Beam Loss Scenarios Review for BLM Simulations

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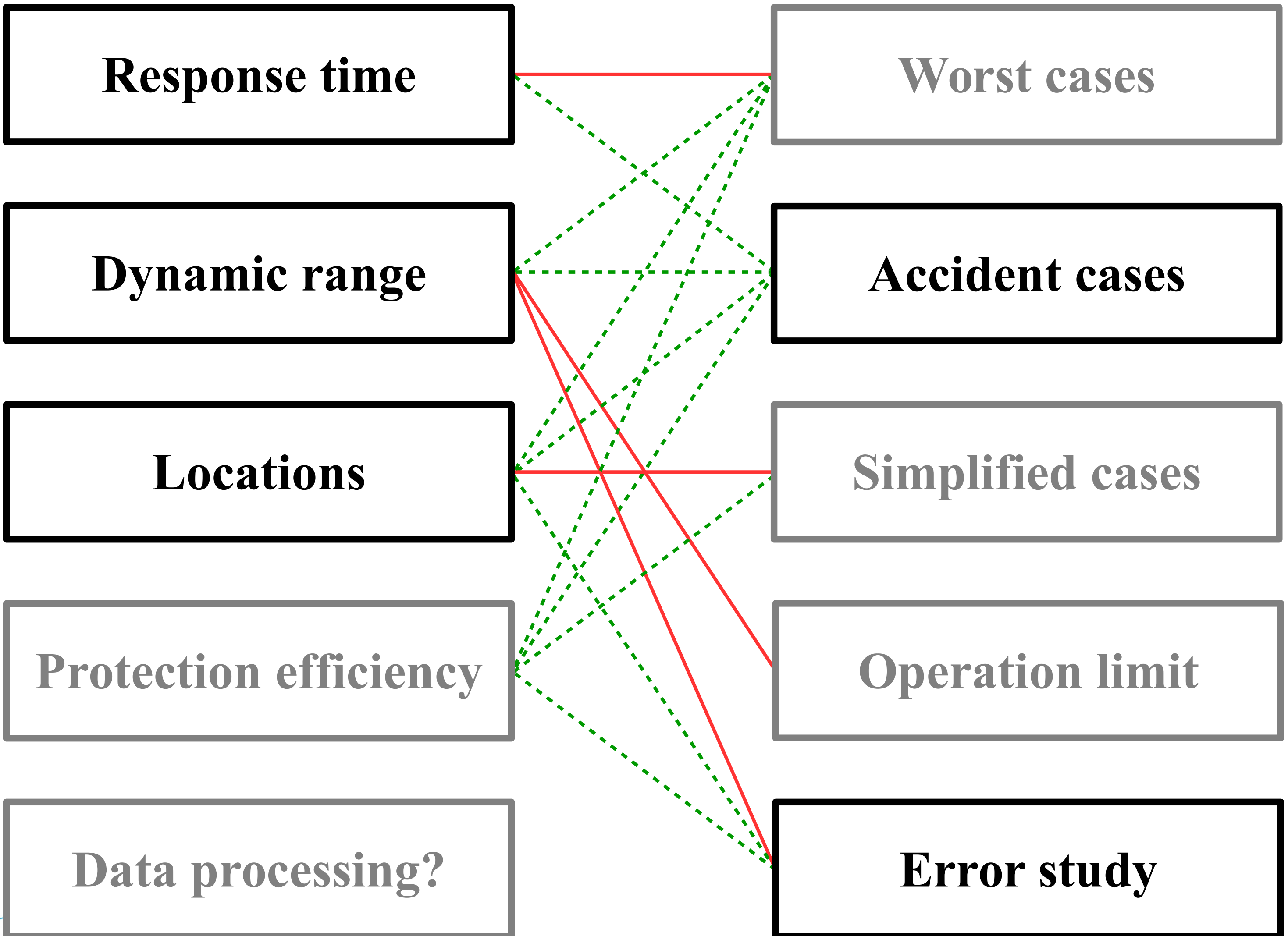
PDR of nBLM+IC

Simplified view of BLM simulation set-up

BD determines/evaluates — **Loss scenarios**



Worst cases:
- Perpendicular hit
- Worst trajectory/angle
- ...

