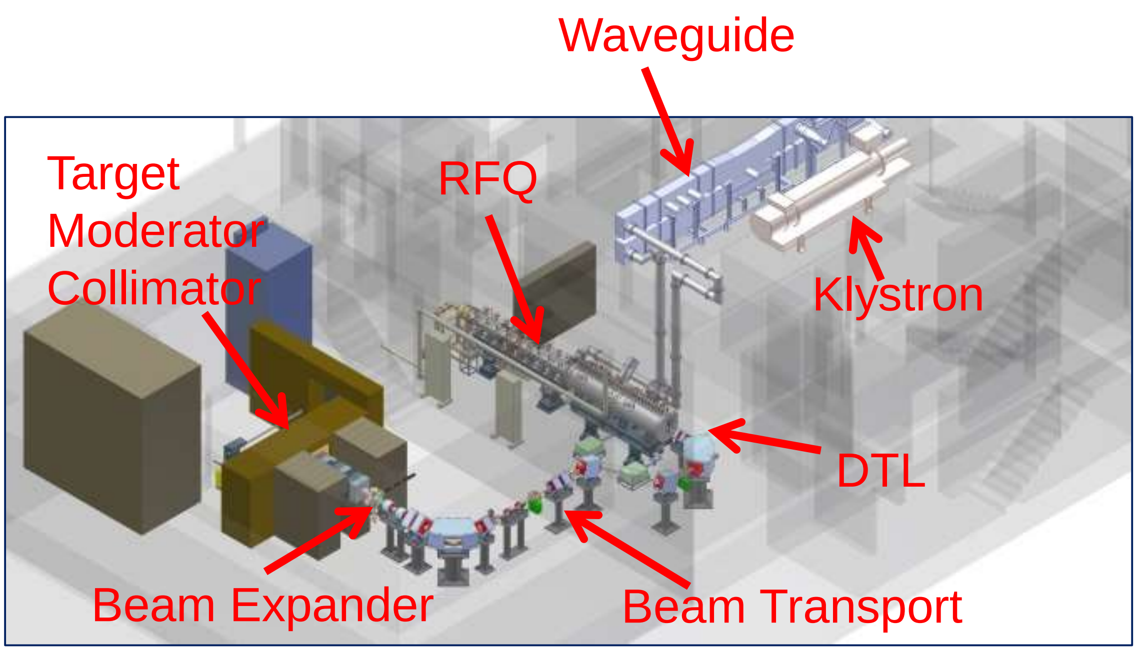
BNCT & Our Project

- BNCT = Boron Neutron Capture Therapy
- Required specs of neutron source
  - Epi-thermal (0.5 eV ~ 10 keV) neutron flux: $10^9 n/cm^2/s$
  - Small contamination of fast neutron and gamma rays
  - Small radio activation
- Our project: *i*BNCT (*i* = Ibaraki)
  - Site is located in Tokai Village, Ibaraki, Japan
    - Right next to the site of J-PARC.
  - Linac-based neutron source for BNCT
  - Collaboration among different parties
    - Univ. of Tsukuba, KEK, JAEA, Mitsubishi Heavy Industry, Ibaraki Prefecture, …

Basic configuration of proton linac



Peak current	Max. 50 mA
Pulse width	Max. 1 ms
Pulse repetition	Max. 200 pps
Duty	20%
Beam power	80 kW



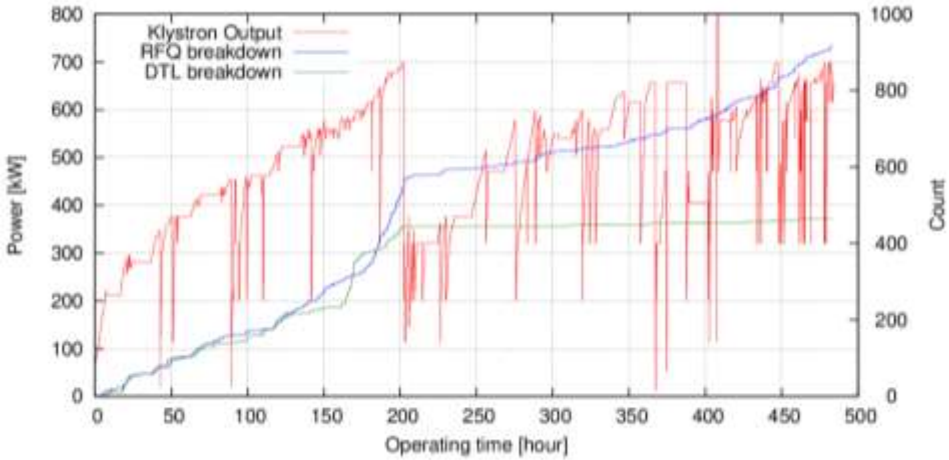
Installation of RF system and beam transport

