First TPSWA test results

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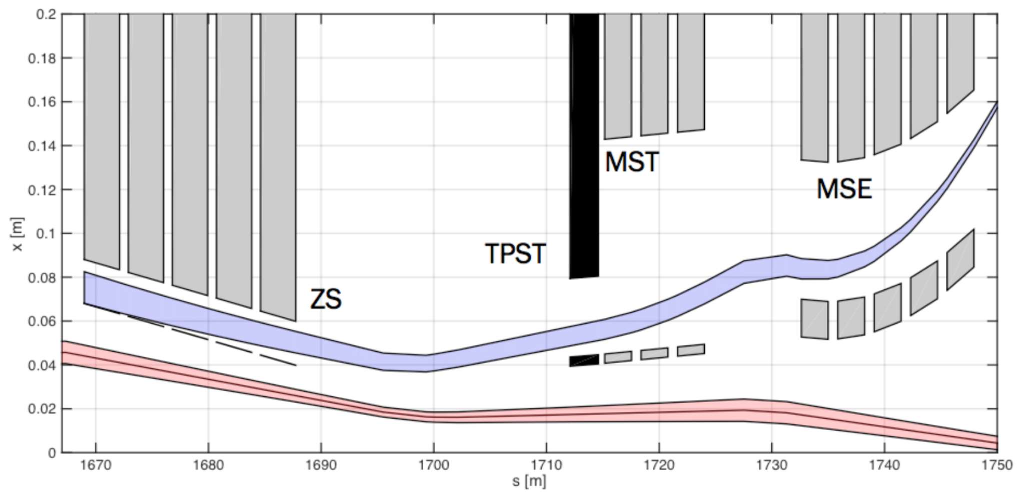
Slow extraction

- Sextupoles at 1/3 integer horizontal tune drive resonant amplitude growth
- Extraction is initiated by a very thin electrostatic septum
- Activation due to beam impacting the ZS wires limits the amount of beam that could be delivered to future experiments, so loss reduction is a hot topic (SLAWG)



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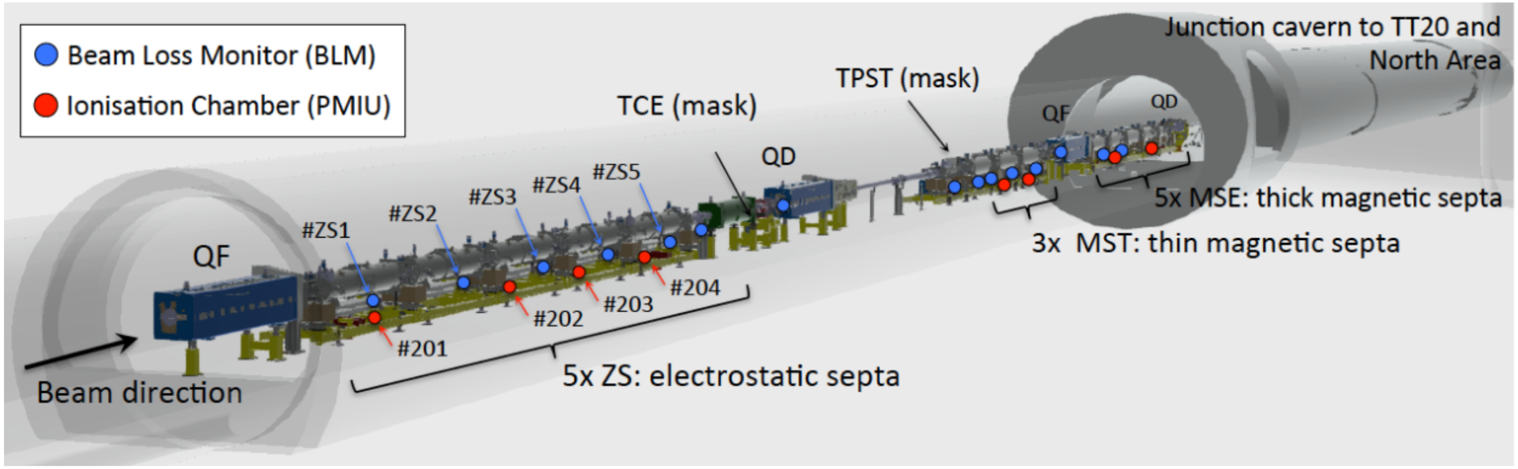
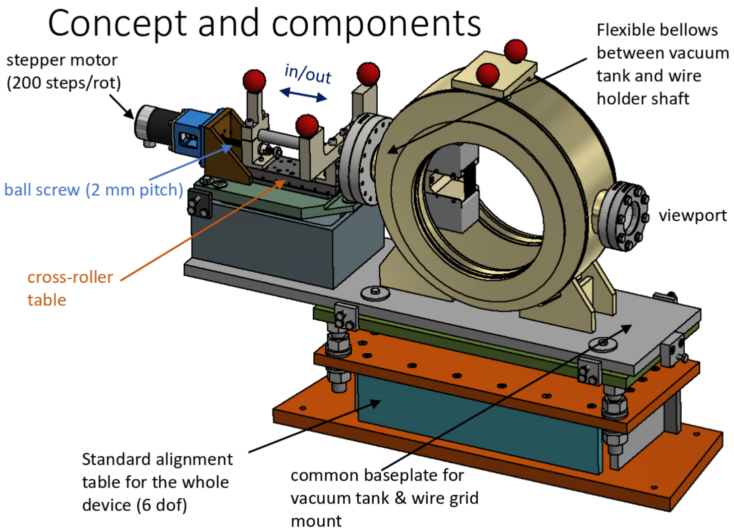
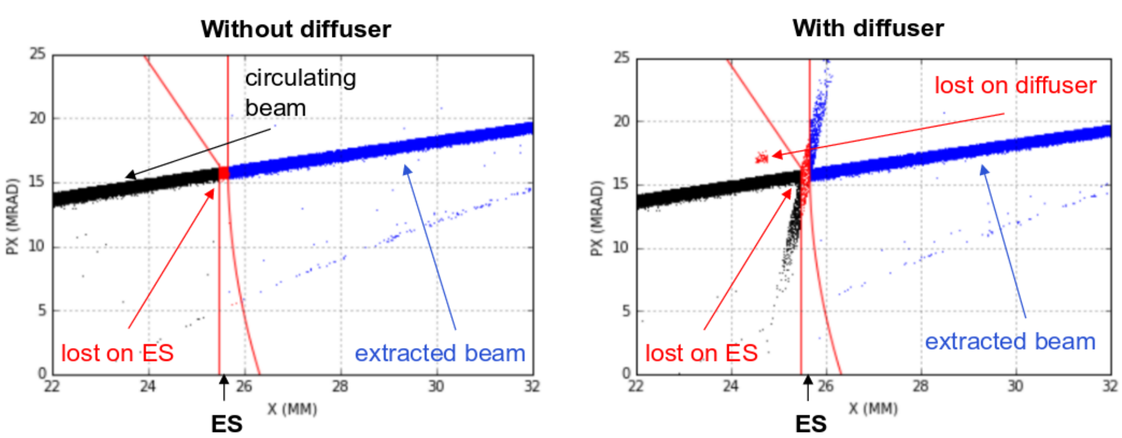