Accident cases:
- Complete failure
- Magnet/cavity decay

Simplified cases:
- Selected range of locations, angle, energy

Operation limit:
- 1 W/m uniform, 1 mrad

Error study:
- Yngve's at HB16

Ref: ESS-0066428

Outline

- Simplified view of BLM simulation set-up
- Level-4 requirements
- Review of Loss Scenarios
- Discussions

Level-4 requirements relevant for BLMs

Type	Description
XXX beam loss measurement	The beam loss shall be measured in the XXX section.
XXX beam loss measurement	A beam current loss of 10 mW/m shall be detected.
XXX PBI peak current range	Proton beam instrumentation in the XXX section shall function over a peak beam current range of 3 mA to 65 mA.
XXX PBI pulse length range	Proton beam instrumentation in the XXX section shall function over a proton beam pulse length range of 5 µs to 2.980 ms.
XXX PBI pulse-by-pulse measurement update rate	Unless specifically stated, all instrumentation shall be able to perform the measurements and report the relevant PV data at a repetition rate of 14 Hz.
XXX PBI damaging beam detection and mitigation	Beam conditions that are potentially damaging to machine components shall be detected by the instrumentation and reported fast enough so that the conditions can be mitigated before damage occurs.

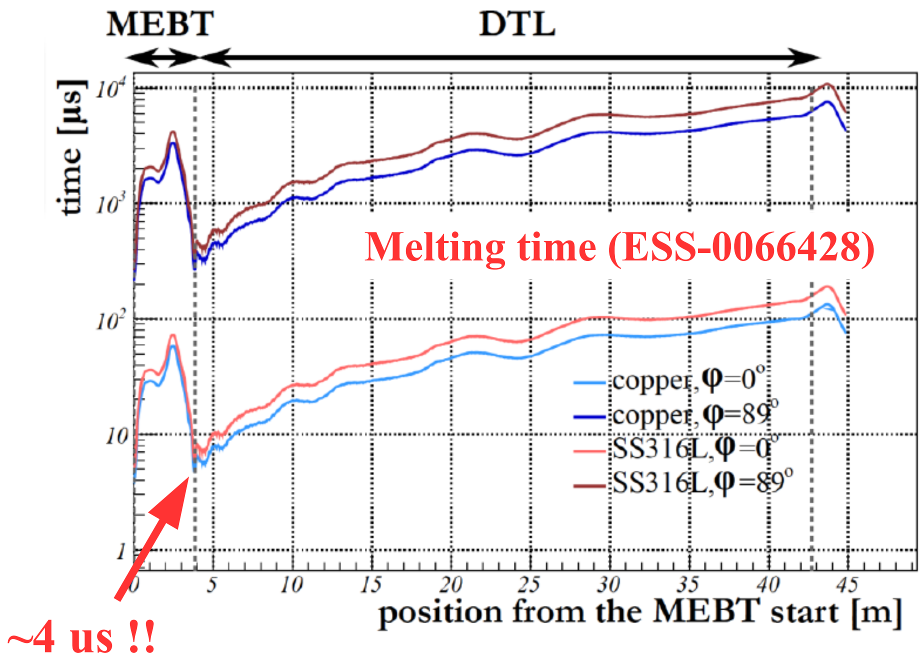
- We want to discuss about the sampling (like the cases of BCMs and BPMs).
  - Can we sample or gate within one pulse? (Let's say every 50-100 us?)
  - Can we look at the leading edge of the pulse? (First 1-10 us?)
  - Just the matter of the fast vs slow modules?

