

Run 2c beam instrumentation: towards specifications

Collette Pakuza on behalf of AWAKE BI

AWAKE Collaboration Meeting

15-17 October 2025

Overview

- **Since last collaboration meeting, a lot of work and discussions to define the functional specifications of the instruments:**
 - BI Internal Review (<https://indico.cern.ch/event/1560227/>)
 - Diagnostics injectors
 - Diagnostics upstream plasma source 1 (<https://indico.cern.ch/event/1586161/>)
 - Diagnostics downstream plasma source 2 (<https://indico.cern.ch/event/1578633/>)
 - Bunch length diagnostic location proposal (<https://indico.cern.ch/event/1593037/>)
 - Infrastructure requirements
 - Continued Coordination and Scheduling meetings (<https://indico.cern.ch/event/1572531/>)
 - Continued AWAKE Instrumentation meetings (<https://indico.cern.ch/event/1583073/>)
 - Continued Electron Spectrometer meetings (<https://indico.cern.ch/event/1583466/>)
- **Today, summary of instruments for Run 2c**
 - The instruments as it stands
 - What still needs to be addressed
 - Focusing on instruments upstream of 2nd plasma source

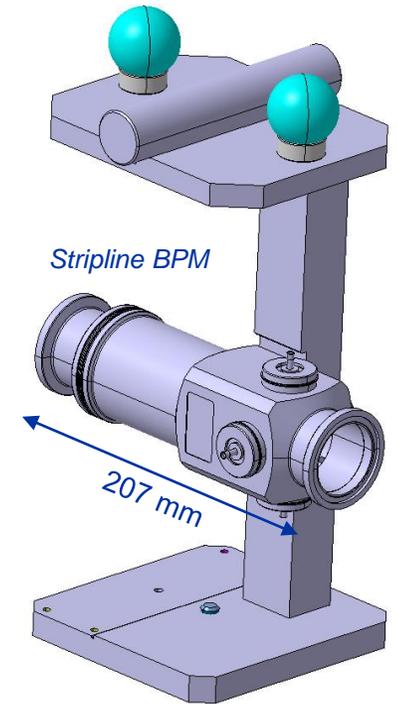
Instruments for the 18 MeV electron line and common line with protons

BPMs

- For most of the BPMs: number and location well-defined
- Re-use 5x40 mm and 4x60 mm-diameter, 207 mm-long **stripline BPMs** (existing)
- Exact location of last BPM (412370) (No.9) needs to be updated from Eleonora's MAD-X file in the official layout

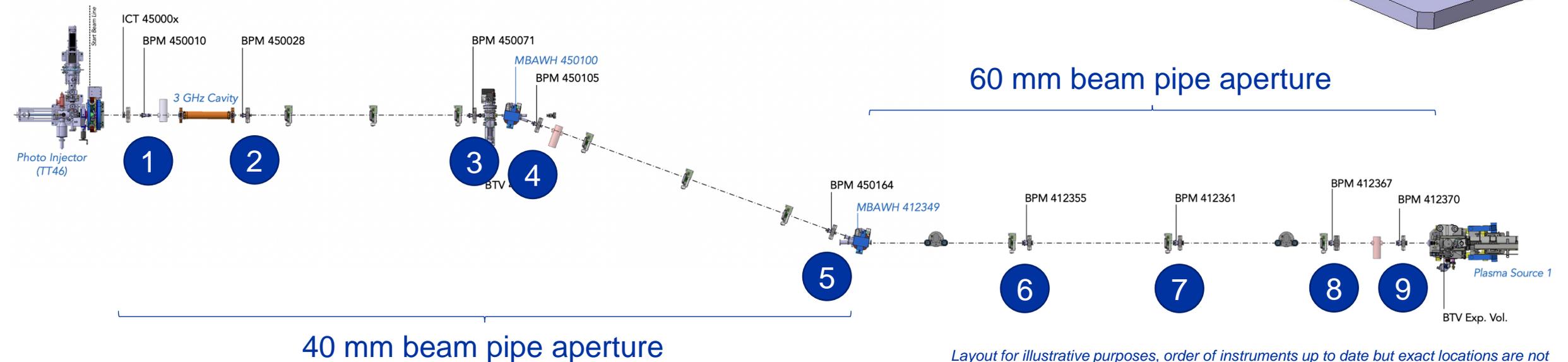
Table 1. Summary of stripline BPMs for the 18 MeV line.

BPM Diameter /mm	Length /mm	Number of Units	Existing	Confirmed
40	207	5	Yes	Yes
60	207	4	Yes	Yes
40	207	1	Yes	No



Stripline BPM

207 mm



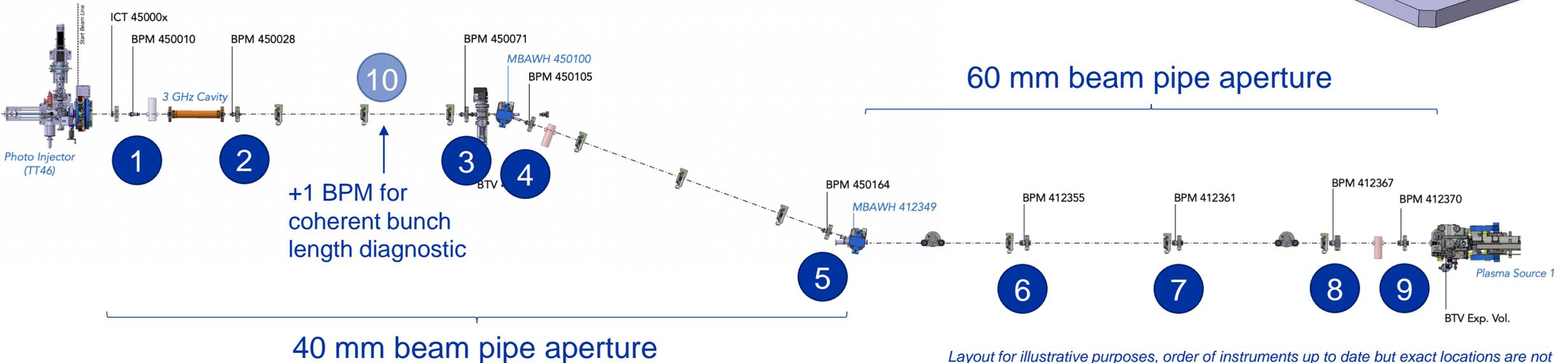
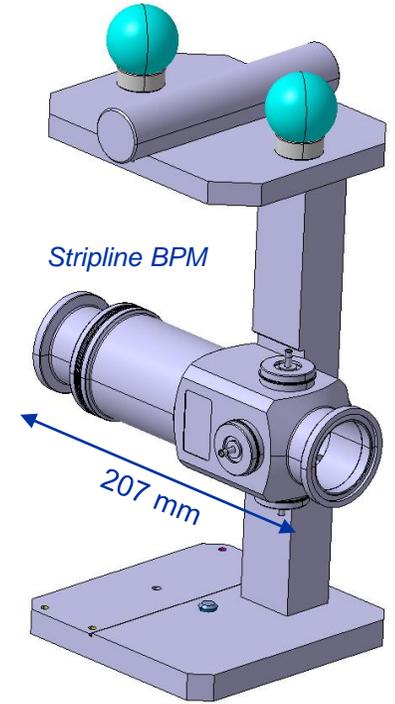
Layout for illustrative purposes, order of instruments up to date but exact locations are not