Diffuser (TPSWA)

- Short wire array upstream of the ZS to 'cut' (scatter) the beam, installed at the start of 2018.
- Out of the beam by default, loss-based alignment during MDs





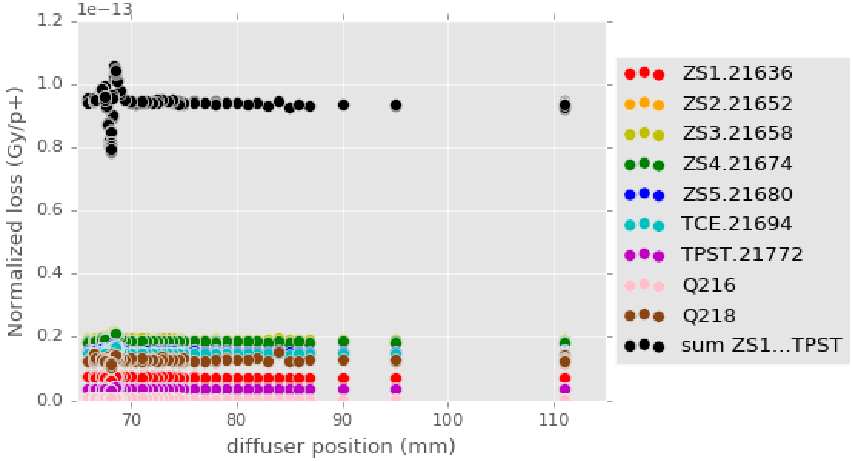
Courtesy D. Barna

Simulation efforts

- Different codes to be benchmarked against each other:
  - MAD-X + pycollimate (detailed, but heavy)
  - Python code with phase space rotation, 4 thin sextupole kicks and an independent monte-carlo scattering routine (faster)
  - FLUKA model of extraction region, with input distribution from MAD-X and new user routine for multiturn-effect of recirculating scattered particles from MAD-X twiss files (very heavy, but allows modelling actual BLM signal)

First test - 5 April

- Smooth test, clear results from BLM loss per p+



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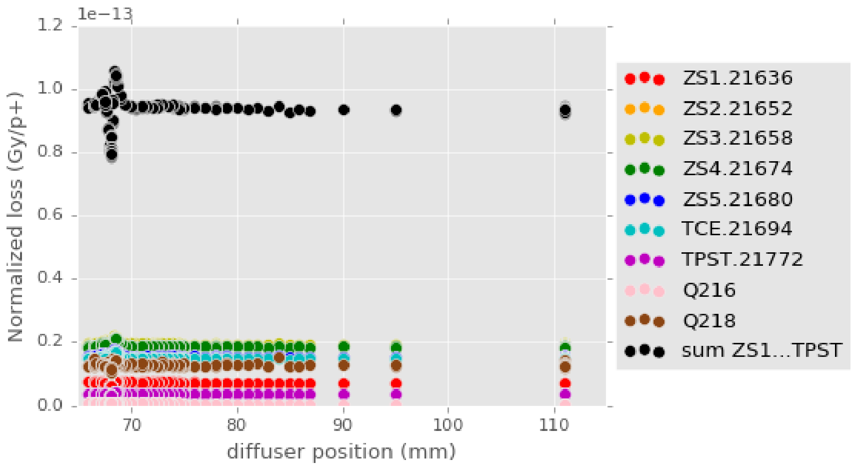