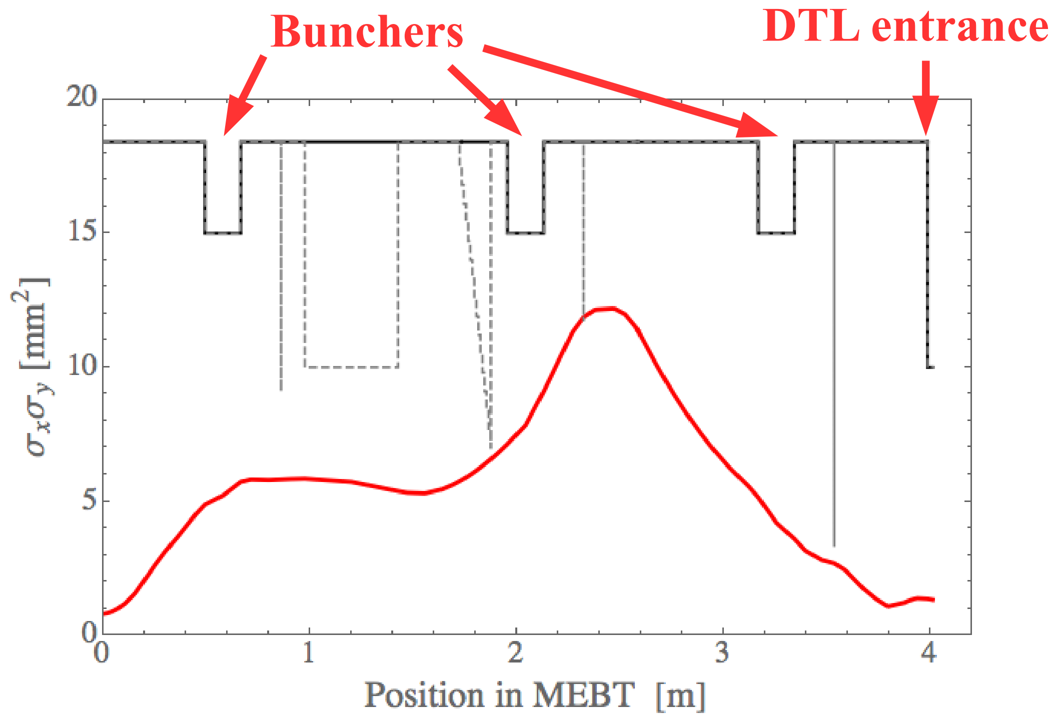
Level-4 requirements on the energy range

Type	Description
MEBT PBI energy range	Proton beam instrumentation in the MEBT section shall function over a proton beam energy range of 3.0 MeV - 3.8 MeV.
DTL PBI energy range	Proton beam instrumentation in the DTL section shall function over a proton beam energy range of 3.0 MeV - 95 MeV.
SPK PBI energy range	Proton beam instrumentation in the SPK section shall function over a proton beam energy range of 75 MeV - 230 MeV.
MBL PBI energy range	Proton beam instrumentation in the MBL section shall function over a proton beam energy range of 75 MeV - 600 MeV.
HBL PBI energy range	Proton beam instrumentation in the HBL section shall fulfil the requirements for a proton beam energy in the range of 75 MeV - 2100 MeV.
HEBT PBI energy range	Proton beam instrumentation in the HEBT section shall fulfil the requirements for a proton beam energy in the range of 75 MeV - 2100 MeV.
A2T PBI energy range	Proton beam instrumentation in the A2T section shall function over a proton beam energy in the range of 180 MeV - 2100 MeV.

- Beam physics should double check the lower limit for SCL.
  - Error study indicated that lost particles in SPK (initial part) are mostly between 3.6 MeV (RFQ) and 21 MeV (DTL1).
  - Error study showed a clear cut of ~216 MeV for the losses in MBL and HBL.

Worst cases (1)