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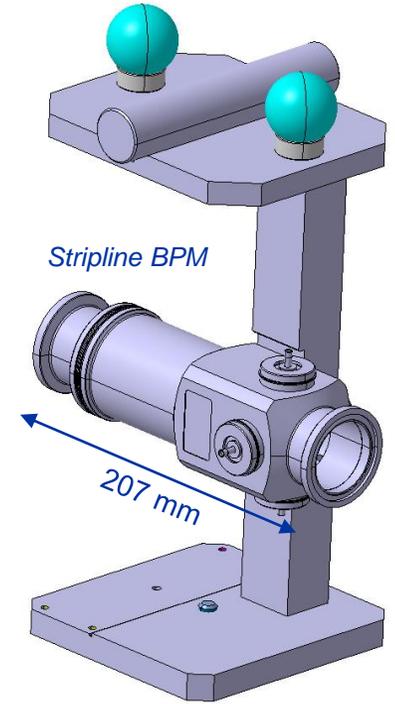
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- Common line: problem of measuring electron beam position in the presence of protons at the nominal proton bunch charge
- Proposal of using a ChDR pick-up coupled to an EO modulator for time-resolved measurements
- From 23rd Instrumentation meeting: presentation on the results of such a system at CLEAR and HiRadMat
- The possibility and suitability of this for AWAKE application needs to be further discussed

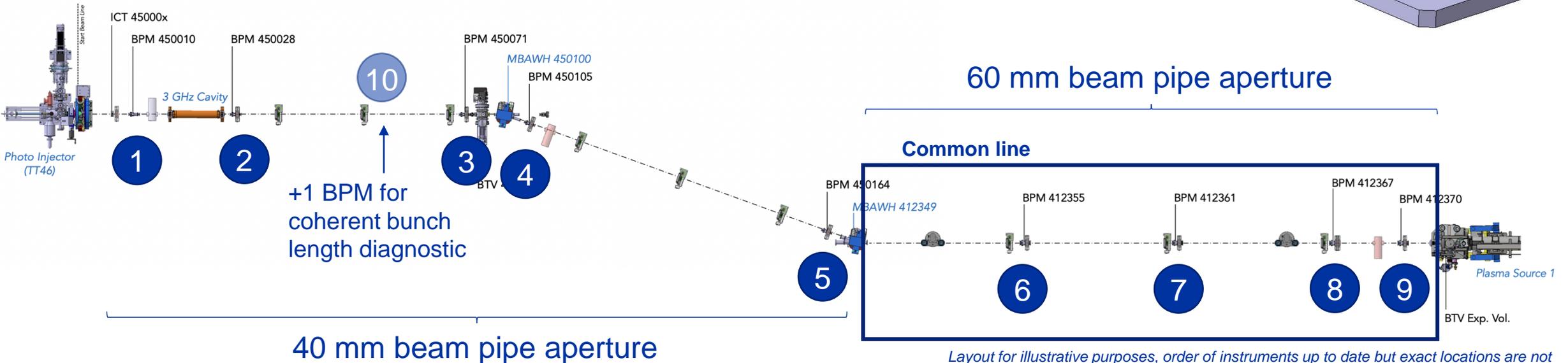
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40	207	1	Yes	No



