Requirements for beam diagnostics for PSB H^- injection system

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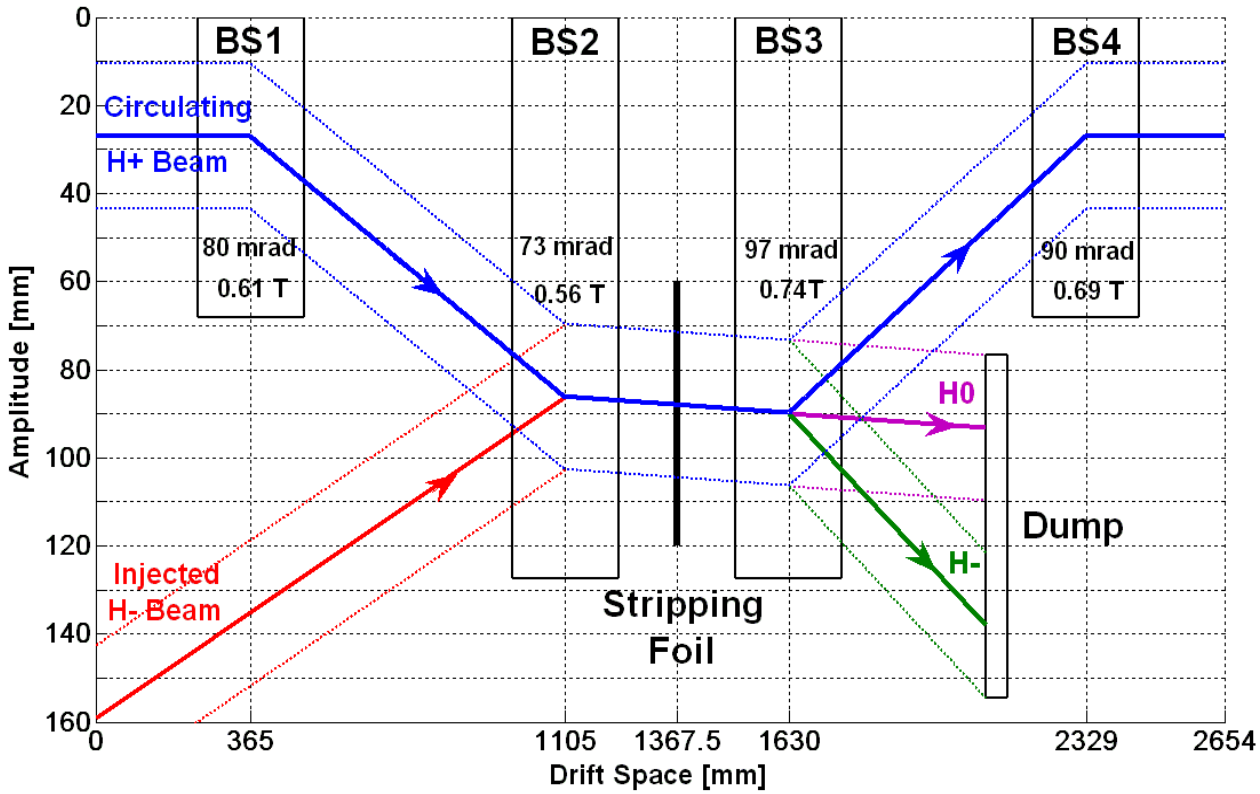
Thanks to several colleagues for input and comments

First iteration for discussion!