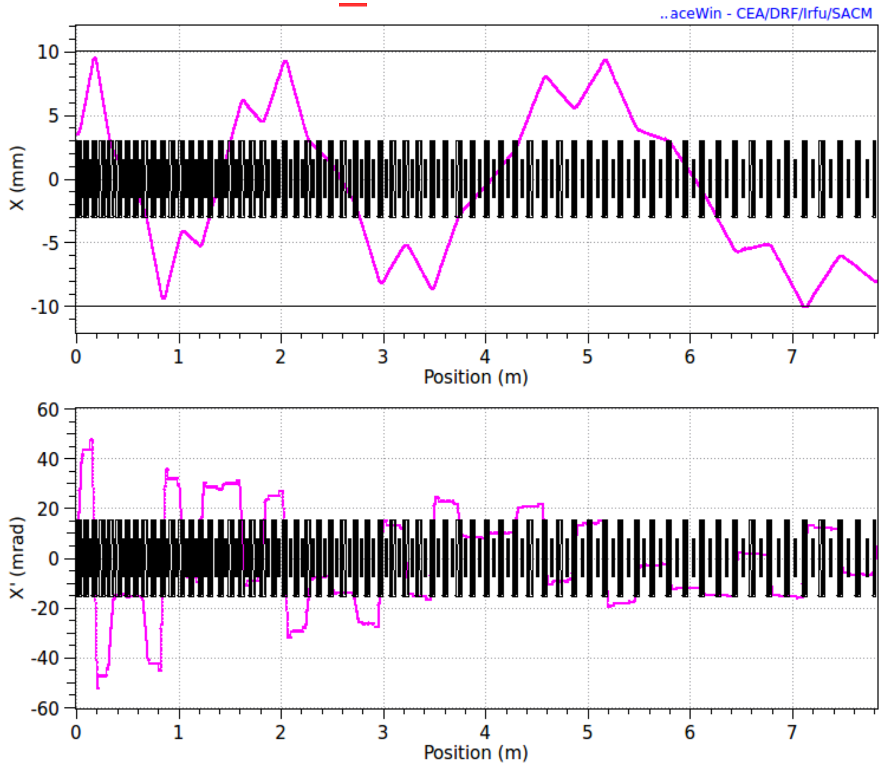




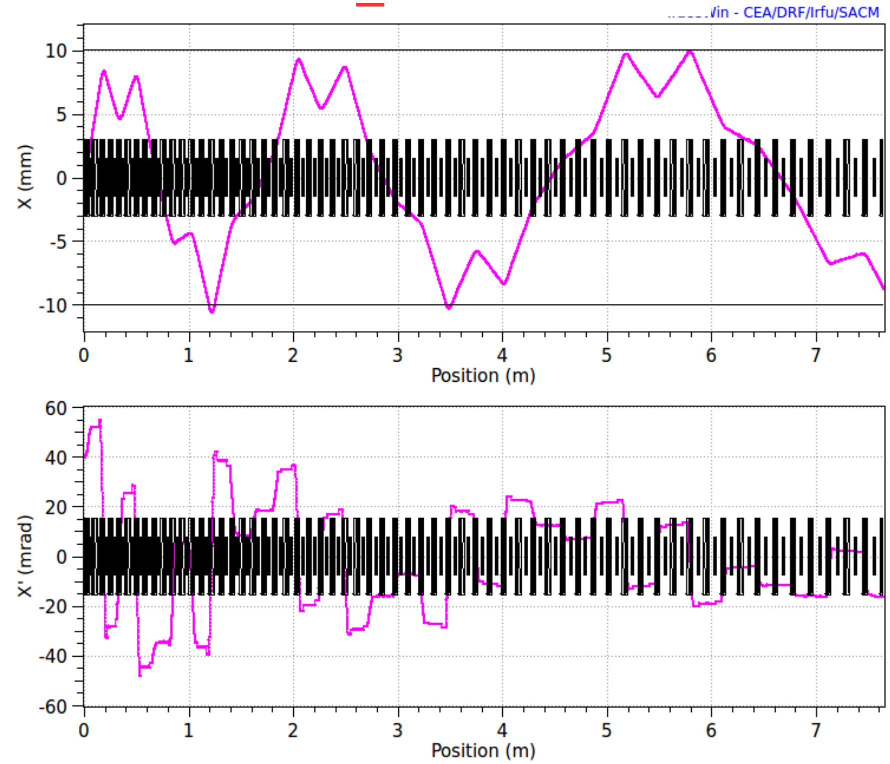
- Perpendicular hit scenario has been used to define the response time.
- We may want to sit down and discuss how to approach this, again.
  - For DTL, perpendicular hits are (practically) impossible in terms of geometry.
  - For MEBT, it could occur at bunchers, collimators, diag box, and DTL entrance but the ~4 us level melting has a “chance” only for the DTL entrance.
    - Collimator 3 is out and the steerer in Q6 is at max.
    - The steerers in Q8-11 are adjusted. (Still ~50% is lost to the 3rd collimator.)