Stripline BPM

207 mm



60 mm beam pipe aperture

Common line

+1 BPM for coherent bunch length diagnostic

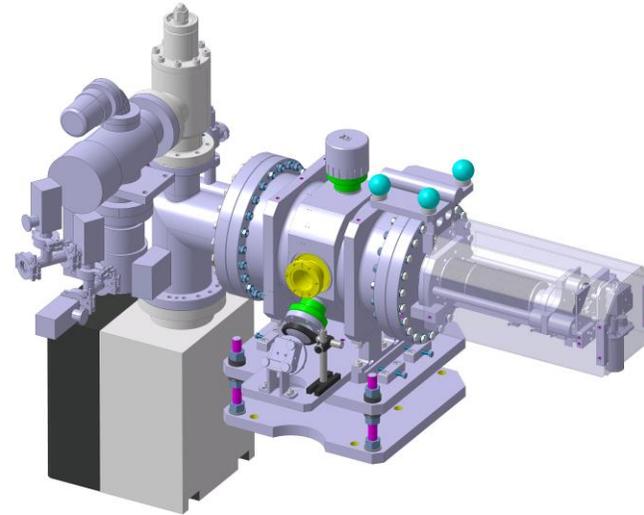
40 mm beam pipe aperture

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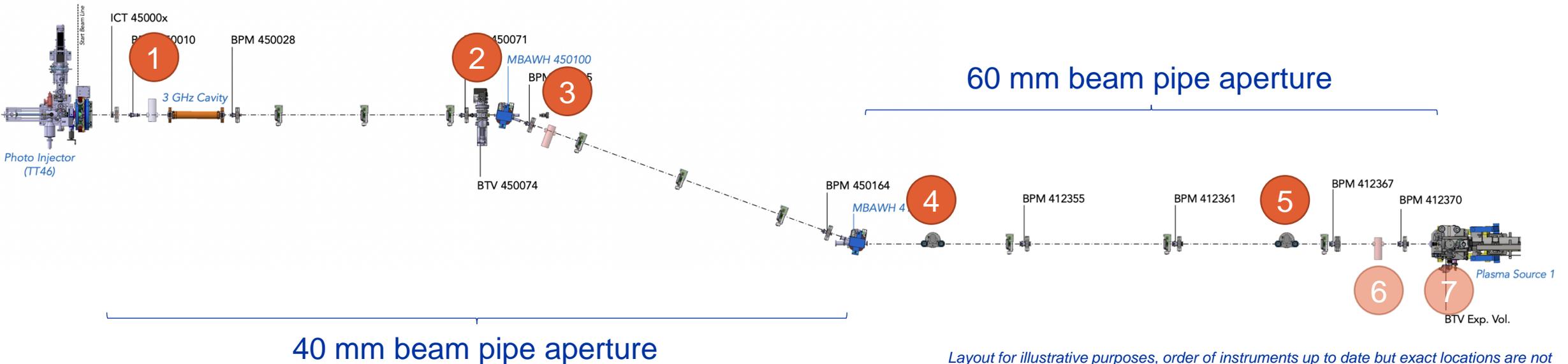
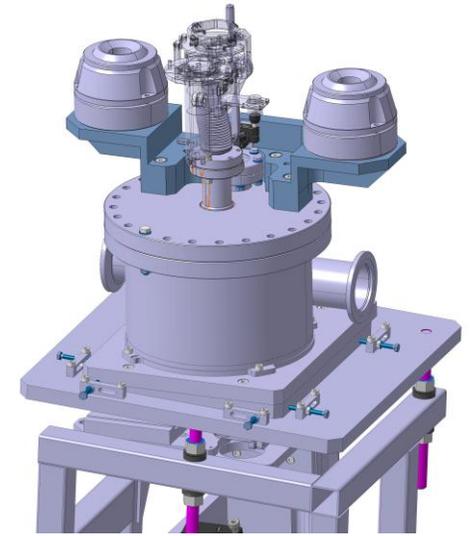
BTVs (1)

- For now, 3 BI BTVs will be re-used from run 2b in this line:
 - BTV 450074 (No.2) – CTF linear-type with OTR, YAG and replacement chamber – for position, emittance (quad scans) measurements and offline bunch length measurements with streak camera
 - BTV 4 and 5 – LHC rotational-type with OTR and Chromox – for proton and laser alignment
 - From previous runs, there were some doubts about the position reproducibility of these rotational BTVs – these have been removed from TT41 to building 867 where they will undergo alignment checks

CTF linear-type
OTR, YAG and replacement chamber



LHC rotational-type
OTR, Chromox



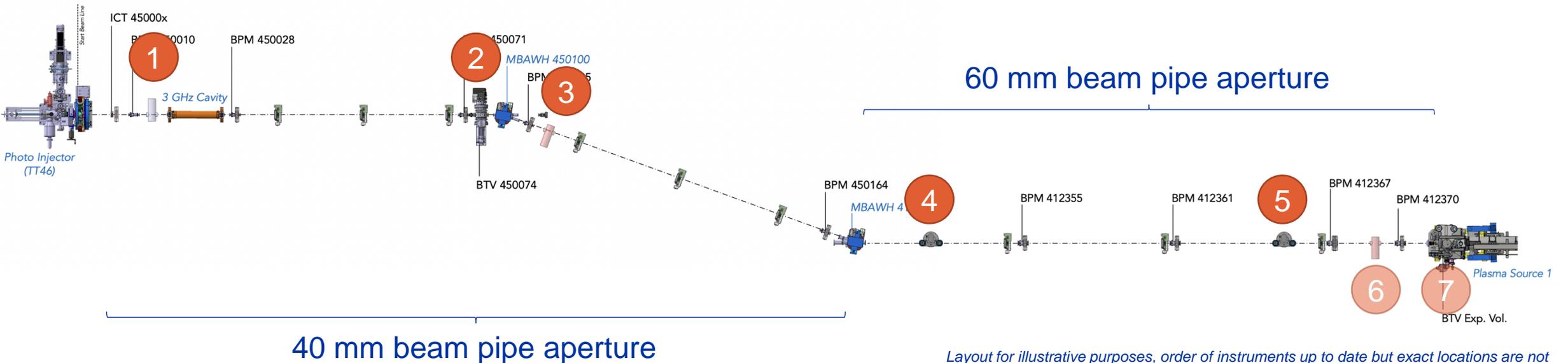
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BTVs (2)

- 2 new BI BTVs with single YAG screen will be installed:
 - Location No.1 replacing the pepper pot
 - After first dipole (No. 3) – for position and energy measurements
- MPP/GWA screens may be replaced or modified:
 - No.6 (previously known as BTV54) still need to decide if we keep or replace with new BI BTV
 - BTV Exp. Vol. (No.7) where the actuator may be replaced by BI (as requested by the Experimental Team)
- Exact positions of BTVs 4, 5 and 6 to be updated from Eleonora's MAD-X file in the official layout

Table 2. Summary of BI BTVs for 18 MeV and common line.