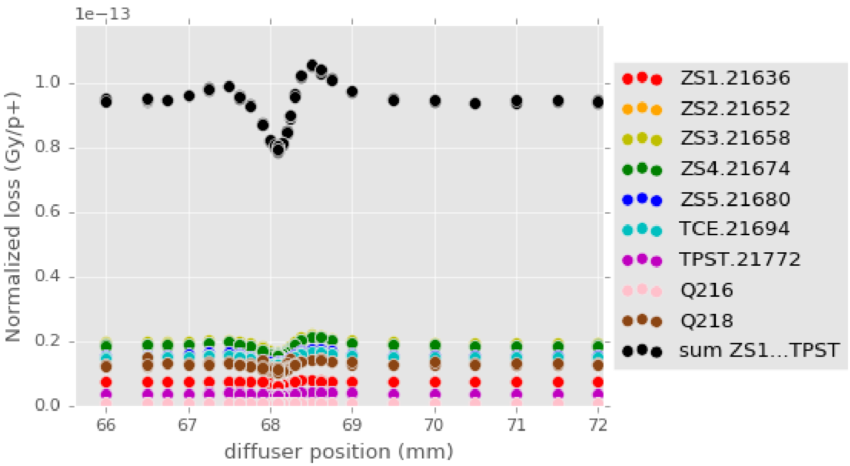

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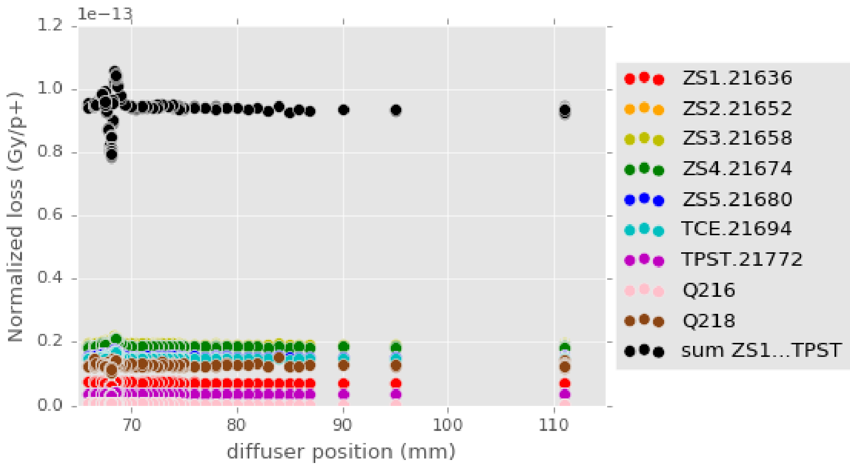
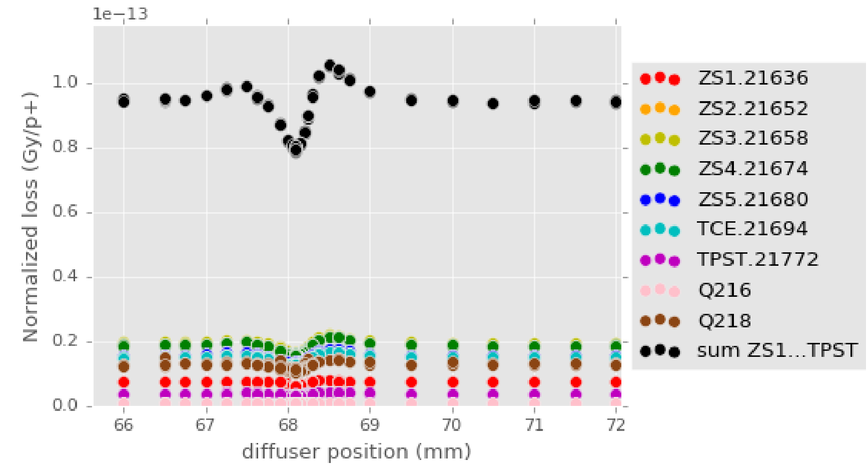
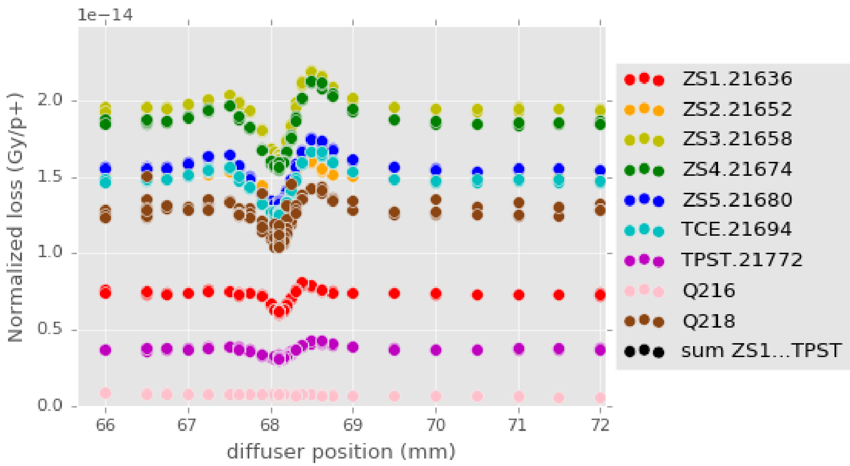
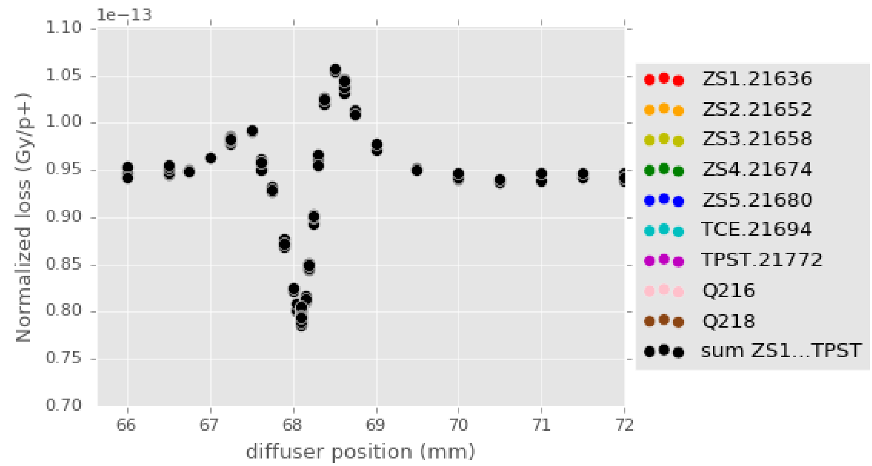


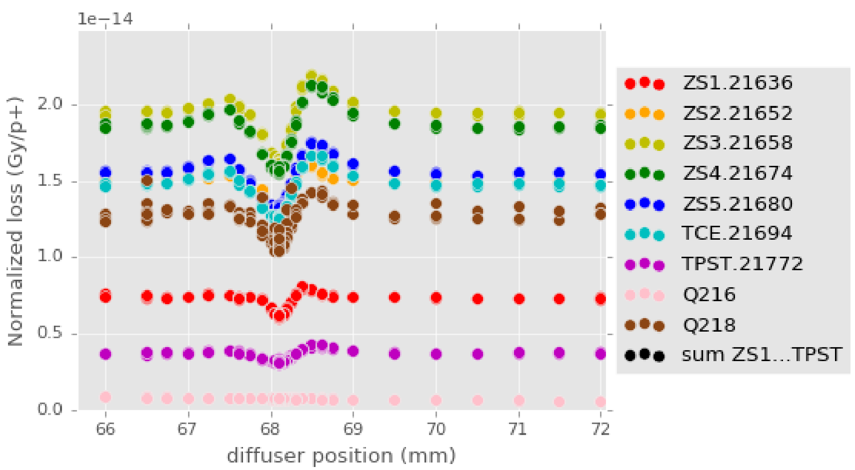


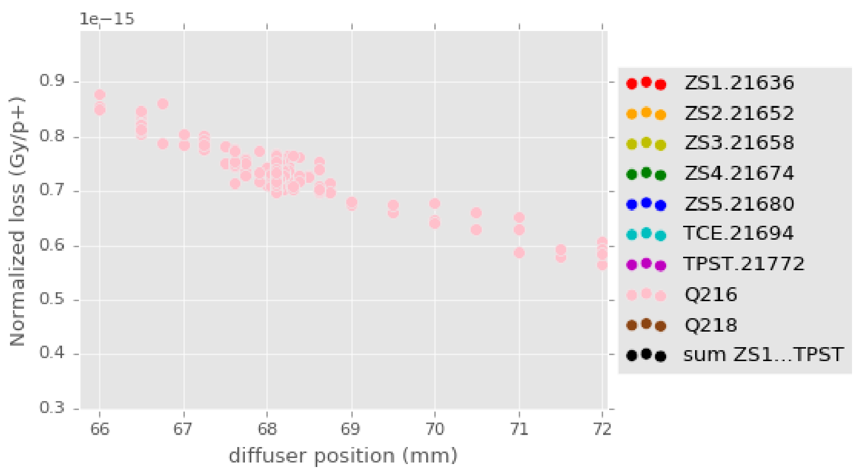




First test - 5 April

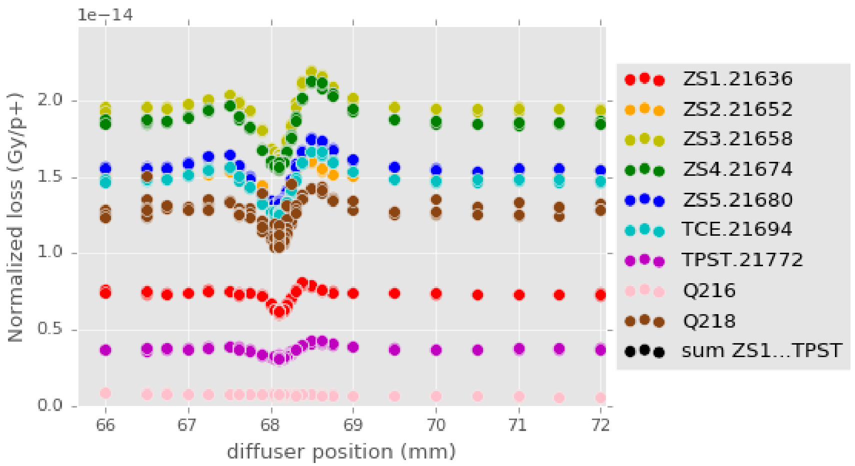
- Smooth test, clear results from BLM loss per p+
- Similar behaviour on all BLMs in the region, except 216
- BLM216 sees losses due to the diffuser, proportional to beam density.
- Negligible loss increase compared to gain elsewhere
  - TED in; transport to target tbc in future MD