1.2 MW Klystron

Modulator

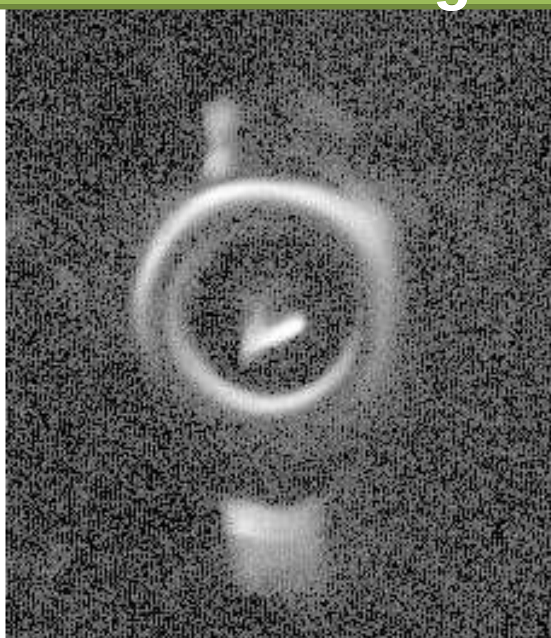
Beam transport & expander

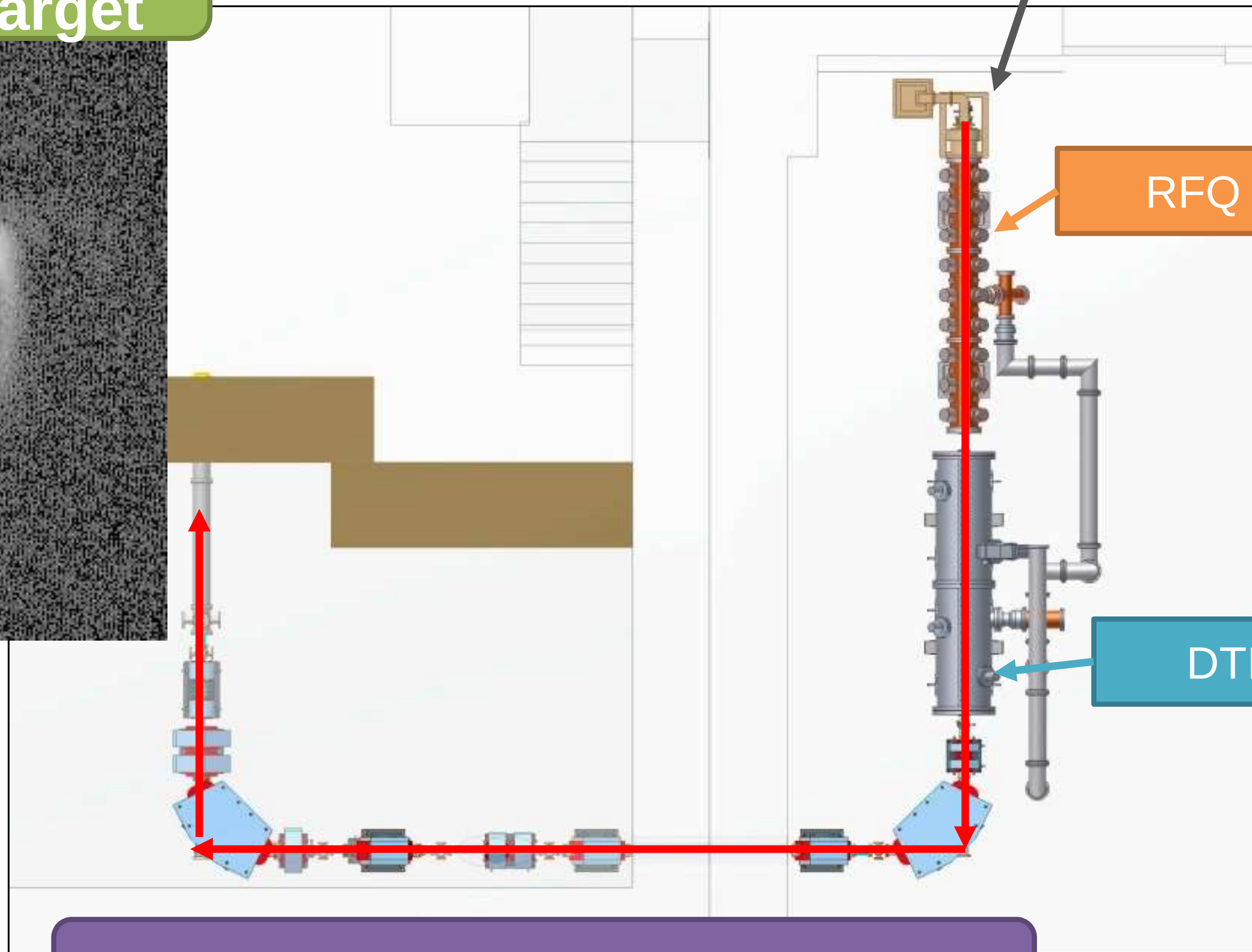
RF Conditioning



First beam (December 2014)