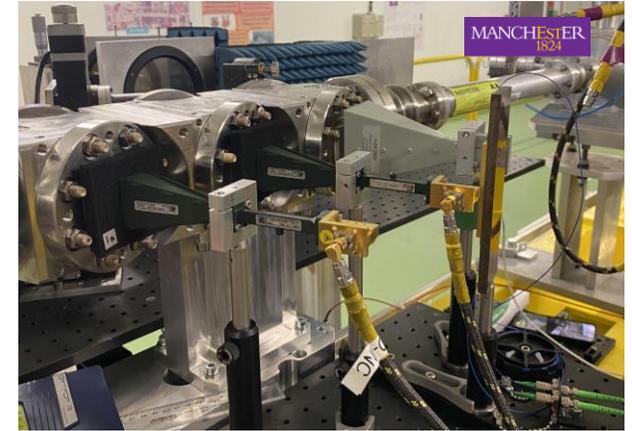
BTV type	Diameter/mm	Number of Units	Existing	Confirmed
CTF linear	40	1	Yes	Yes
LHC rotational	60	2	Yes	No, awaiting alignment checks
New single-screen	40	2	No	Yes
New single-screen	60	1	No	No



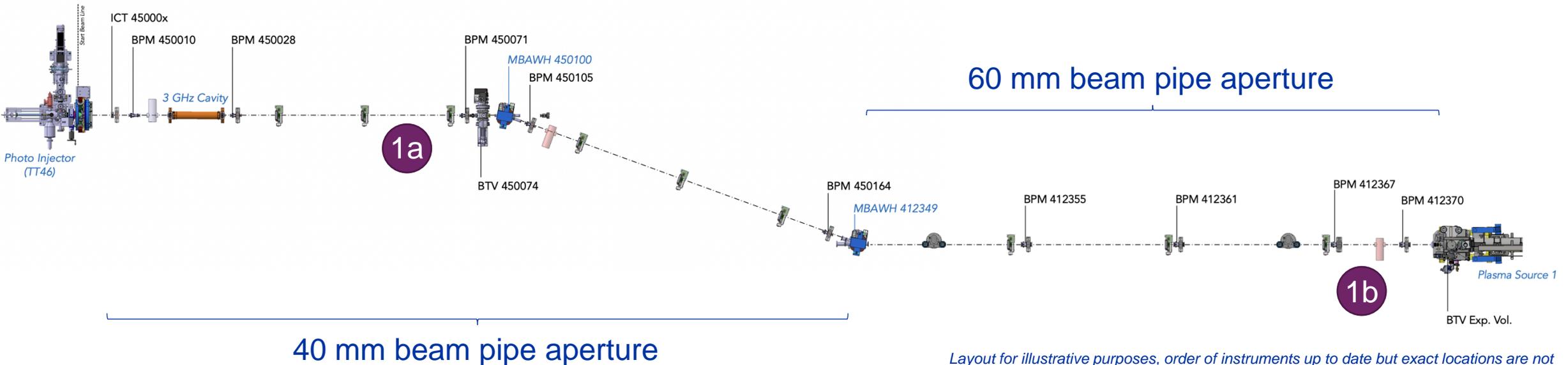
Bunch length

- Few options for bunch length diagnostics (presented by institutes in the BI Review, 4 July)
- Since the Coherent ChDR bunch length monitor is 450 mm-long, propose to install this in the 18 MeV line where there is more available space in location before the dogleg (1a)
- During commissioning, the instrument can be moved to a location before plasma source 1 (e.g. 1b) for verifying bunch length after dogleg
- Then for operation, moved back to 1a for online measurement even when proton bunches are present (not possible at location 1b)
- Instrument requires an ICT and BPM close by for normalization, and space for transitions (instrument aperture 50 mm)
- **A proposal, the locations need to be verified and agreed by the institutes**

ChDR bunch length monitor installed at CLEAR.



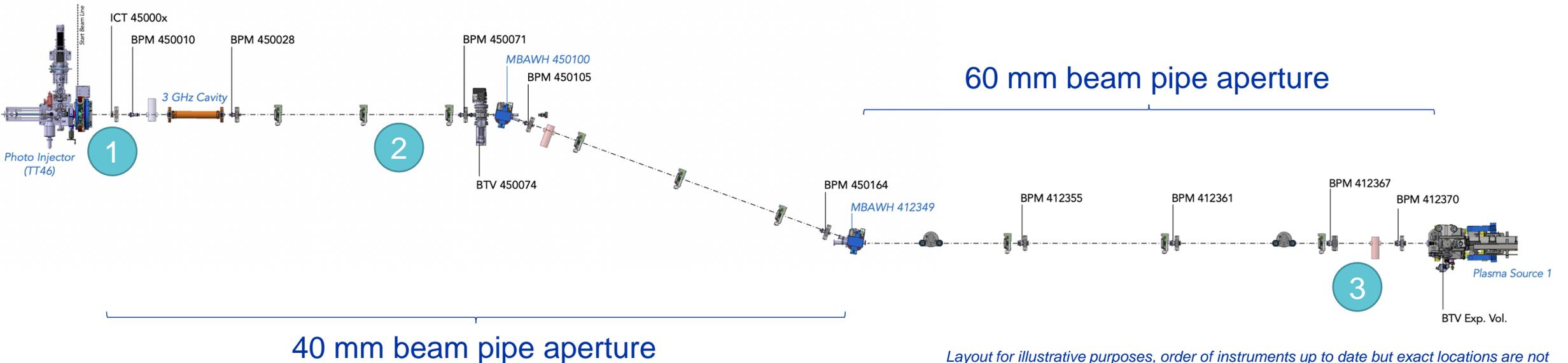
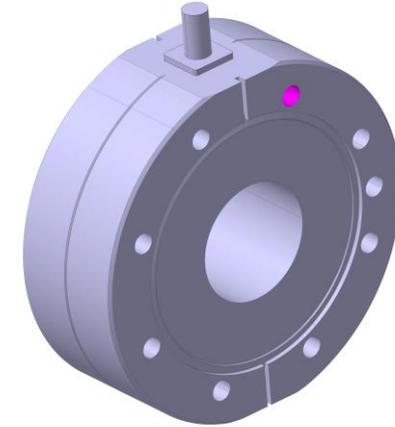
Jack McGunigal's talk tomorrow on results from CLEAR



Layout for illustrative purposes, order of instruments up to date but exact locations are not

Bunch charge

- Well-defined 38 mm aperture ICT at the gun (No.1)
- +1 38 mm ICT before dogleg for coherent bunch length monitor signal normalization (No.2), if this is installed then no need for Faraday cup after first dipole
- During commissioning: re-use existing 60 mm ICT before plasma source 1 (No.3)