Worst case (2)

$x\_ini = 3.5$ mm

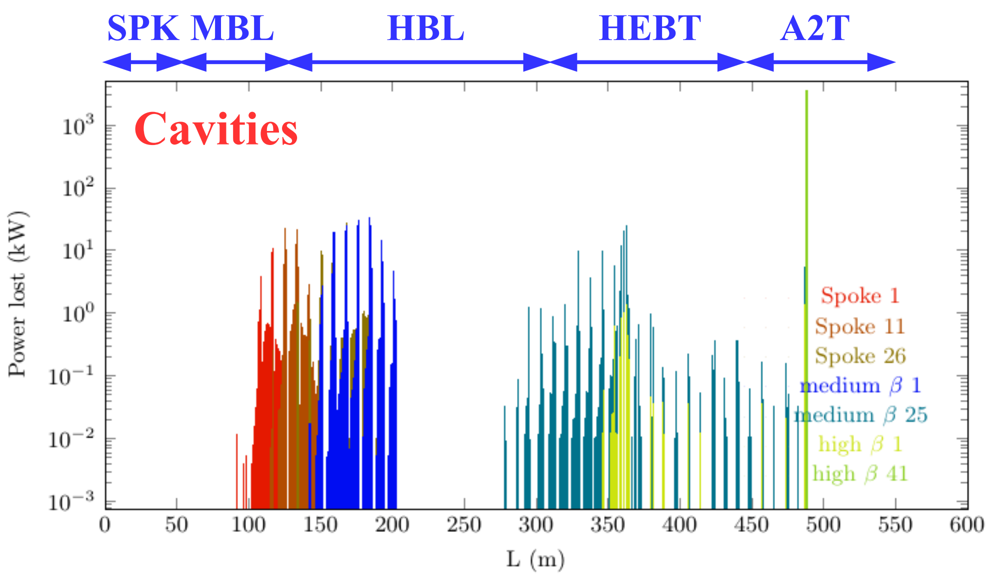


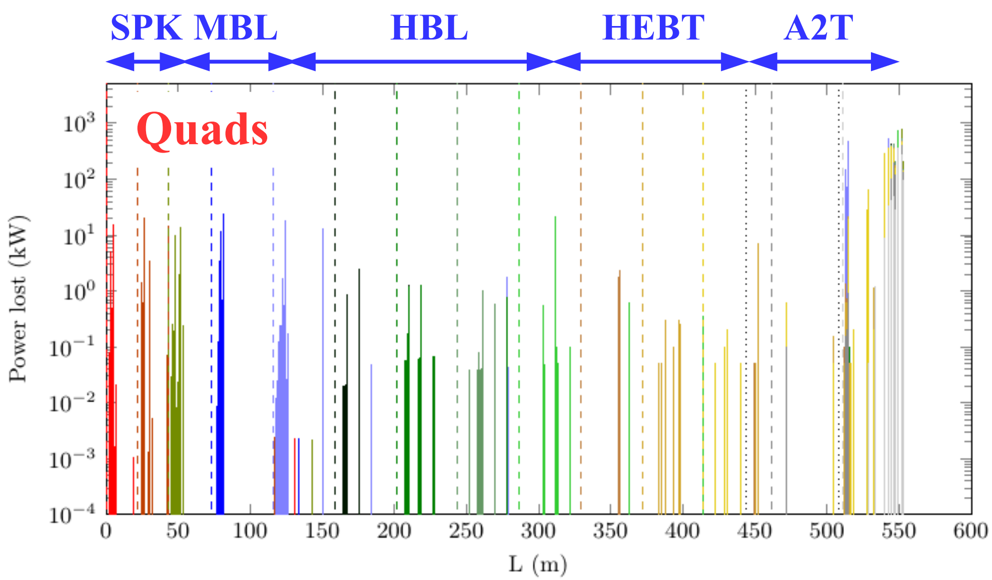
$x'\_ini = 40$ mrad



- The worst angle for a section was estimated with a simplified (acceptance) test.
- The result was also used as an input to the study of the DTL detector locations.
- We may want to be careful with some locations, e.g., the initial part of DTL1.
- Beam physics should update this with a more proper acceptance study?