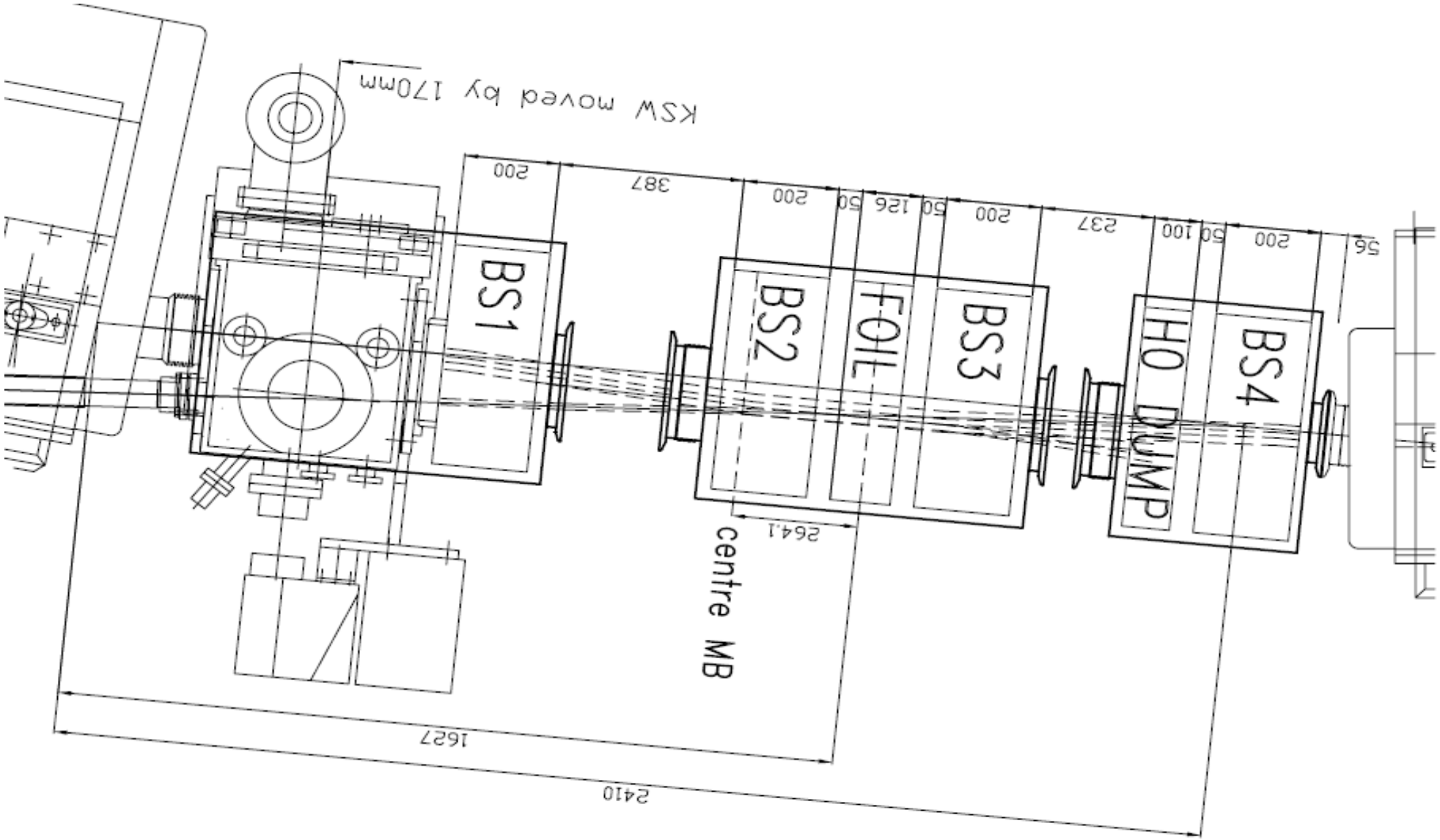
The injection process and elements

- *Two independent closed orbit bump systems:*
  - *Injection Chicane, 4 pulsed dipole magnets (BS), located in the injection region, giving 60 mm beam offset during the injection process.*
  - *Painting Bump, 4 horizontal kickers (KSW), located outside the injection region, giving 27 mm closed orbit bump with falling amplitude over the injection process for transverse phase space painting.*



- *BS1 must act as septum.*
- *BS4 adjacent to internal Dump.*
- *Stripping efficiency of ~98%.*

Overview of injection region



Assumptions on injection setting up/operation

- Injected beam size (1σ) is about 2 mm.
- Foil position can be adjusted in the horizontal plane by several (~10?) mm.
- Beam position and angle can be adjusted at the foil (DVT/DHZs in BI line).
- Chicane bump and KSW bump amplitudes and closure can be adjusted.
- Foil size about $\pm 4\ \sigma_x$: 16 mm for $D_x = 0$ (additional 20 mm for $D_x = -1.5$ m).
- Maximum injection per turn is $4\ 10^{13}$ /100 or $4\ 10^{11}$ p+
- A “commissioning” beam would be reduced intensity for 1,2,… turns – could imagine $2\ 10^{11}$ p+ / turn (OK for Linac4?).
  - Something for commissioning WG?