Layout for illustrative purposes, order of instruments up to date but exact locations are not

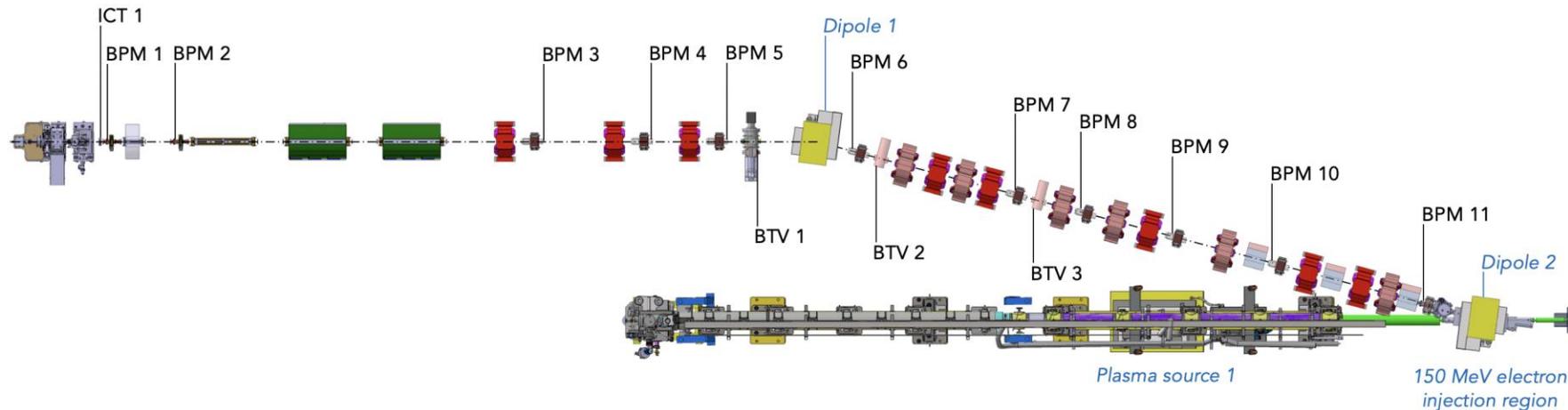
Instruments for the 150 MeV electron line

BPMs (1)

- News: updated specifications means that magnet positions and hence instrument positions are not frozen
- I will present the status as now – quantity of instruments will likely remain unchanged but location, and aperture, may change
- BPMs 3-10 will be the new 307 mm-long stripline BPMs designed to accommodate for longer corrector length:
 - 7x 40 mm and 1x 60 mm aperture at large beta region (BPM 7)
- **If possible, try to avoid the 60 mm one-off design during the optics update for budget and time reasons**

Table 3. Summary of stripline BPMs for the 150 MeV line.

BPM Diameter /mm	Length /mm	Number of Units	Existing	Confirmed
40	307	7	No	No – awaiting final optics
60	307	1	No	No – awaiting final optics
40	~260	3	No	No – awaiting final optics



Layout for illustrative purposes, order of instruments up to date but exact locations are not

BPMs (2)

- Procurement of electronics ongoing as planned (major expenses in 2026 in 2027)
- Prototype electronics will be tested with beam in the LHC in 2025 and 2026
- Production plan after news of specs modification: 2x 40 mm BPMs manufactured as a pre-series in 2026. Rest of the series will be produced as soon as the pre-series is fully validated (end of 2026 / early 2027). For now, production of 60 mm BPMs put on hold until the beamline layout is frozen
- Under discussion: design of the BPMs 1, 2 and 11 which at the moment are designed to be ~260 mm-long stripline BPMs accommodating for space in these regions
- One BPM removed as has same functionality as BPM 3

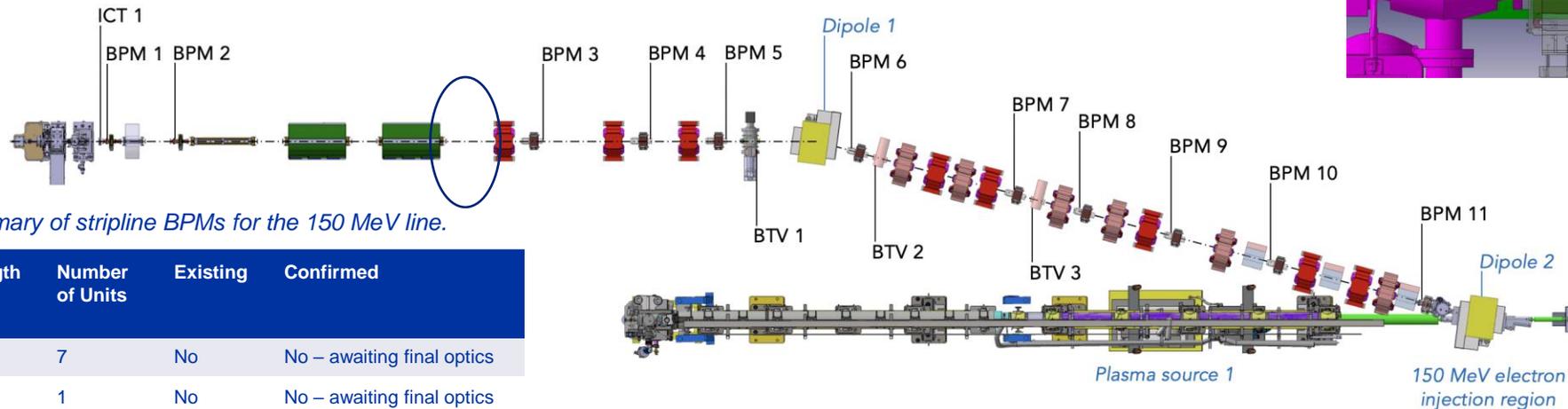
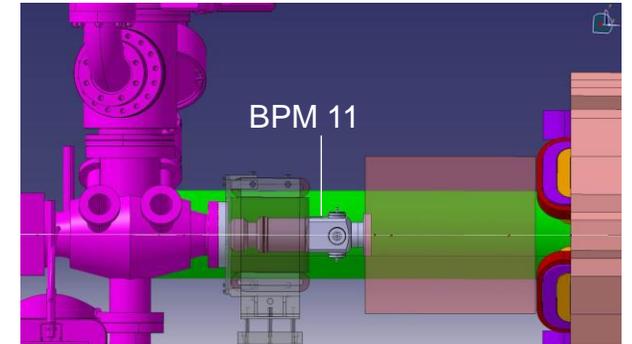
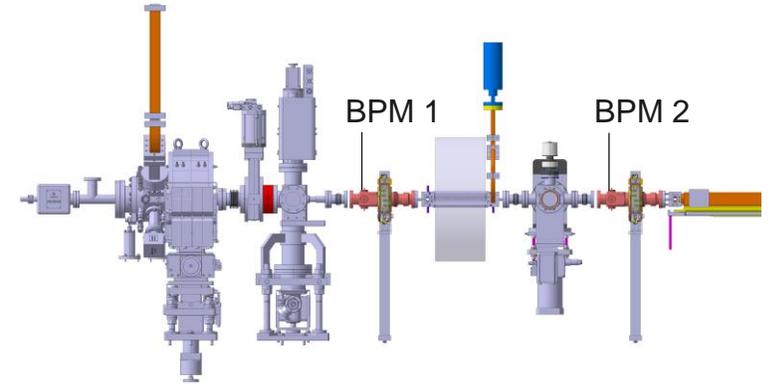