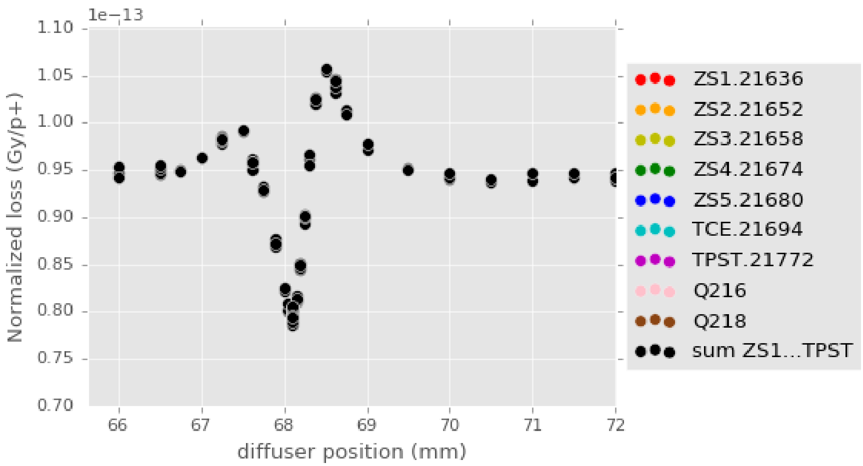




First test - 5 April

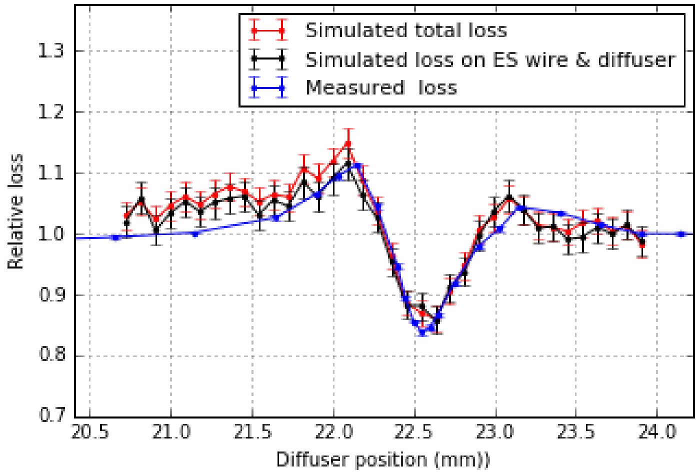
- Smooth test, clear results from BLM loss per p+
- Need for ~ 50 um positioning accuracy predicted by measurements is confirmed
- 15% normalized (per extracted p+) loss reduction, compared to case without diffuser
- Characteristic profile observed in MD can be used to tune simulations

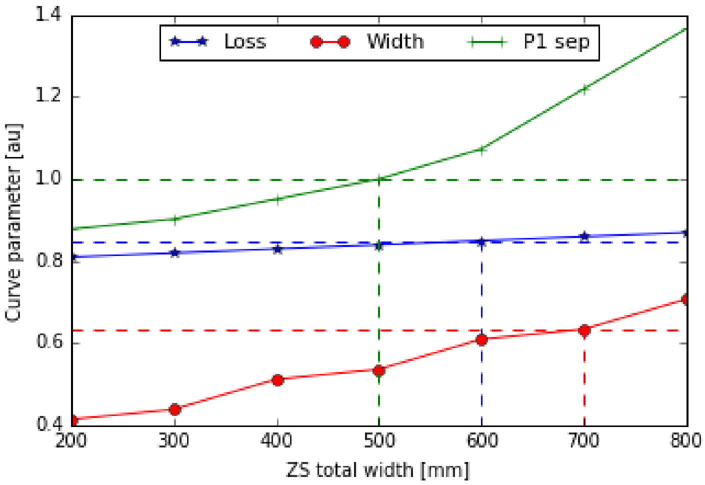




First test - 5 April

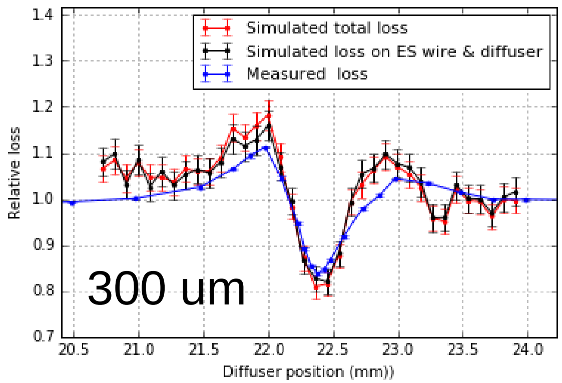
- Good agreement between measurement and python simulation, if we
  - Assume 600 um effective ZS width (previous estimate 200 um, but consistent with FLUKA prediction)
  - Flip the data left-right around the optimum (possibly due to ZS alignment, to be investigated)