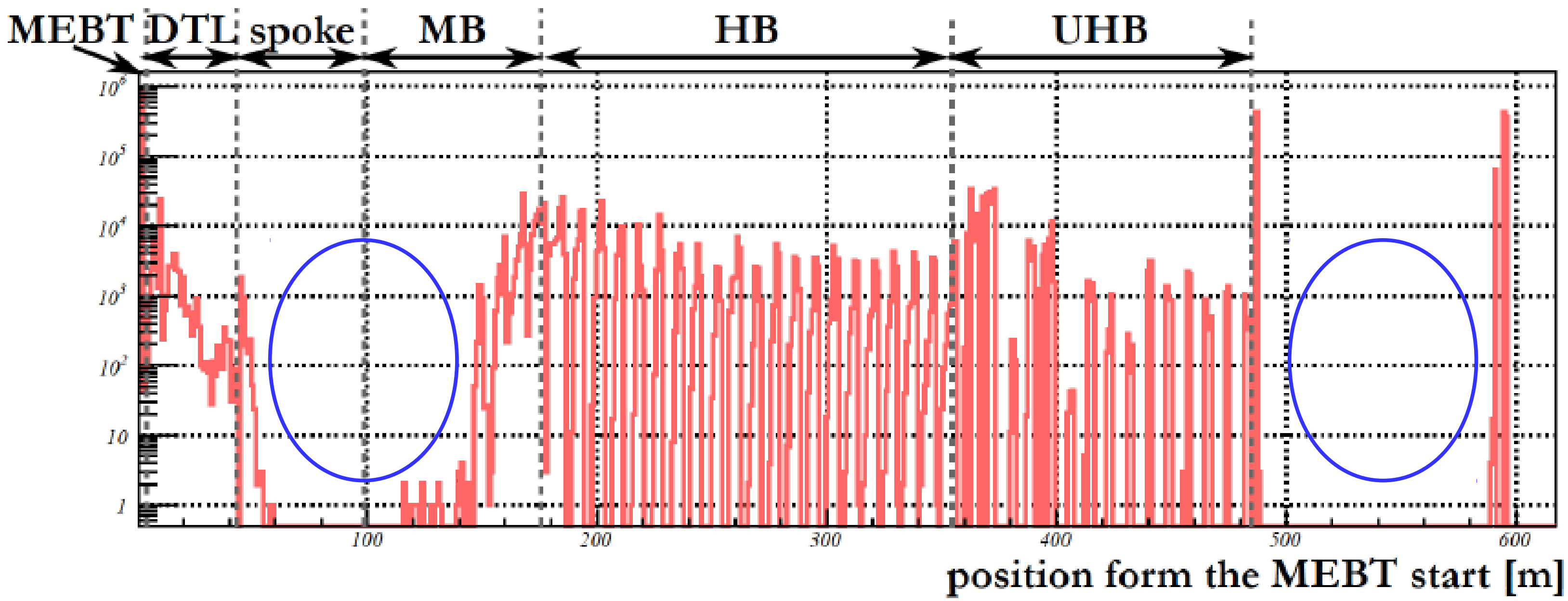
Accident cases





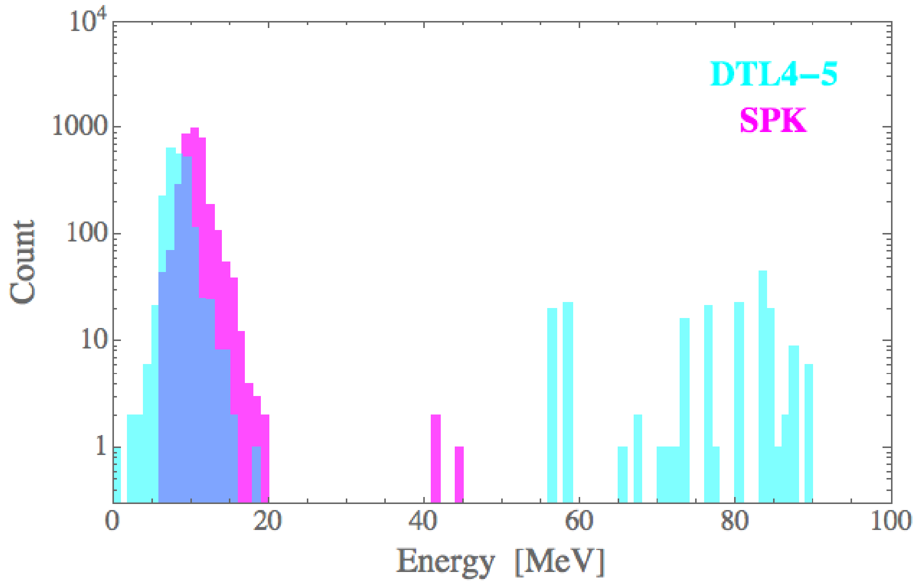
- Accident cases fully used, yet?
- Complete failure of a cavity or quad was studied (ESS-0031413).
  - The study is for the failure between two pulses.
  - The study also provides some ideas for loss patterns.
    - Losses due to a **cavity** failure are spread **over tens of meters** and appear much **later**.
    - Losses due to a **quad** failure is **localized to meters**. Immediate or not depends on the case.
  - Beam physics can go back and look at the "local pattern", e.g., LWU vs cryomodule.
- Study on the transient cases on-going...
  - This is a complex problem involving many parties, e.g., MPS has been collecting the decay times. An improved coordination may be needed.