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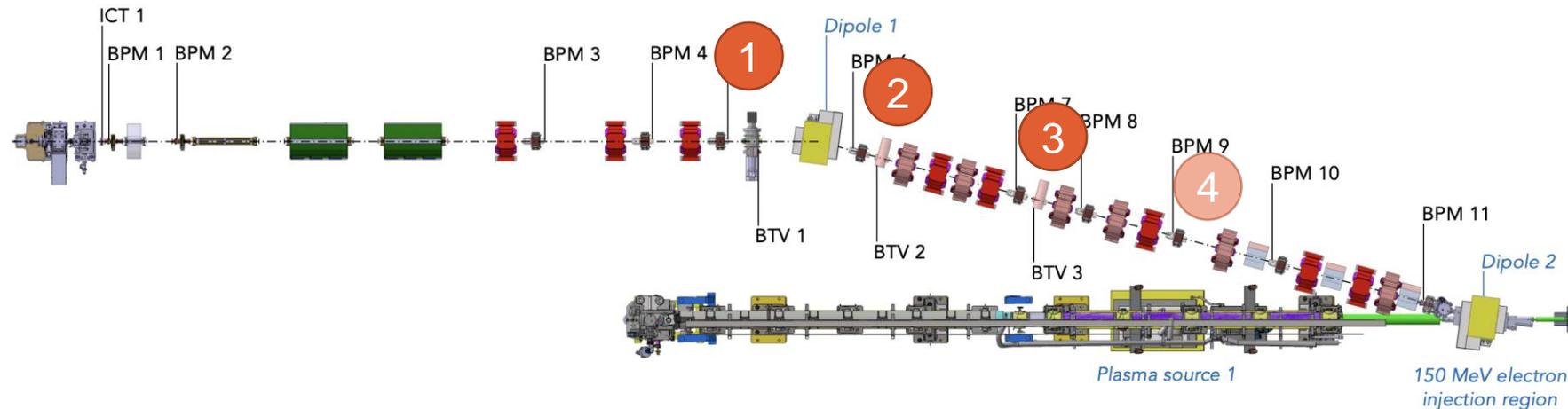
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BTVs (1)

- BTV 1 will be a multi-screen linear BTV used in run 2b in 18 MeV line so that both lines are equipped with multi-screen BTV
- BTV 2 and 3 will be 40 mm and 60 mm aperture versions of the new BI BTV with single YAG screen respectively
- Again, **try to avoid 60 mm aperture version if possible in the new optics**
- Possibly another 40 mm BTV in space after BPM 9 – to be seen after optics have been updated
- Another expansion volume screen before entrance into dipole 2 vacuum chamber which may require BI actuator

Table 4. Summary of BI BTVs for 150 MeV and common line.

BTV type	Diameter/ mm	Number of Units	Existing	Confirmed
CTF linear	40	1	Yes	Yes
New single-screen	40	1 (maybe 2)	No	No
New single-screen	60	1	No	No