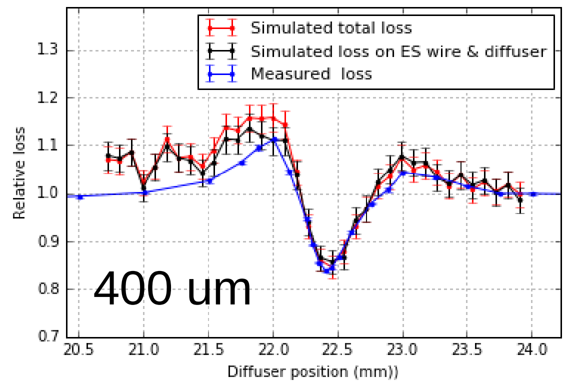


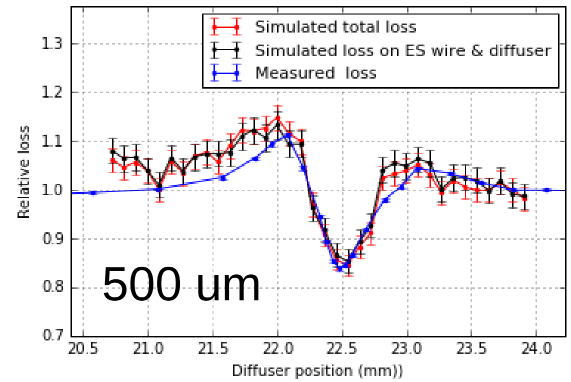


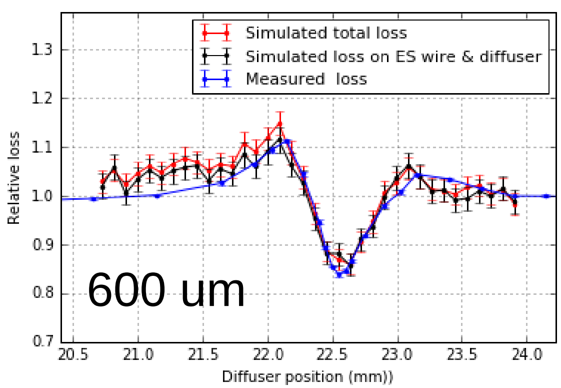
First test - 5 April

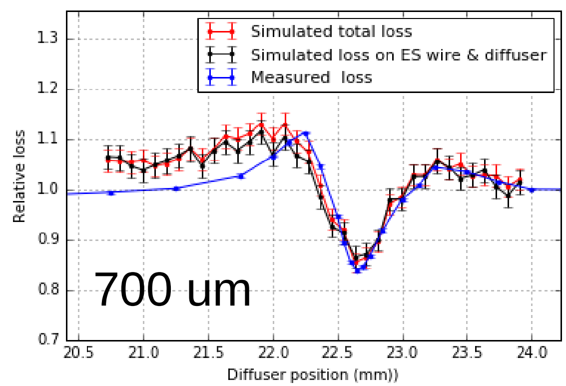
Simulated relative loss for different effective ZS thicknesses, compared to measured. ZS width seems ~600 um, consistent with absolute loss calibrations.

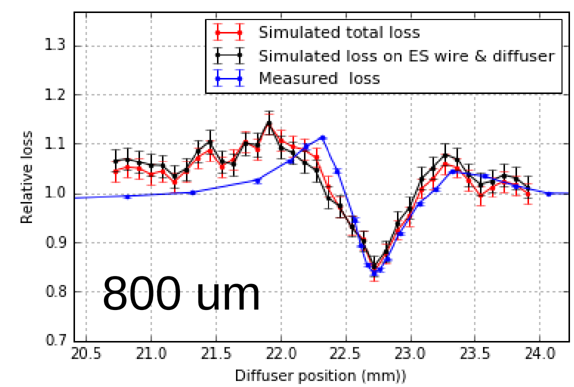








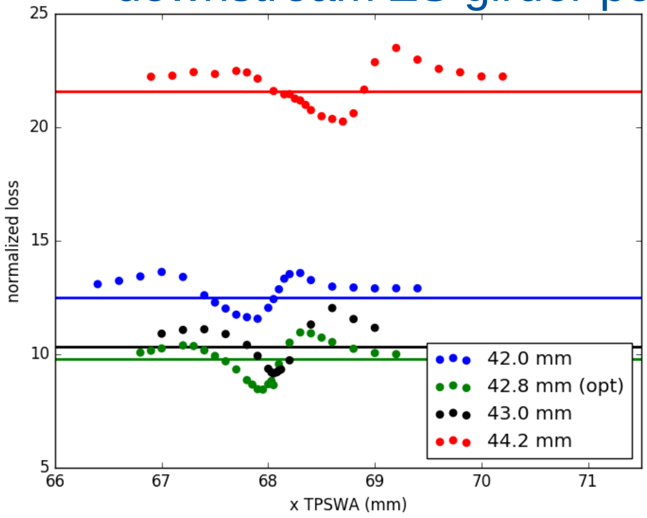


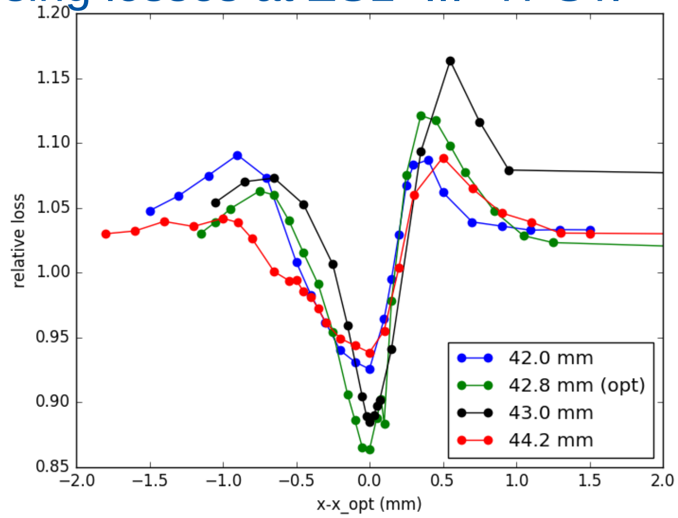


Girder alignment – 25 April

- Same diffuser position optimum easily found again
- Changes with girder misalignment
  - Relative loss improvement
  - Location of optimum and width of dip
  - Relative height of peaks (left and right)

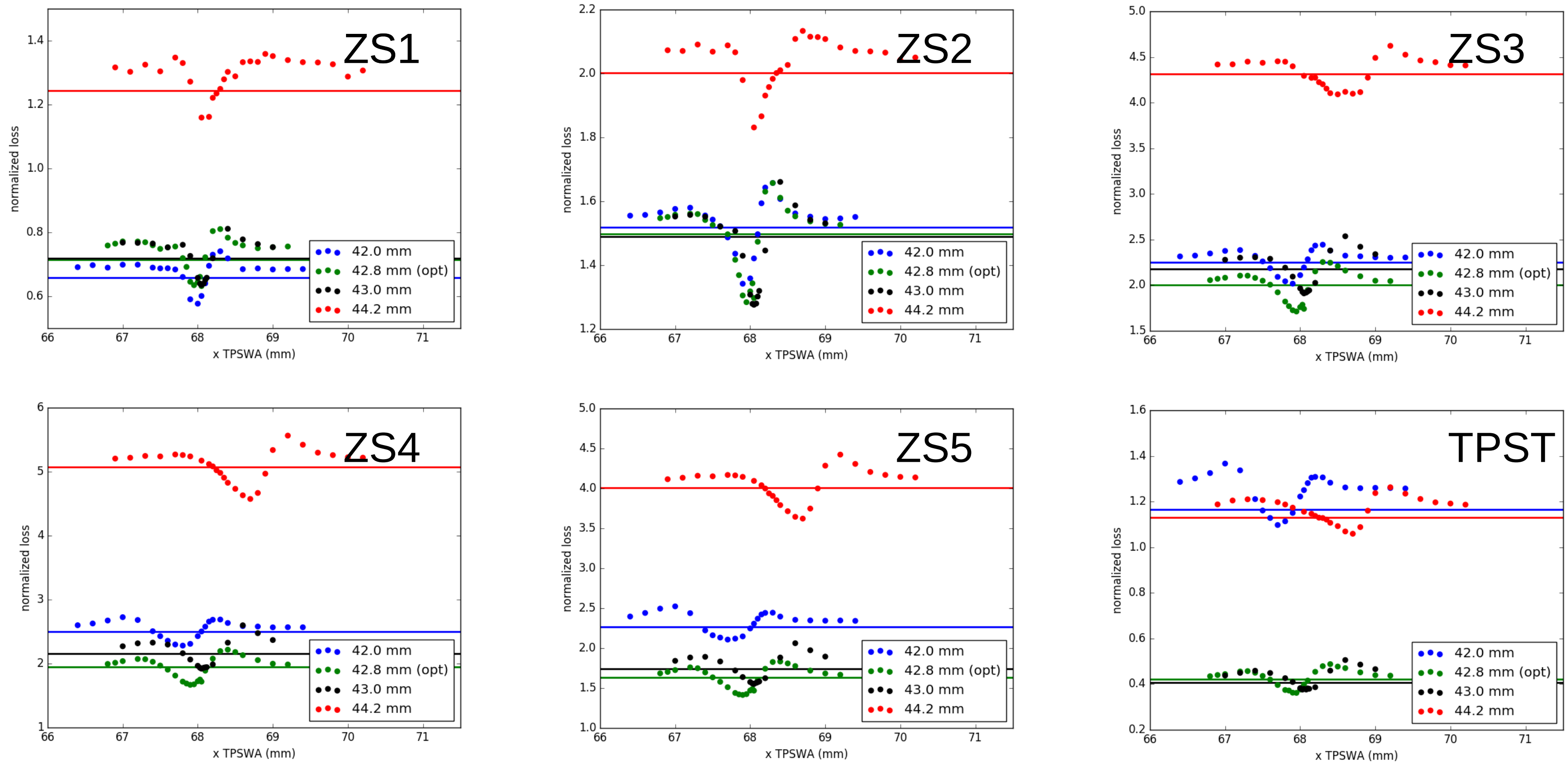
Normalized loss (left) and relative loss (right) vs diffuser position, for different downstream ZS girder positions. Using losses at ZS1+...+TPST.