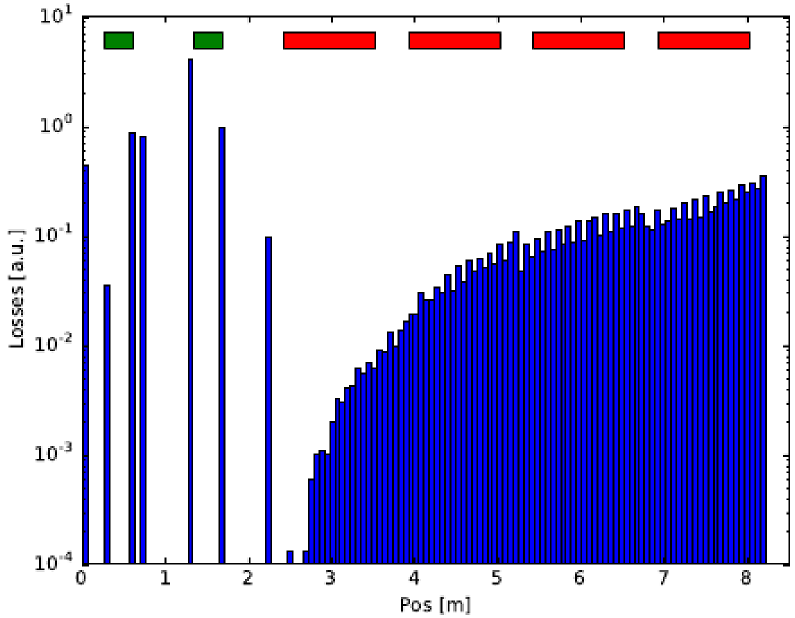
Error study (1)

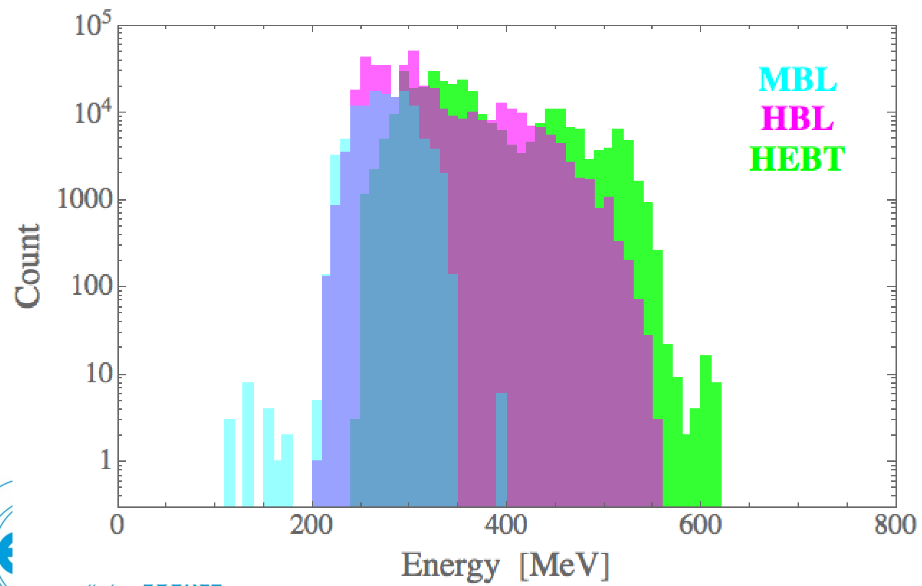


- An error study with large statistics was performed in 2015 (HB16, TUAM3Y01).
  - 10k linacs with 600k particles.
  - Dynamic error increased (200%) to "produce" losses.
- The result was used to study the lower limit of the detector's dynamics range.
- By design, the linac is robust against the anticipated errors around the nominal setting.
  - Despite the large statistics, the error study only covers several cases and thus only shows the most vulnerable aspects of the linac.
  - The pattern may be still worth to look (like the case of the failure study) but the system of BLMs should cover a much larger set of cases.