Fluorescent screen on target

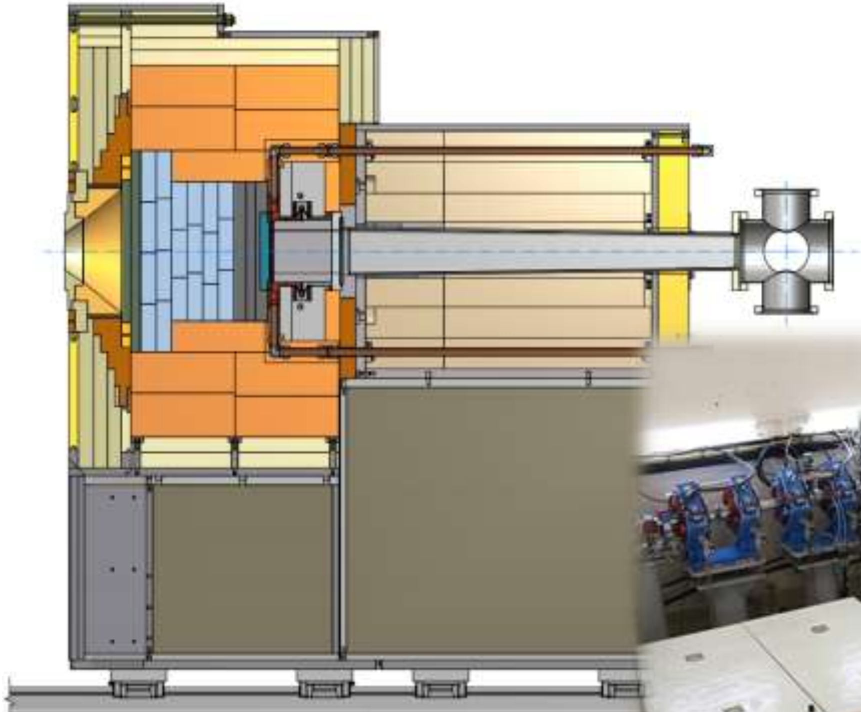




Very low peak current: ~ 1 uA

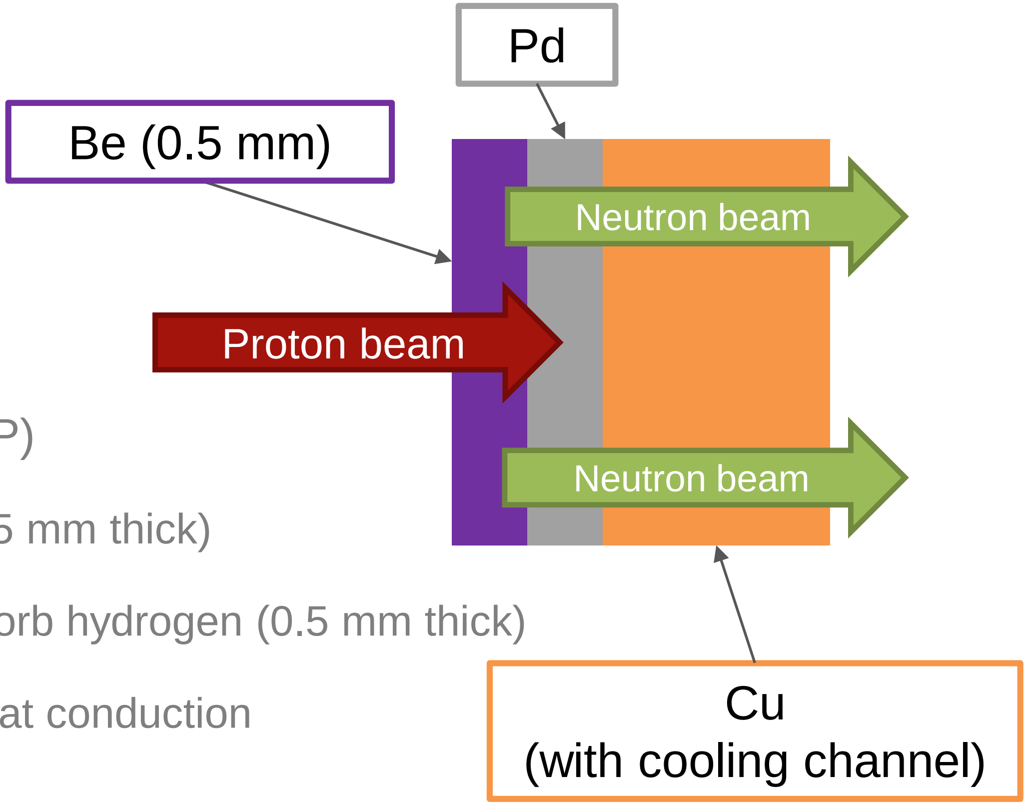
Installation of TMCS

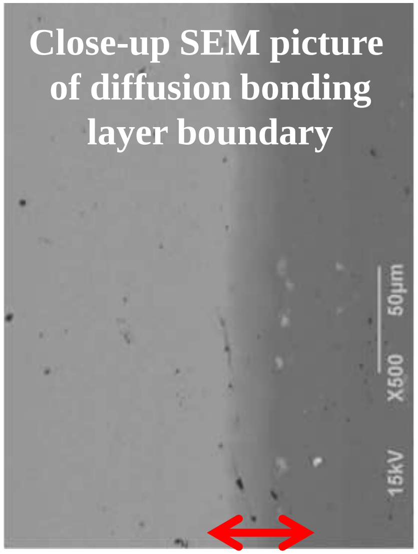
- Target, Moderator, Collimator and Shield
  - Installation was completed except shield.
  - We plan to make a minor modification to the collimator in order to make the residual activities lower.



Target

- General problems of target
  - Blistering
  - Cooling
- Our design
  - Three layer target (bonded by HIP)
    - 1st layer:
      Beryllium to generate neutron (0.5 mm thick)
    - 2nd layer:
      Palladium to stop proton and absorb hydrogen (0.5 mm thick)
    - 3rd layer:
      Oxygen-free copper for higher heat conduction
  - Performed test
    - Measurement of heat conductivity
    - Thermal cycle test
    - Observation of diffusion bonded layers
    - Tension test
  - To be tested
    - Cooling
      - High velocity is required for nucleate boiling.
      - Velocity of cooling water: 10 m/s is the designed value.
    - Life time



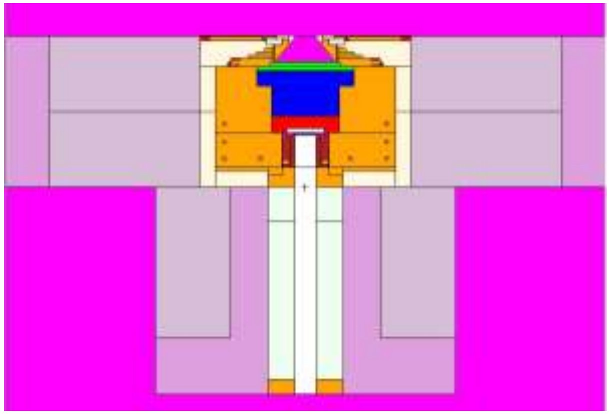


Neutron flux and dose (MCNP)