Girder alignment – 25 April

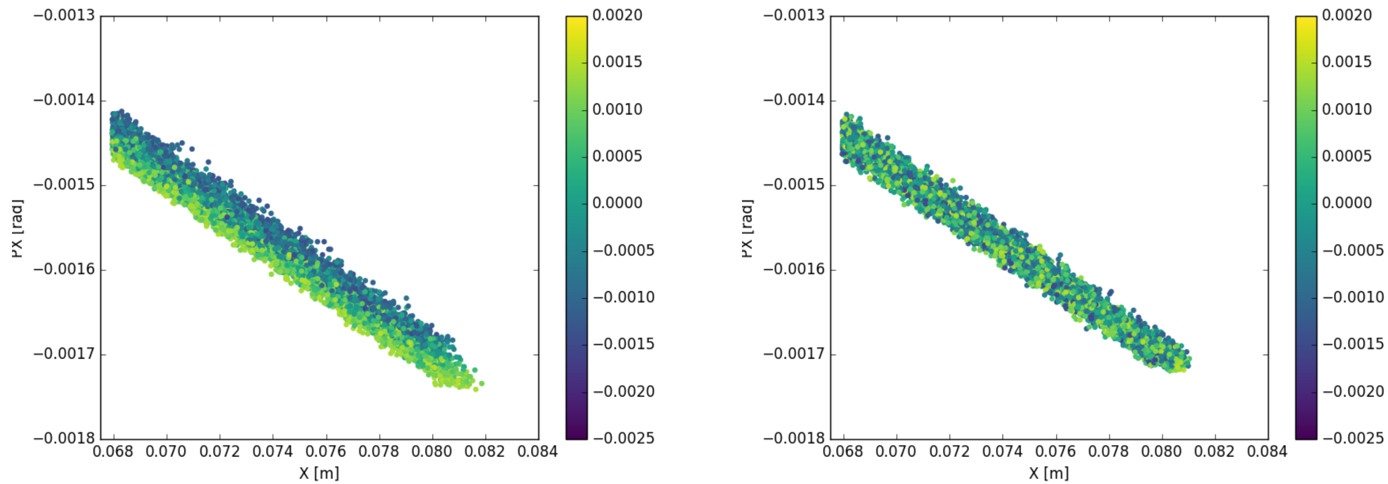
Normalized loss vs diffuser position, for different downstream ZS girder positions, split per BLM



COSE

- COSE is a new slow extraction technique, scaling all magnets by the magnetic rigidity as the resonant momentum changes, rather than only sweeping the main quads → same resonant optics for all momenta
- Set up still in progress, but available in MDs

Extracted beams: nominal (left) vs COSE (right)



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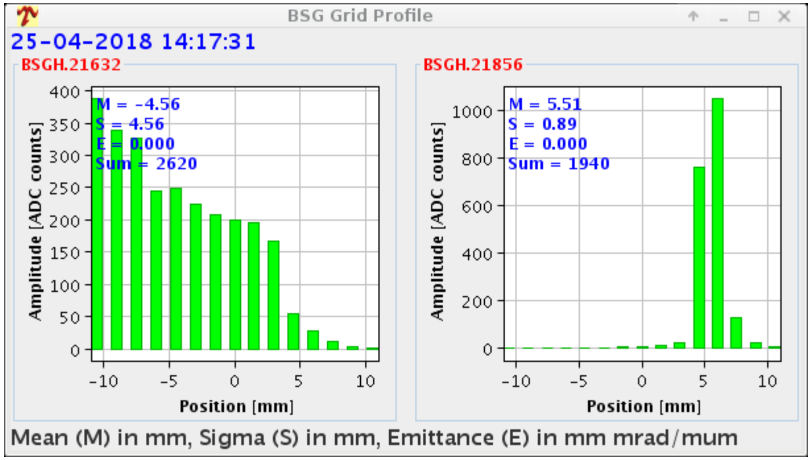
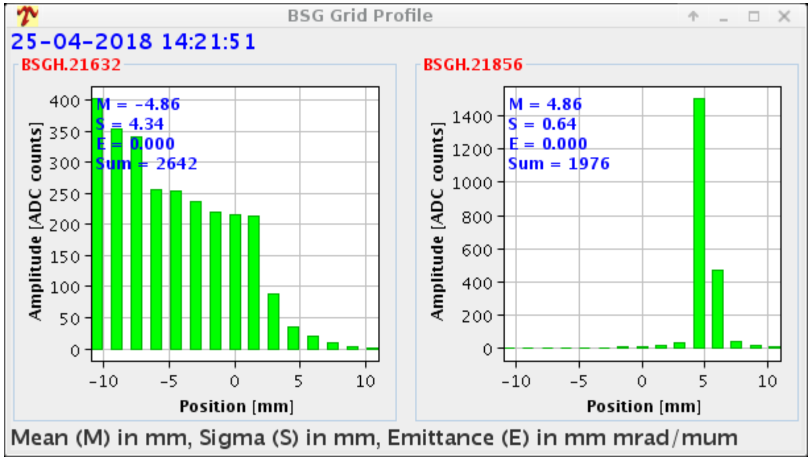
Beam measured on grids: nominal (left) vs COSE (right)