Parameters to be monitored

Injection efficiency	← BCTs?
Beam position and size on the foil (H+V)	← Foil camera
Beam position/size upstream of BS1 (H+V)	← SEM grids
Beam position/size at H^0/H^- dump (H^0, H^- and p+)	← SEM grids
Foil temperature	← Foil camera
Beam losses at aperture limits (BS1, H^0/H^- dump, foil)	← BLMs
Beam losses from foil scattering	← BLMs
Stripping efficiency	← BCT + dump current
BS and KSW bump closure	← Ring ε / BPMs?
Emittance of injected beam after filamentation	← Ring ε monitor
Beam “current” at H^0/H^- dump?	← Dump current?
Stripped electron current?	← e- current monitor?
Injected beam orbit?	← 352 MHz BPM?

Beam loss monitors

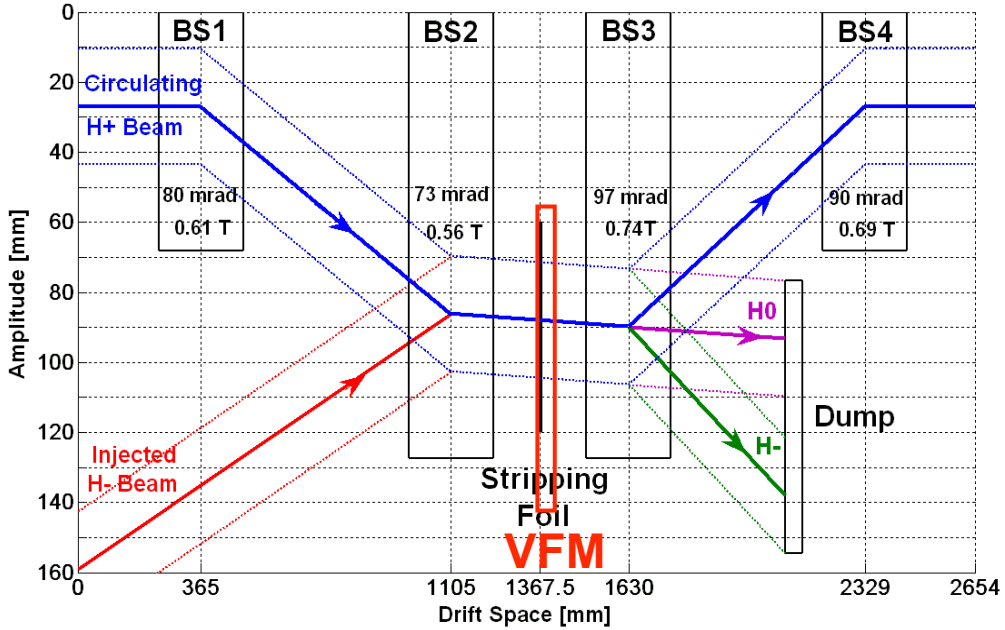
- Need temporal resolution for loss at injection and subsequent turns
  - Time resolution <= 500 ns (gives 2.4 M samples for full 1.2 s cycle!)
  - Should be possible to PostMortem entire BLM buffer if required
  - Systematic logging of first 1 ms (2 k samples) at 500 ns and full cycle at 1 ms (1.2 k samples)
- Sensitivity limits:
  - Largest loss: 4 10^{13} 160 MeV p+ in 1 turn
  - Smallest loss: would like to resolve few % of losses on 1 turn → 10^{10} p+
- Interlocking and thresholds
  - No need to make ‘fast’ reaction to stop Linac4 pulse (?)
  - Cut next injection if integrated losses above threshold…
  - Do losses on one ring act on the interlocking of other rings?