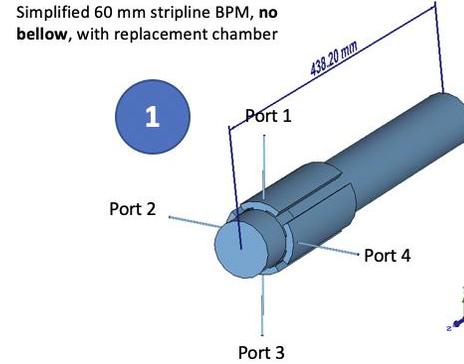
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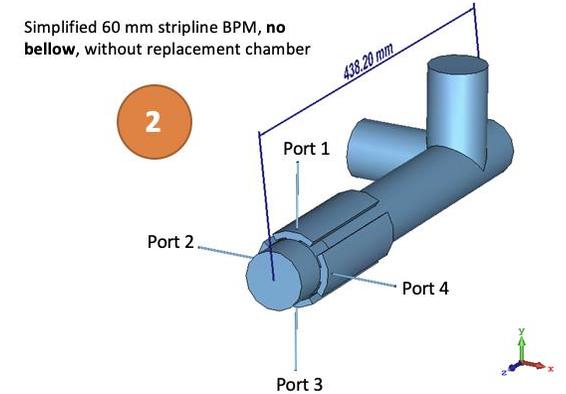
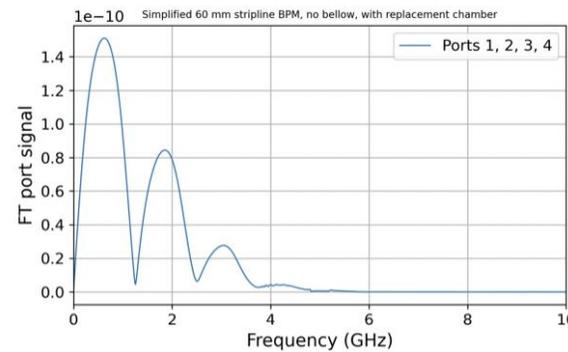
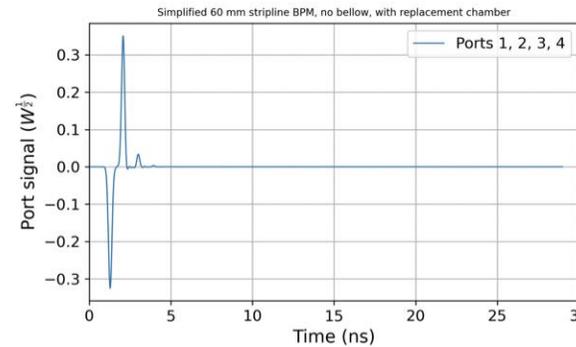
- For the new BI BTV design: question about the need for replacement chamber and its effect on the BPM signal
- Simulations have been done with and without the replacement chamber
- This is the worst-case scenario **if the beampipe aperture does not exceed 60 mm and the BPM-BTV distance does not go any shorter**
- BPM sensitive to the effect of replacement chamber
- However since signal filtering done at lower frequencies, not an issue for BPM electronics -> **no replacement chamber needed for stripline BPM operation**
- Generated wakefields could be an issue for close by high-frequency and EO pick-ups – ideally simulated with real beam (but very computationally heavy for such short bunches)
- At the moment, **we don't see the need to make a bigger and more complex design with the replacement chamber** but we keep in mind that the HF and EO monitors should be placed as far away as possible from BTVs without replacement chambers

BPM+BTV model

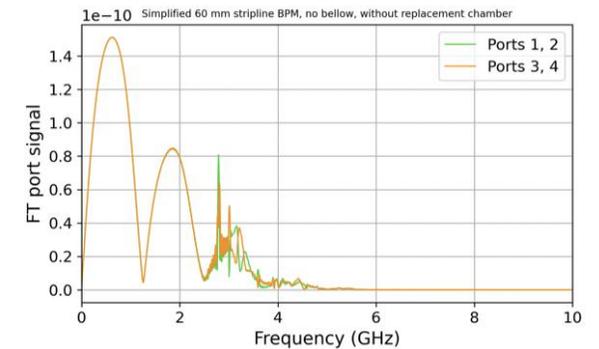
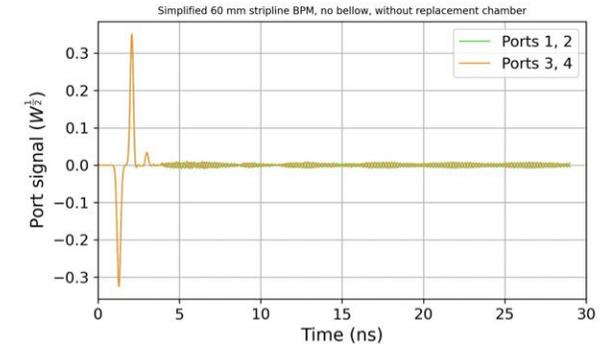
Beampipe aperture: 60mm
Simulation bandwidth: fmax = 20 GHz
Bunch sigma = 100 ps
Bunch charge = 200 pC