Condition

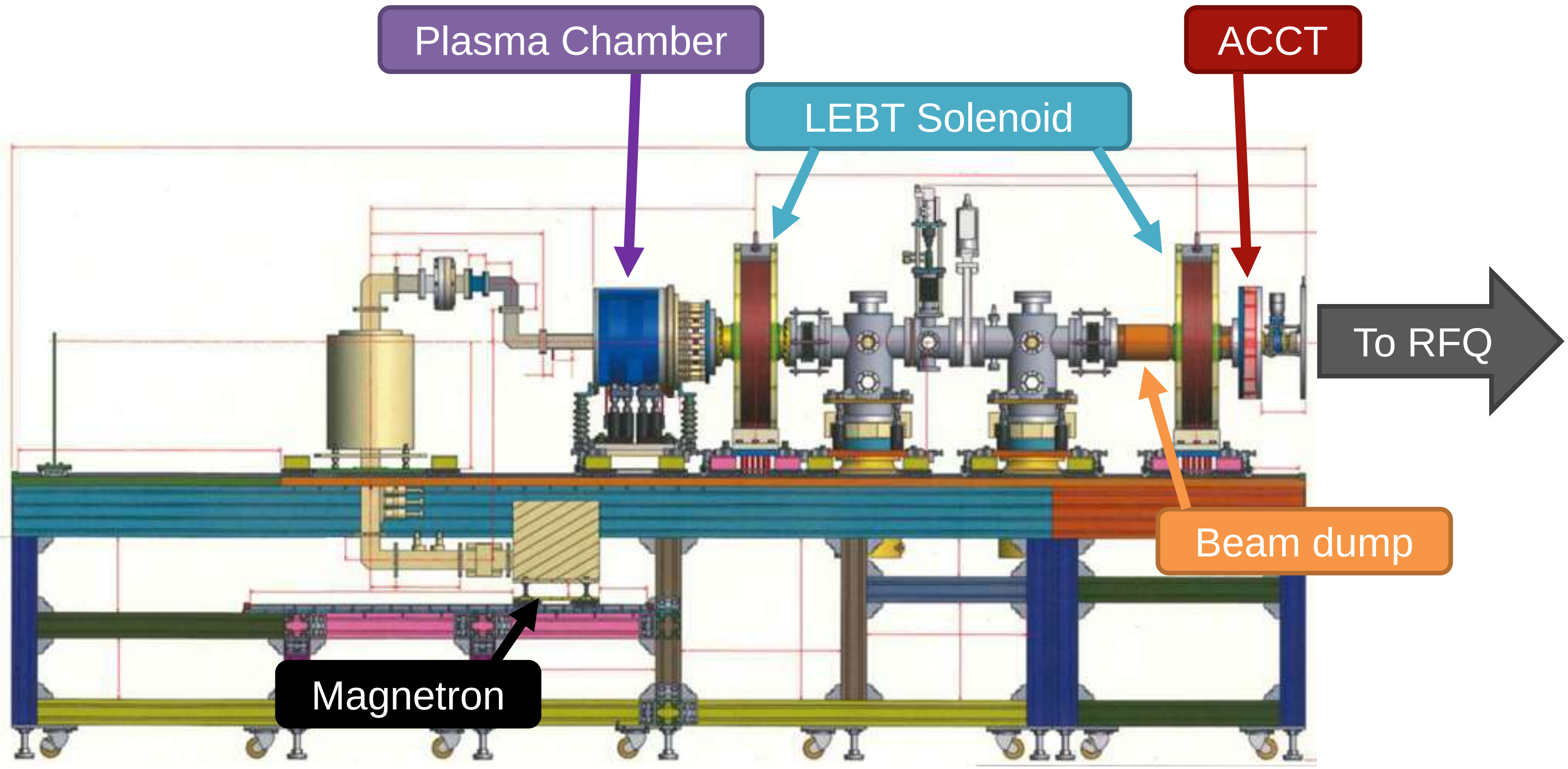
Φ12 cm, 10 mA average beam current, 8 MeV

Neutron Flux	Thermal (~ 0.5 eV)	1.85×10^{8} n/cm^2/s
	Epi-thermal (0.5 eV ~ 10 keV)	**4.34×10^{9} n/cm^2/s**
	Fast (10 keV ~)	4.70×10^{8} n/cm^2/s
Gamma ray dose		0.74 Gy/h
Contamination ratio	Fast neutron	5.28×10^{-13} Gy · cm^2
	Gamma ray	4.75×10^{-14} Gy · cm^2