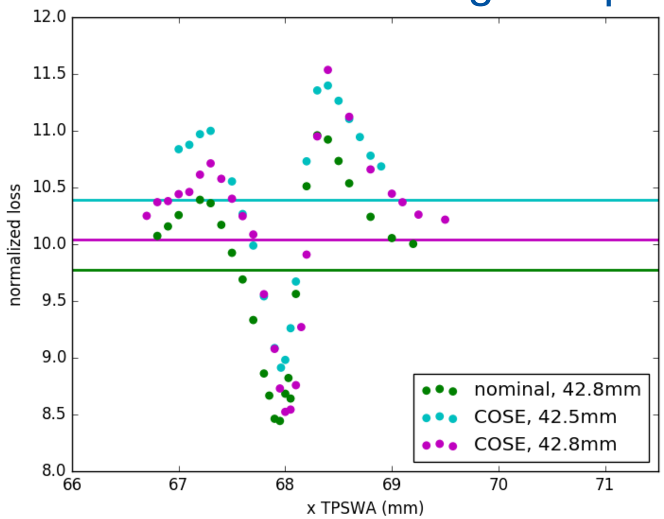


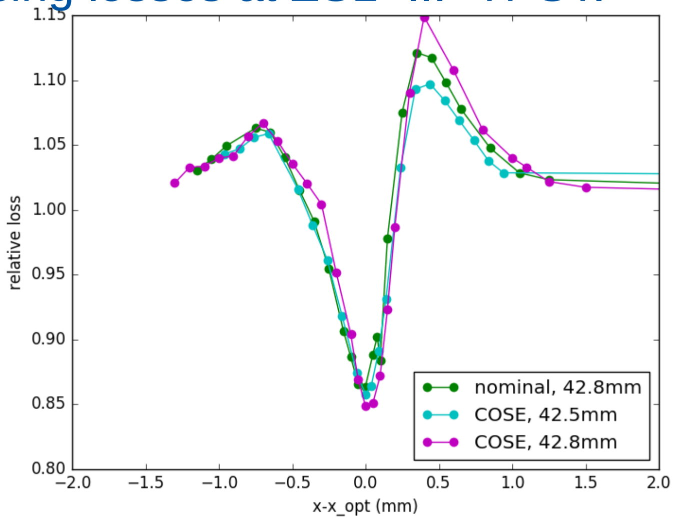


TPSWA and COSE – 25 April

- COSE performs slightly worse than nominal in MD at the moment, optimization still to be done
- Loss reduction profile very similar, except for the right-hand side loss peak

Normalized loss vs diffuser position, for different optics and downstream ZS girder positions. Using losses at ZS1+...+TPST.

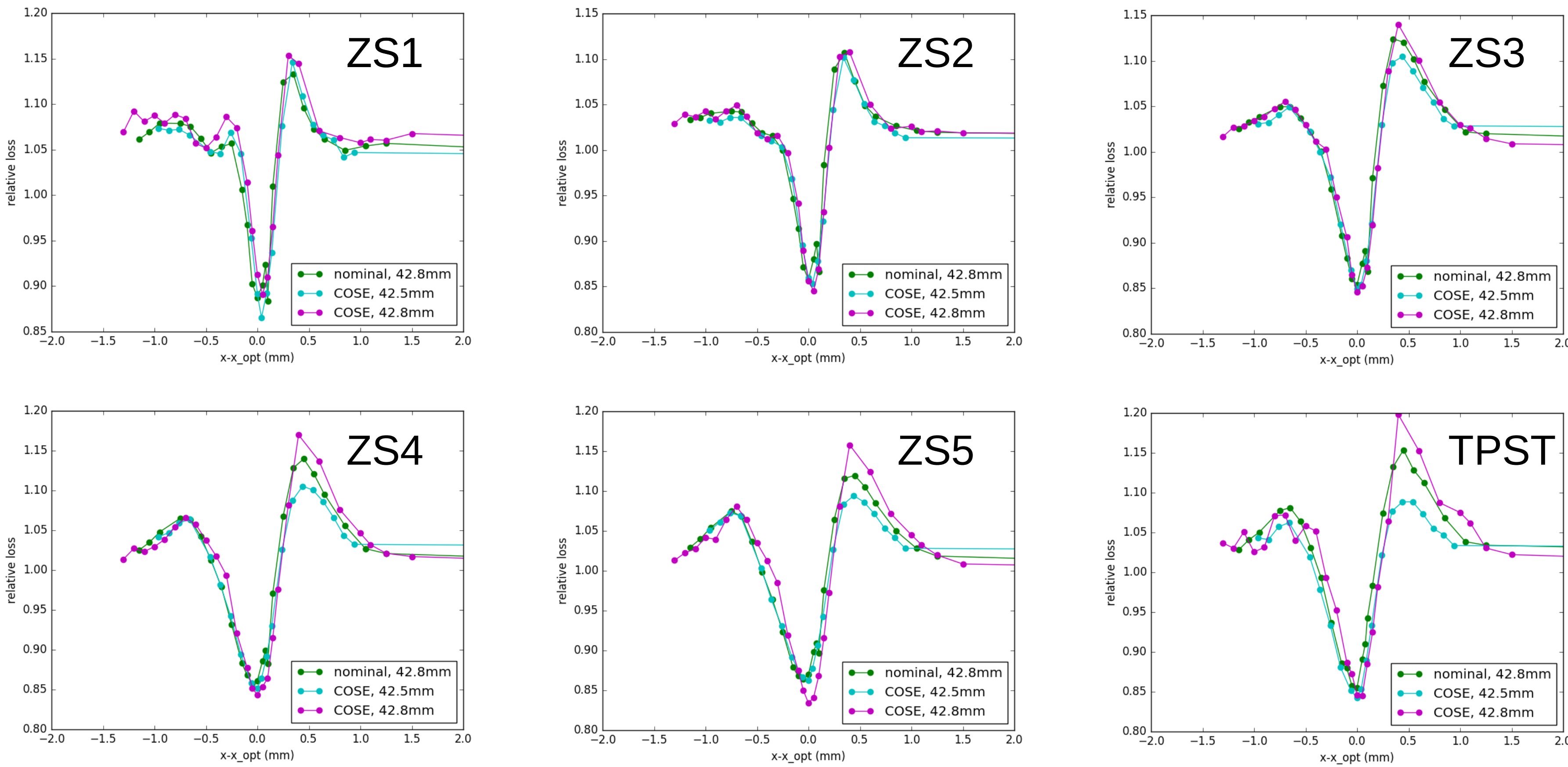




Magenta data from 9 May

TPSWA and COSE – 25 April

Relative loss vs diffuser position, for different optics and downstream ZS girder positions, split per BLM