With replacement chamber



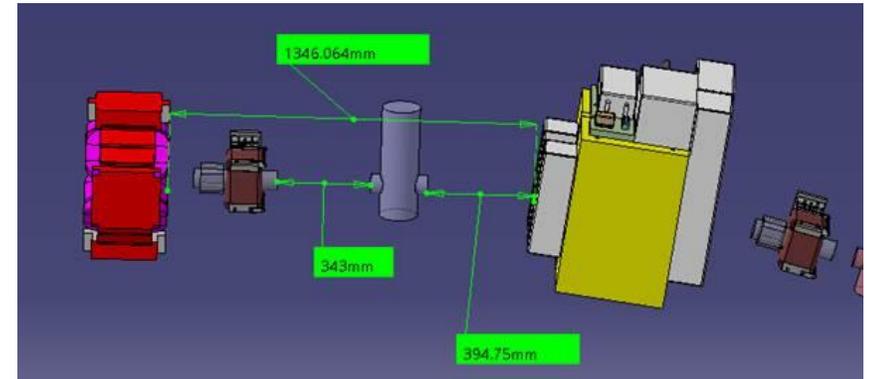
Without replacement chamber



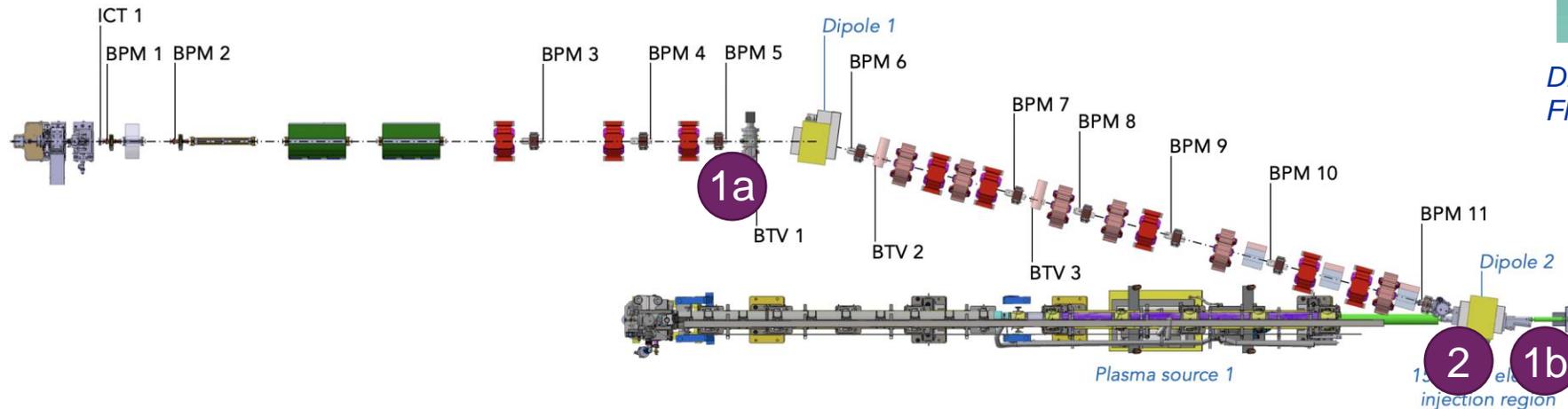
Bunch length

- Requirement: online, non-destructive measurement before and after the dogleg
- EO bunch length monitor offers this capability – see **Sam Norman's talk** tomorrow on results of EO measurements from CLEAR
- Propose to have one of these monitors in space before the dogleg (1a)
- If electrons can be propagated after plasma 2 (to be checked from optics), a second EO monitor would be useful
- This can be used first on the test bench during commissioning (1b), cross-calibrated with the Coherent synchrotron radiation diagnostic (**U. Liverpool**) (2) and then moved to after plasma 2 during operation (provided there is space)
- Otherwise, 1x EO monitor used interchangeably before and after dogleg during commissioning

Space before Dipole 1



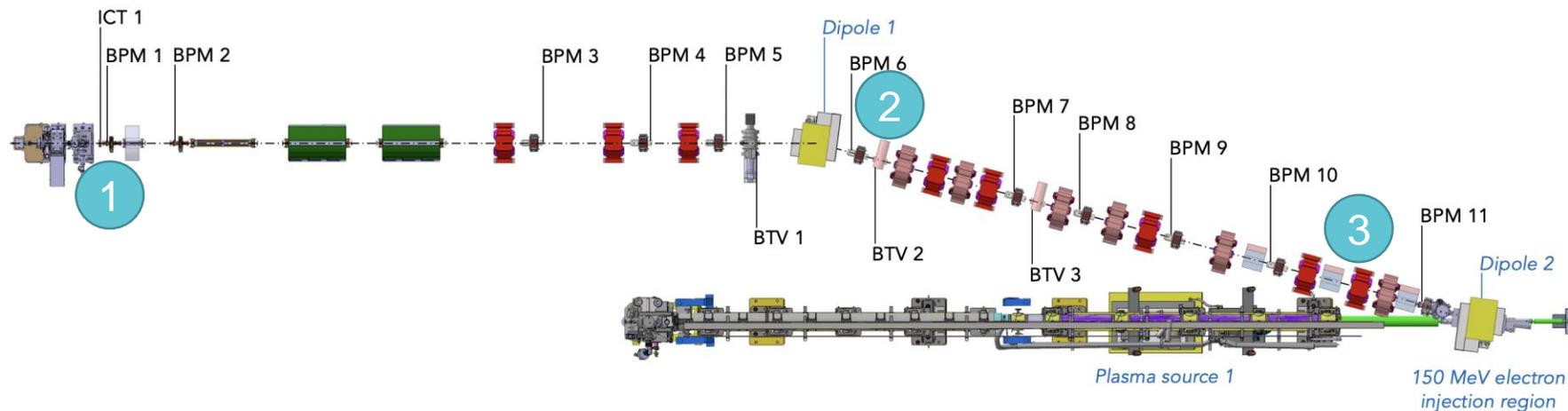
DN40CF 6-way cross
Flange-to-flange 125 mm



Layout for illustrative purposes, order of instruments up to date but exact locations are not

Bunch charge

- Well-defined 38 mm ICT at the gun
- Potentially one existing Faraday cup after Dipole 1 since no other charge measurement close by
- Another 38 mm ICT either installed in the line if there is space (needed for Coherent synchrotron radiation diagnostic) or used only during commissioning



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Instruments for the proton line

Upstream plasma 1

BPMs:

- Well-defined number and locations
- 19 proton button BPMs up to plasma source 2 (BPM 412346 being the last of the 19)
- In addition the stripline BPMs can also be used for proton position measurements

BTVs:

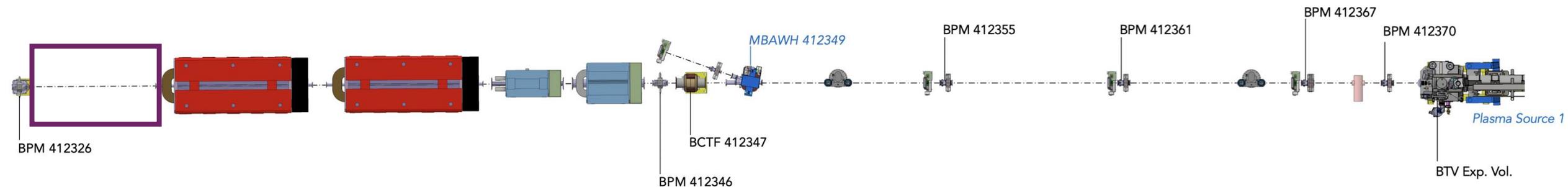
- 2x rotational BTVs for laser and proton alignment into plasma 1, distance between made as large as possible

Charge:

- Keep existing BCTF 412347 before 18 MeV injection dipole

Spectrum:

- Considering EO BPM or Coherent ChDR diagnostic in space before 18 MeV injection dipole – needs further discussions



Summary

Work ongoing:

- Defining diagnostics after plasma source 2
- Use of BLMs to be addressed
- Cabling request to be updated and finalised
- Cameras running scenarios to be defined
- Ongoing discussions on stepper motors

Conclusions:

- Almost full functional specifications for the 18 MeV and common line upstream of plasma 1
- 150 MeV line not yet frozen – end of this year
- Once proposals are agreed by the experiment and institutes, specs will be published
- Revise cost estimation based on changes
- Propose readiness dates for instruments to be installed
- Planning can be updated accordingly

Thank you for your attention!
Questions?



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