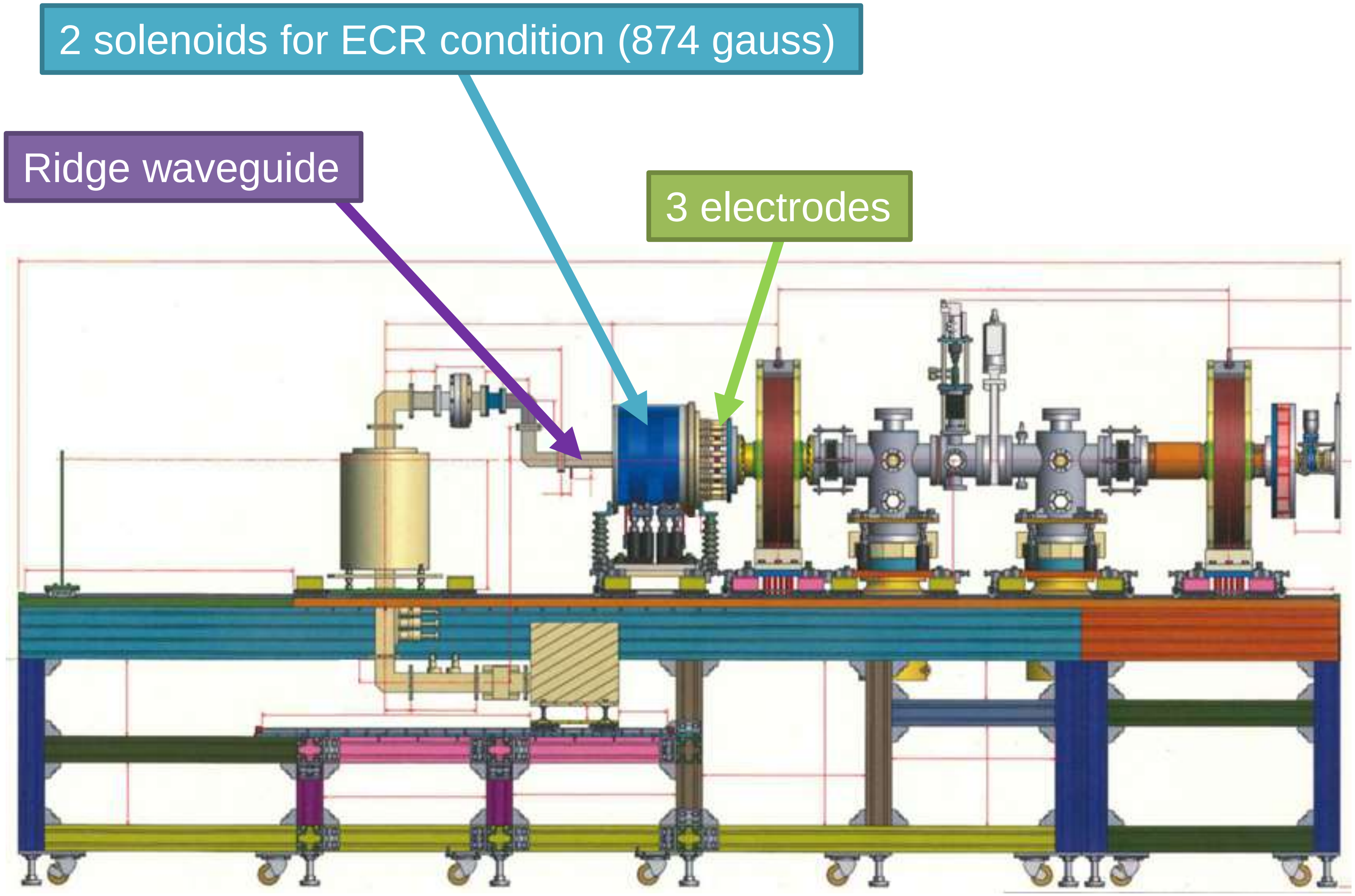


High intensity ECR ion source (on-going)

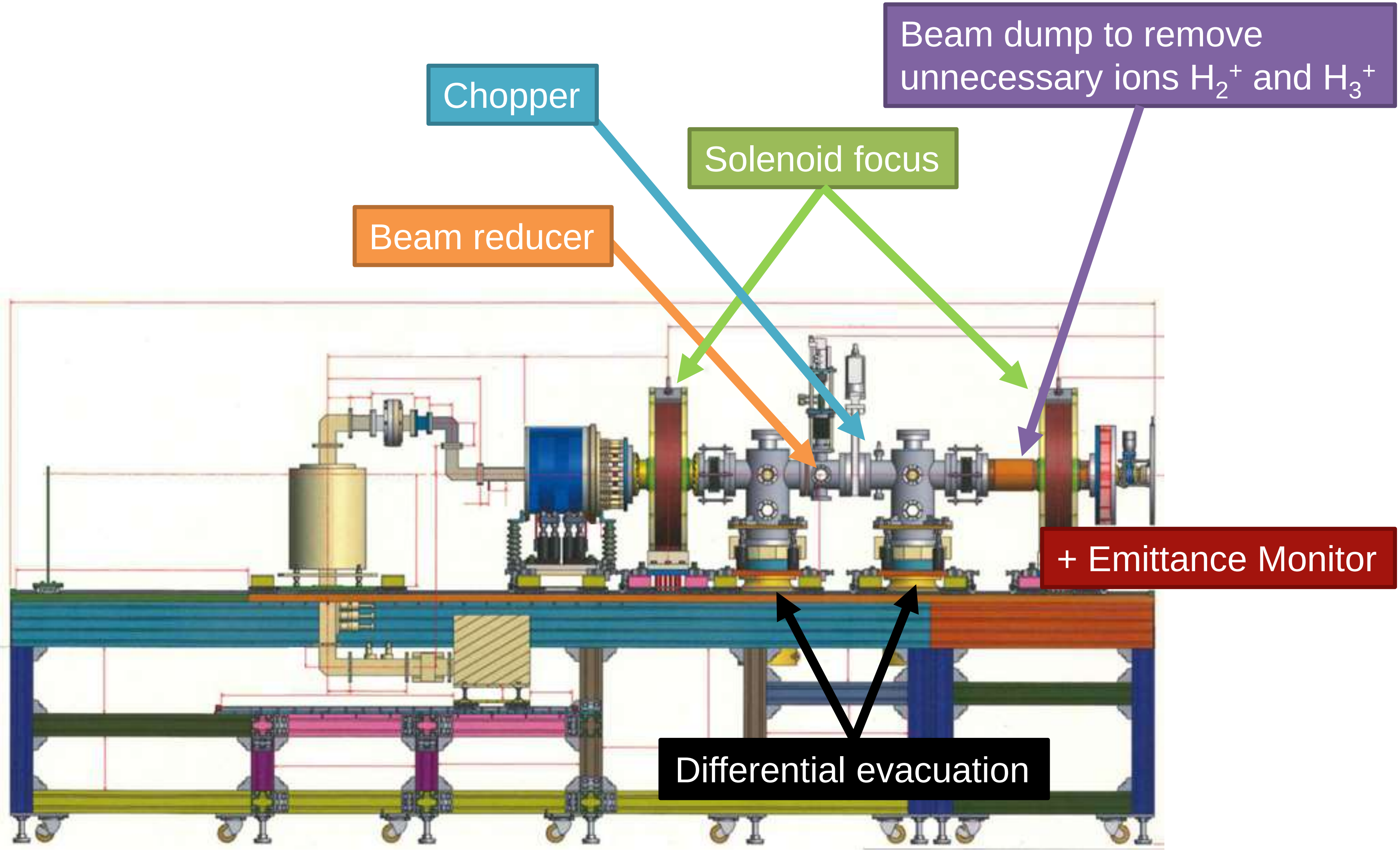
- ECR ion source (50 keV, 2.45 GHz pulse RF)
- New LEBT