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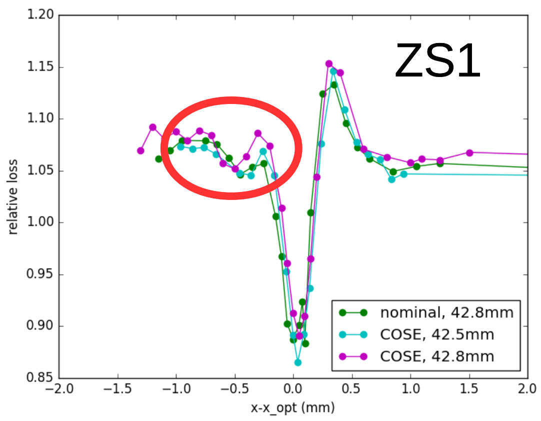
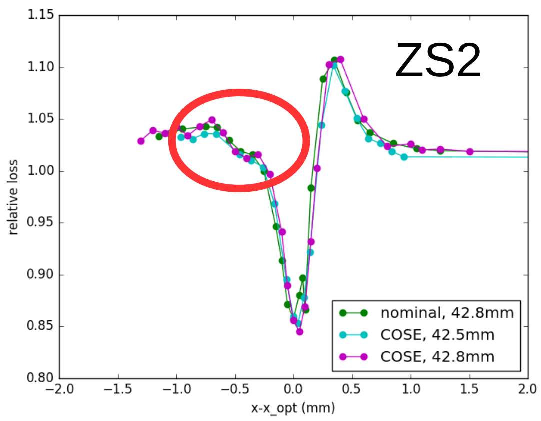
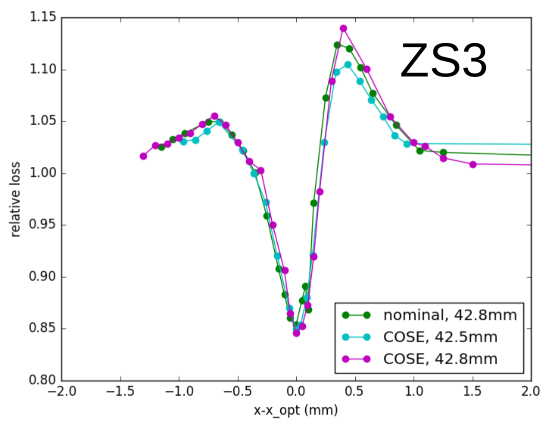




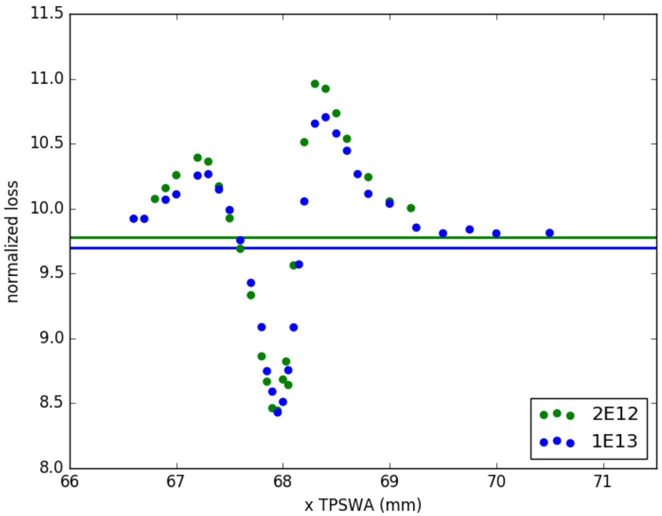


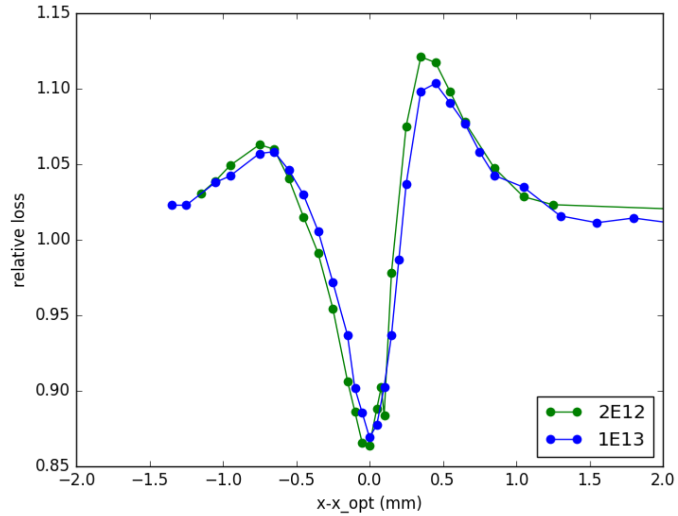
- Detailed physics of the diffuser or hint there is something wrong with the ZS?

Higher intensity – 9 May

- Losses seem very similar for 2E12 and 1E13 ppp
- Gives good hope for operational potential

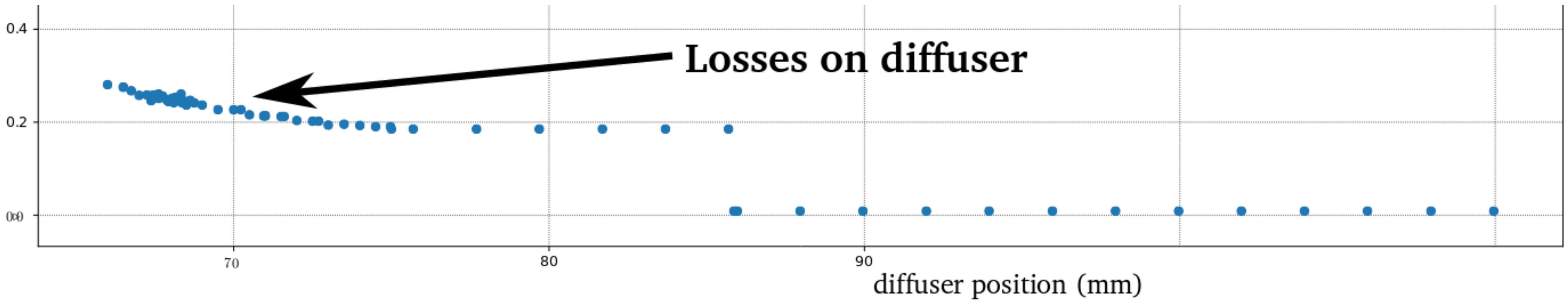
ppp	Base loss [Gy/p+]	Min loss [Gy/p+]	Reduction [%]	$X_{TPSWA,opt}$
2E12	9.77E-14	8.44E-14	13.6	67.95
1E13	9.70E-14	8.43E-14	13.1	67.95





Other data

- The LHC BLM installed at the diffuser gives a detailed view of the extracted beam density as we scan the diffuser position, analysis ongoing by M. Pari



Conclusion

- MD data will be used to tune simulations
- There is probably more information about the ZS alignment hidden in the data, but will require study and comparison to simulations
- Successful loss reduction method for slow extraction
- Small increase in loss near the diffuser, but otherwise uniform reduction throughout the extraction region
- 15% gain seen, ~30% possible with diffuser width optimized to 600 um ZS thickness
- Very easy and quick to setup, and reproducible, only 1 degree of freedom. Encouraging for operation.

Next steps

- Thermo-mechanical checks for diffuser wire integrity at high intensity operation
- FLUKA checks of expected increase in residual radioactivity upstream of 216
- MD: transport through TT20 (effect of increased halo)
- MD: Scale to operational intensity
- Discussing a voluntary misalignment of the TPSWA in ITS1 to increase its effective thickness for MD study.
- Discussion: to be used in operation this year?
  - Planned to exchange diffuser with crystal in ITS2, so we do not want to activate this the area.
- Upgrade of ZS in LS2 will hopefully allow improved ZS alignment compared to today