Error study (2)







- Two vulnerable points are the longitudinal capturing at the MEBT-DTL and SPK-MEL interfaces.
- We can take further close loot at the patterns but, at the same time, don't want to focus too much on the specific cases.

Simplified and operation limit cases

- Simplified case
  - Used for the study on the detector's sensitivity vs location.
  - Conditions:
    - Selected location
    - Angle from ~2 mrad to the worst estimated
    - Energy from the min anticipated to the nominal of the location
- Operation limit case
  - Used for the study on the dynamic range.
  - Conditions:
    - 1 W/m uniform (upward) throughout the considered part
    - 1 mrad
    - Energy of the location
- The assumptions of these cases seem reasonable. But, beam physics may be able to provide slightly more realistic inputs by a proper acceptance study...

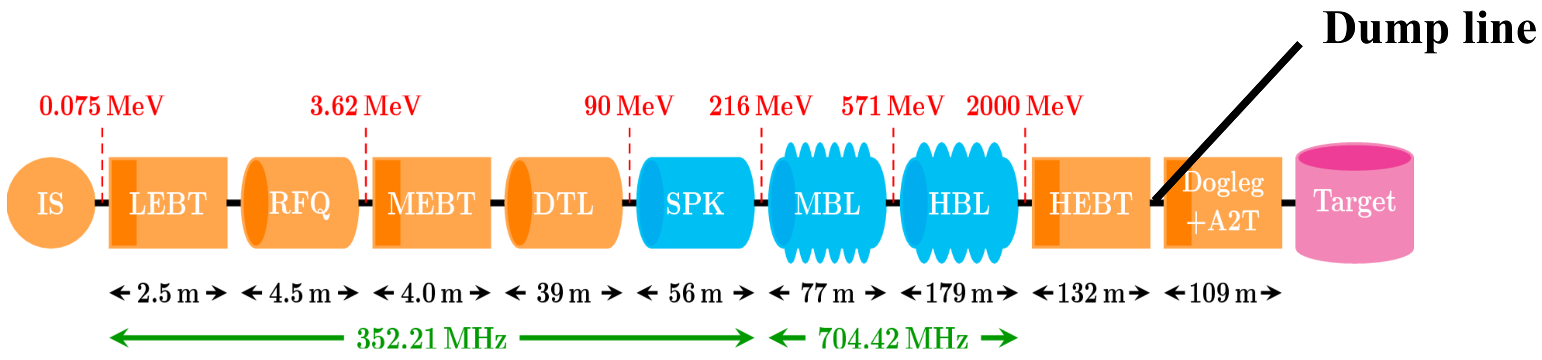
Comments and possible future works

- MEBT and DTL1
  - There was mentioning of nBLMs near the MEBT collimators but enough neutrons produced from ~0.5% of the beam hitting TZM?
  - There are some well know possible loss locations.
    - MEBT chopper entrance and exit.
    - MEBT Q6.
    - Between BPM pairs in DTL1.
    - ~4 m from the DTL1 entrance during the phase scan.
- The worst case, simplified case, and the operation limit case MAY BE replaced and improved by a proper acceptance study.
  - The idea is to observe the loss patterns of the particles on the "surface" of the 6D acceptance.
  - This, in theory, allows to separate the scenarios and physically possible patterns.
  - This could end up as a mini-campaign of an acceptance study so the issue is as usual the resource...

Thanks!

And, time for discussions.

Temporary and permanent beam stops



Location	Mode	Limits
LEBT (exit)	Temporary	1 Hz
LEBT (between the solenoids)	Permanent	N/A
MEBT (before the final quadruplet)	Permanent	(5 us, 14 Hz), (50 us, 1 Hz)
DTL (tank 2 exit)	Permanent	(5 us, 14 Hz), (50 us, 1 Hz)
DTL (tank 4 exit)	Permanent	(5 us, 14 Hz), (50 us, 1 Hz)
Spokes (doublet #1)	Permanent	(5 us, 14 Hz), (50 us, 1 Hz)
Medium-β (doublet #6)	Permanent	(5 us, 14 Hz), (50 us, 1 Hz)
Dump line	Permanent	(5 us, 14 Hz), (50 us, 1 Hz), 12 kW*
Target	Permanent	N/A

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