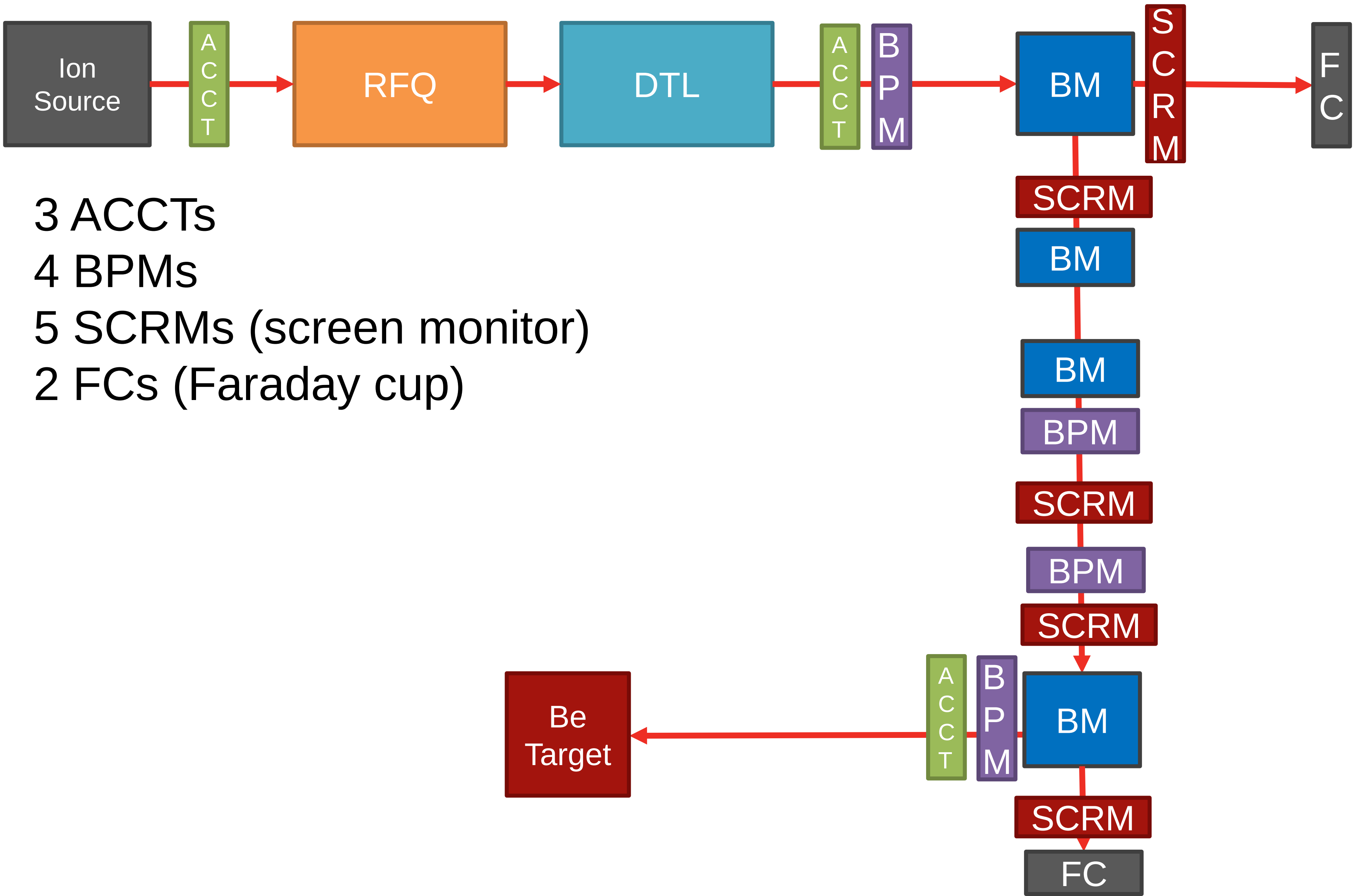
Ion Source: what's new



LEBT: what's new

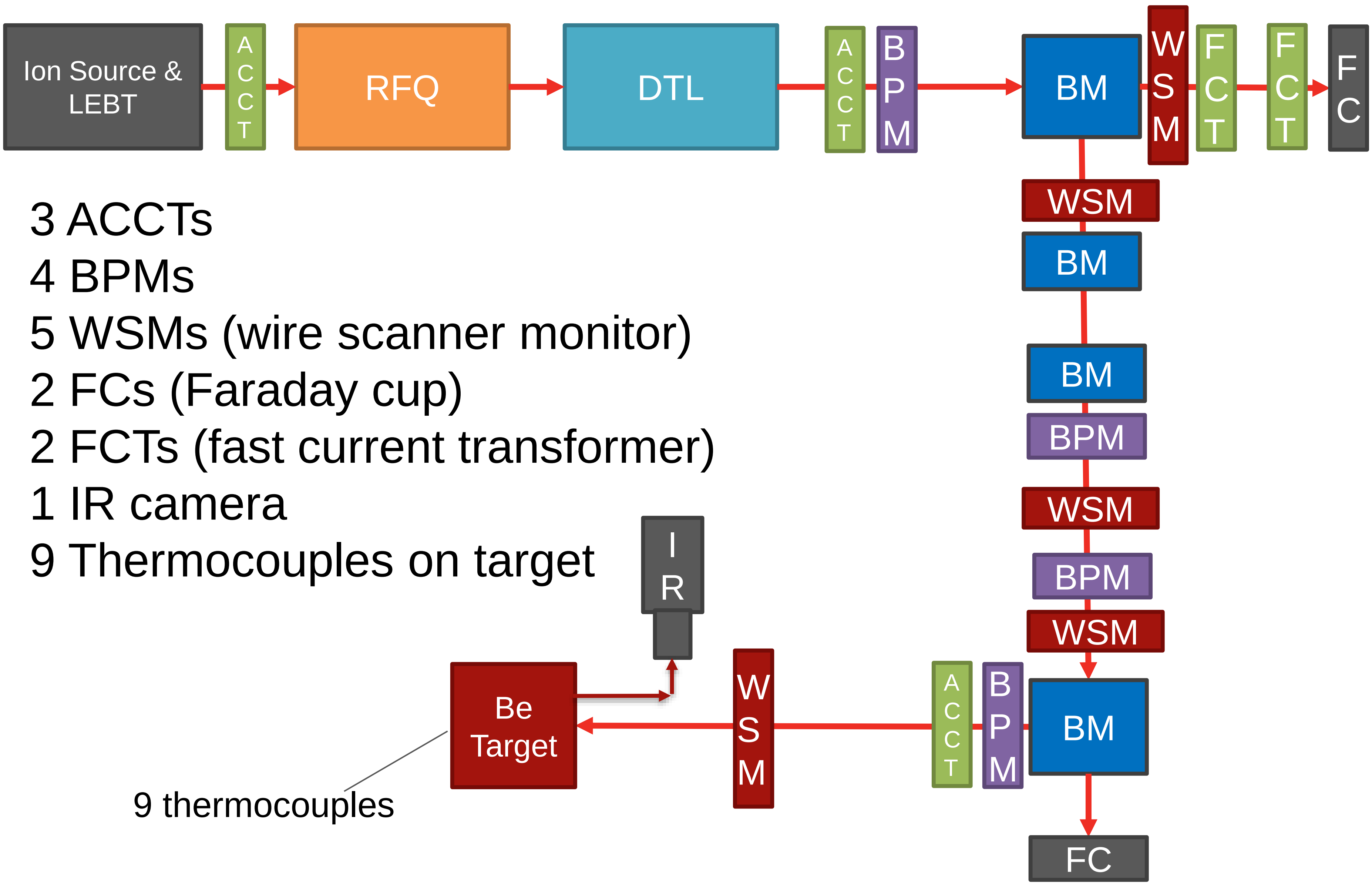


Beam Diagnostics (for low current)



3 ACCTs
4 BPMs
5 SCRMs (screen monitor)
2 FCs (Faraday cup)

Beam Diagnostics (for high current)

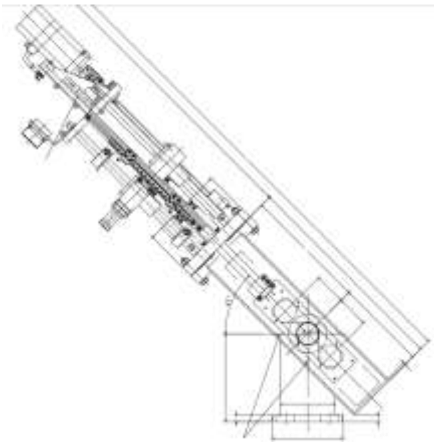


3 ACCTs
4 BPMs
5 WSMs (wire scanner monitor)
2 FCs (Faraday cup)