Beam position monitors (pick ups)

- Assume that beam pickups in BI line are kept
  - Any performance upgrades needed/required for modified injection parameters (beam size, intensity, bunch structure?)
- Should check that trajectory correction is still OK with ‘new’ injection steering layout with displaced BHZ/DVT magnets
  - assume that this is not an issue as these correctors are so downstream
- Idea of a 352 MHz resonant pickup for the PSB ring
  - Measure injected bunches with linac4 beam structure on first turns
  - Or can chop lower-frequency structure into beam – may allow to measure bump closure by multi-turn acquisition

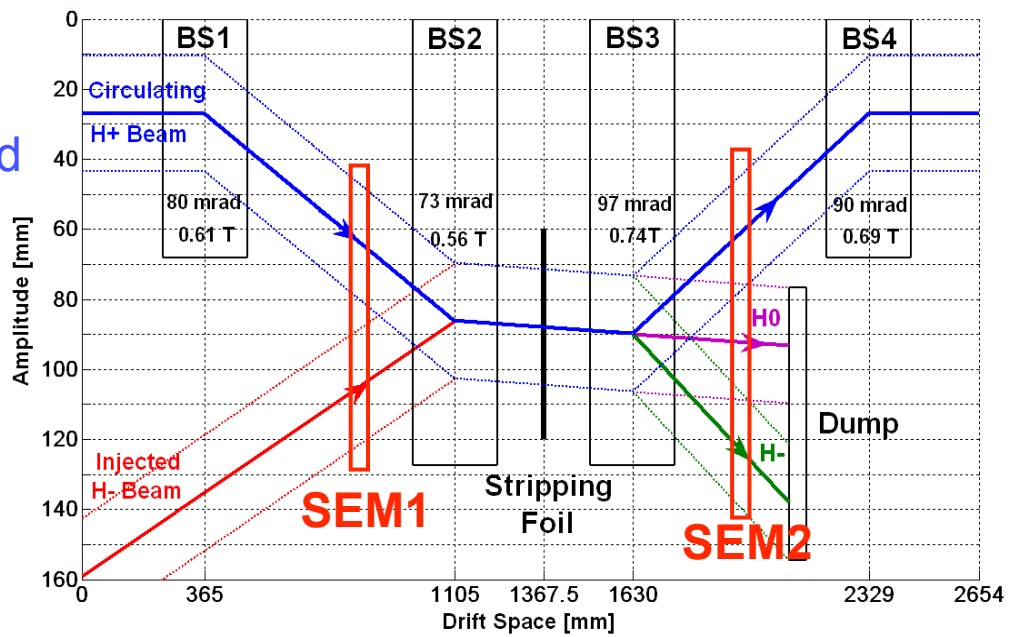
Video foil monitoring

- Collect light emitted from foil (thermal, luminescence, OTR?)
- Video foil monitor to record beam profile/position on stripping foil
  - H and V profiles and positions, plus 2D image (frame grabber)
  - Information about foil condition
  - Foil exchanger to contain one luminescent screen ‘position’
    - Position ±1 mm, resolution ±0.5 mm (Gaussian fit). Width 10% / 5%
  - Single shot acquisition
  - Intensity 1e11 → 4e13 @1.1Hz
  - Lamp to illuminate screen/foil
  - To measure H^- and p+
  - Radiation hardness of camera?
  - Integration issues…?
  - Implications for foil (45° angle) ?



Beam profile/position monitors (grids and screens)

- SEM grids possible in locations SEM1 and SEM2 between chicane dipoles
  - Measure beam position, size and distribution in H and V (also HV?)
  - Position accuracy ±1 mm, position resolution ±0.5 mm (Gaussian fit).
  - Width accuracy 10%, width resolution 5% (ditto)
  - To work for both H^- and p+ beams (different SE characteristics?)
  - Single shot acquisition – plus multiturn for matching?
  - Intensity 1e11 → 4e13 @1.1Hz
  - SEM1 to monitor H^- but also p+ from first turn (issues of damage limits and protection?)
  - SEM2 to monitor unstripped H^-, unstripped H^0 and stripped p+
    - Does it work for H^0???
  - Size ~100 mm x 50 mm
  - Retractable….