2 FCTs (fast current transformer)
1 IR camera
9 Thermocouples on target

Beam energy measurement

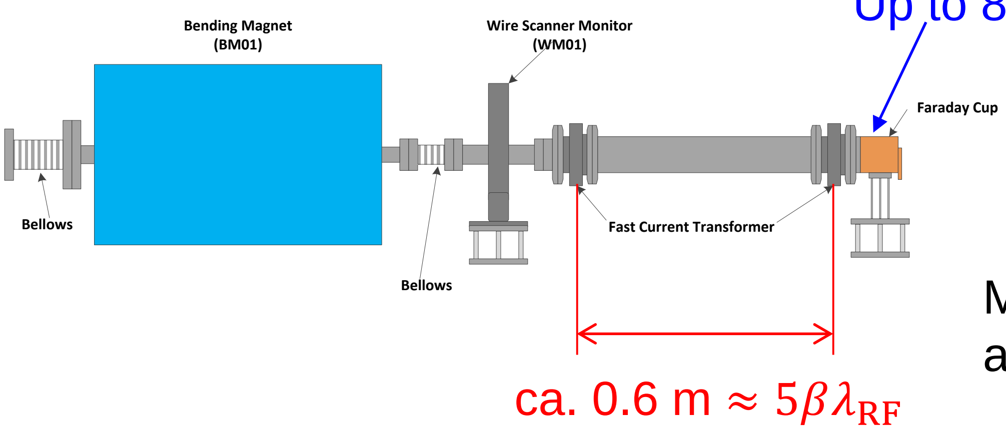
Wire scanner monitor

Screen monitors will be replaced by wire scanner monitor to observe beam profile.



Gold-coated tungsten wire (diameter is 30 um).
→ Can withstand up to several mA beam current @ 1 pps repetition rate. Actual limitation depends on beam size.

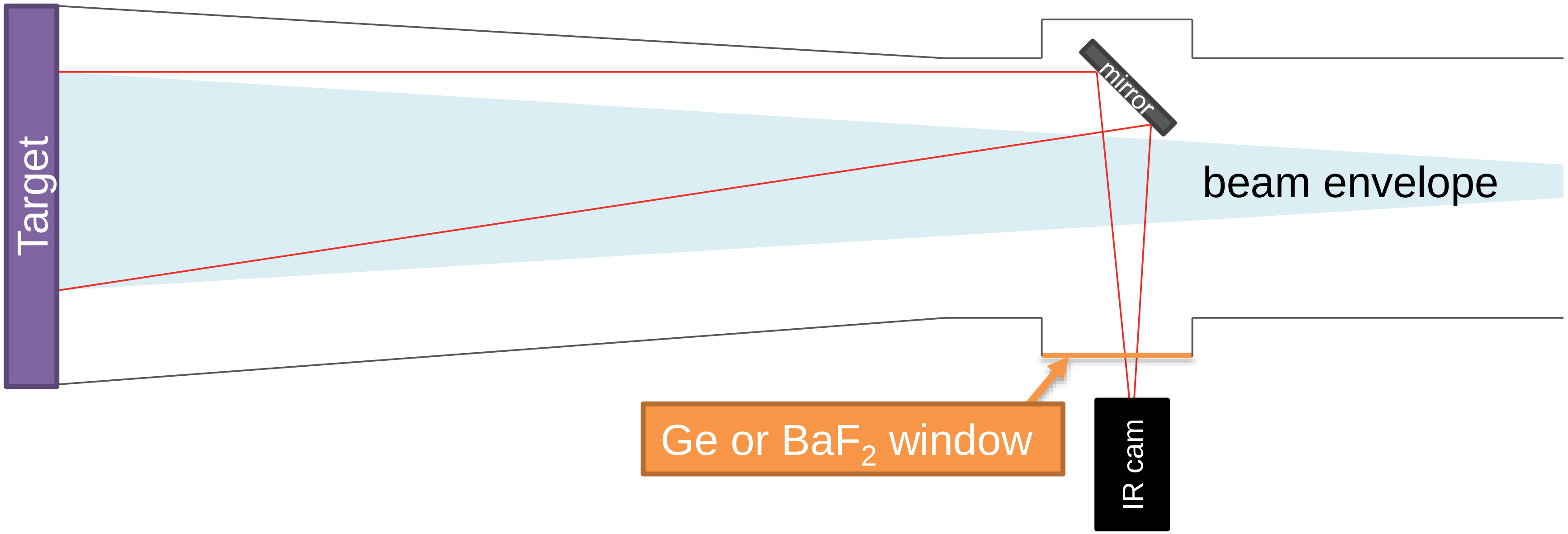
Beam energy measurement by TOF



Measurement resolution will be around 0.01 MeV.

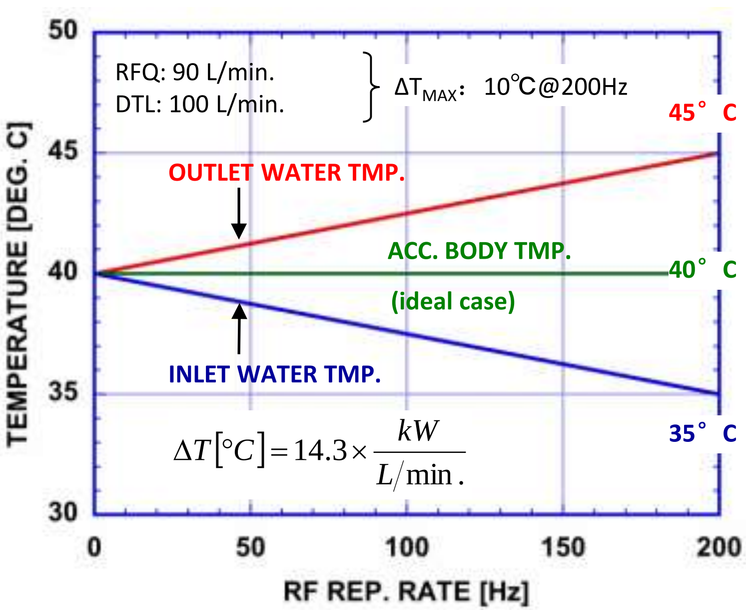
Target monitor

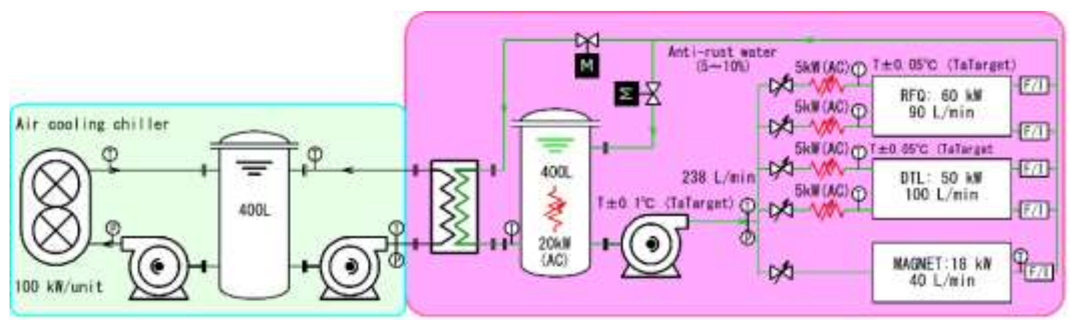
- Thermocouples
- IR camera (optics are in design)
  - Beam and temperature profile observation.



RFQ & DTL

- Maximum surface electric field
  - RFQ: 31.56 [MV/m] (1.77 kilpatrick)
  - DTL: 13.48 [MV/m] (0.76 kilpatrick)
  - Discharge rate of RFQ would be the most important factor for high availability.
- Cooling
  - Due to high duty operation (20%), average RF wall loss will end up to be 132 kW.
    - To suppress temperature increase down to 0.1 deg C, we would need ca. 20,000 L/min cooling water for RFQ and DTL in total, which is not realistic (in hospital).
  - We will control temperature of inlet cooling water (190 L/min) depending on RF wall loss.
    - Operational temperature is designed to be 40 deg C.
- Beam matching between RFQ and DTL needs to be reconsidered for high beam current operation.





Upcoming project: OIST BNCT

- Project duration: 2015 – 2019 (construction)
- Preliminary design work has started.
- Possible changes
  - Final beam energy (a bit higher than 8 MeV?)
  - Beam energy between components
    - Beam energy at the exit of ion source
    - Beam energy at the exit of RFQ
  - Pulse length and repetition rate
  - RF source & frequency

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THANK YOU!

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