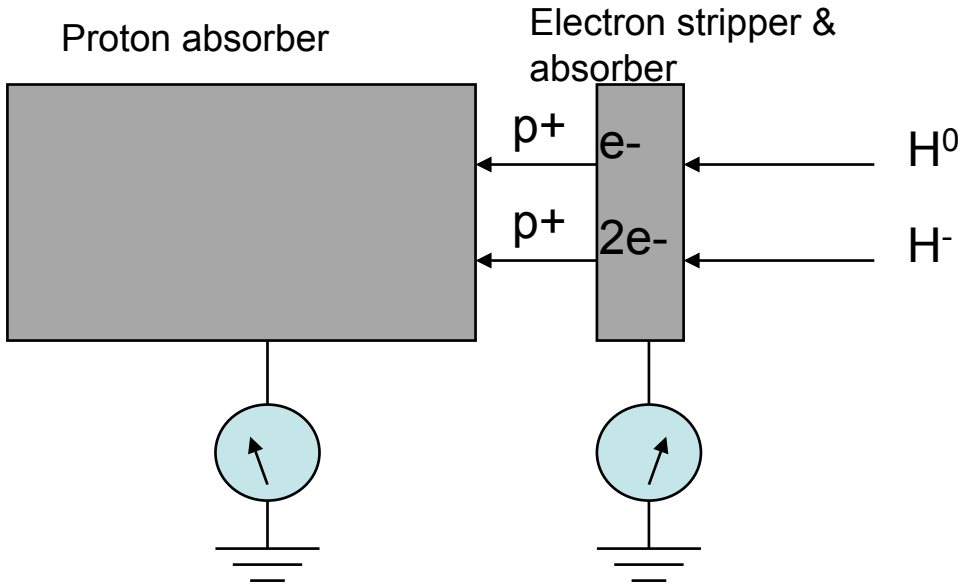


SEMs in injection straight

- If Video Foil Monitor is feasible do we need SEM grids in injection straight?
  - Pros
    - Measure beam position and size with good accuracy – tuning of injection line and characterisation of injected beam
    - Can get some measure of foil efficiency if SEM can measure 2% of H^0
    - More diagnostics and information for injection setting up
  - Cons
    - May be lots of interference from losses, electrons, … in this region
    - Beam position and size can be obtained from screen in VFM
    - Very difficult to integrate these devices here…
  - Maybe just use SEM2 position – but most difficult location for space
  - Matching monitor can be ‘anywhere’ in PSB

H^0/H^- Dump monitoring

- Would be extremely useful to monitor intensity on H^0/H^- dump
  - During setting up without any foil – 100% of injected intensity
  - During operation of H^0/H^- intensity to monitor stripping inefficiency
  - Faraday cup + dump functionality combined….
  - Large dynamic range - should measure 4e13 p+ to 1e10 H^0 (!)
  - Any way to distinguish H^- from H^0 ?? (measure total charge?)
  - Careful about impact on dump design (insulation, thermal load, …)



BCTs

- Need to monitor injection efficiency - using BI line and ring BCTs?
- Important for monitoring foil condition and detecting changes
- With nominal current absolute calibration to within 5%. Feasible?
- Need to detect efficiency change of 1% (aiming for 98% stripping efficiency, with maybe 2% beam missing foil). Feasible?
- Would like to have time-history within the 100 us injection pulse at ~10 MHz
  - What is the time resolution possible?
  - Assume this will be in a PM mode only (large data rate)
- Minimum requirement is turn-by-turn readout of intensity during injection process
  - Would be better to have 10 MHz or even better
- BI line BCT and ring BCT should be synched to correlate injected turns

- Can BCTs provide this accuracy???

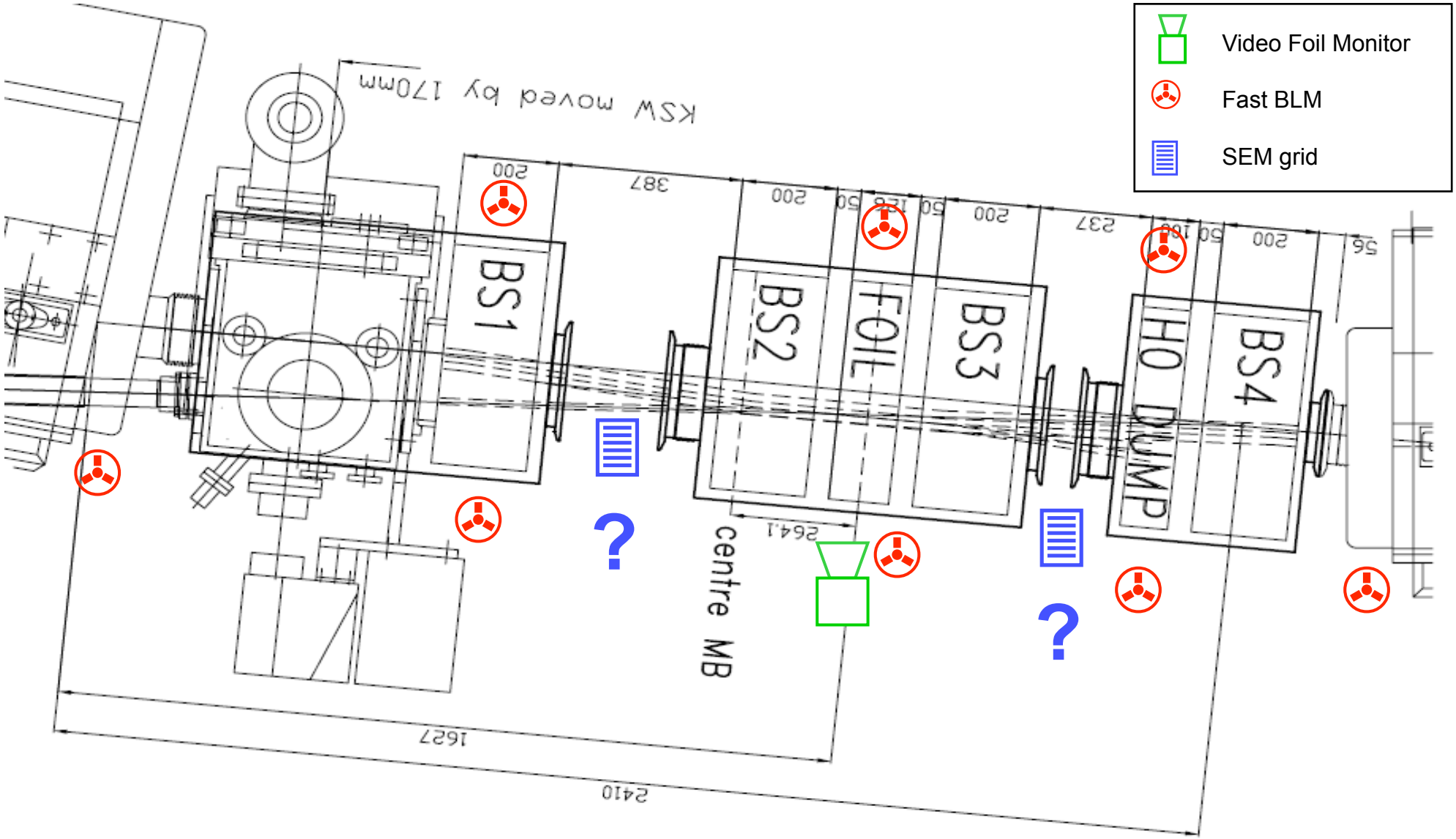
Emittance measurement

- For optimisation of injection painting must measure beam emittance after filamentation
- Also for optimisation of KSW and BS bump closure (using single turn and matched injection trajectory)
  - LHC beam is 2 π.mm.mrad per plane
  - Would like absolute measurement to within 0.2-0.3 π.mm.mrad
  - Resolution of 5 % to see effects of modifying painting
- Expect beam sizes of about 2-3 mm (1 σ) in PSB with injection mismatch.
- Are existing tools adequate?

Instruments at critical locations in BI line

- Fast BLMs at the BI.DIS and BI.SMV units

Inventory


Video Foil Monitor
Fast BLM
SEM grid
KSW moved by 170mm
BS1
BS2
FOIL
BS3
HO DUMP
BS4
centre MB
?
?
200
387
200
128
50
50
200
237
50
100
200
56
2641
1627
2410

Concluding remarks

- Fast BLMs with PM buffers and sub us time resolution seem essential
- Is there a fast interlocking system to cut Linac4 *during* injection process?
  - losses during injection over threshold, BI.DIS malfunctions, foil failure, …
- Does the longitudinal painting need any other special diagnostics?
- SEM grids in injection straight will be very tricky – really needed?
  - Limited space, mechanical considerations, movements to retract, …
  - Different responses for H^-,H^0 and p+?
  - Dynamic range between full injected H^- to 2% unstripped H^0
  - Protection from circulating beam, …
- Video Foil Monitor may be even trickier
  - Less space
  - Integrate with foil exchange module
  - Radiation hard camera
  - Low foil temperature – any light to see?

Next steps

- Organise a more general discussion with all concerned
- Agree inventory of required functionalities, observables, possible instruments and required performance
- Issue specification documents