SPS slow-extraction (in)efficiency measurements: 2016 vs. 2017

15th MSWG meeting, 27th October 2017

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- Motivation
- Recap of 2016 measurements* and first checks of BSI logging and FESA variables
- New measurements in 2017:
  - reminder that BSI.210279 was replaced in last EYETS16-17: installed in TT10
- Summary of results and conclusions
- Follow-up and open questions

*See MSWG meeting #11 in 2016, Friday 19thAugust, for the details of the measurement procedure: https://indico.cern.ch/event/559108/

Motivation

- We want to measure how (in)efficient our slow-extraction system is, in terms of fraction of protons lost...

  …losses are expected to be a few %

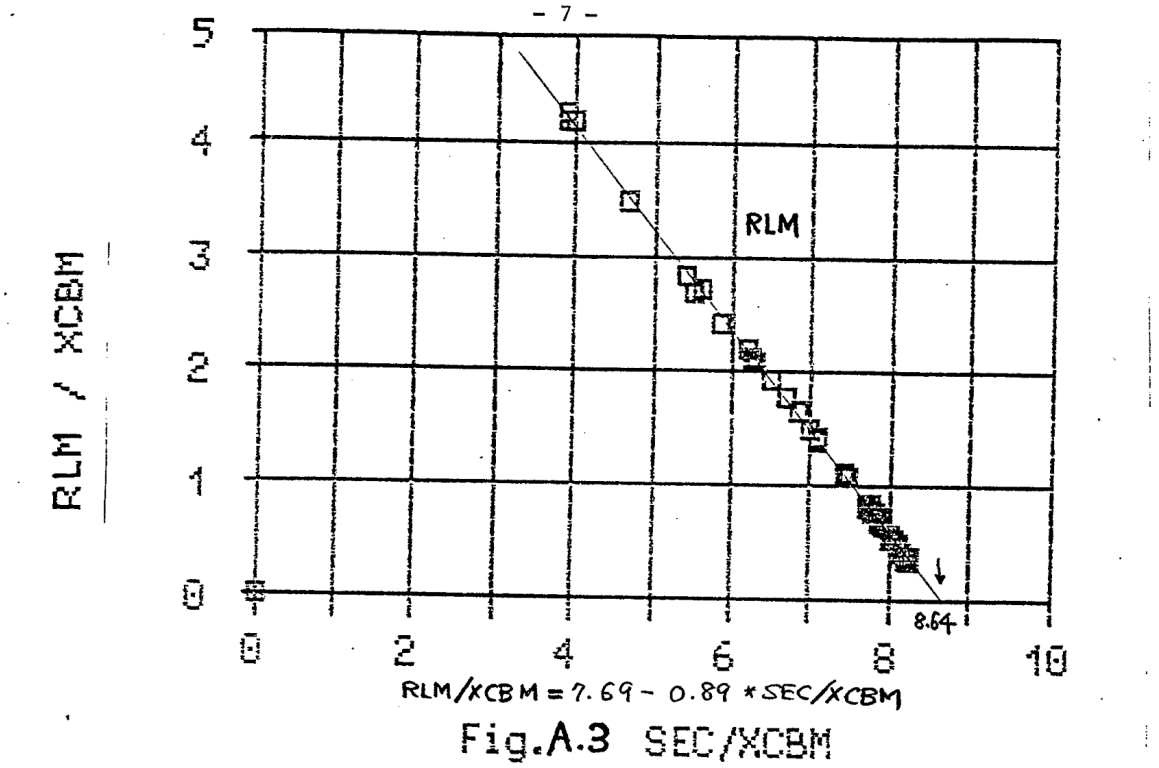
- However, the absolute calibration of instrumentation for the DC beams in the North Area is rather unknown…

  …certainly >> few %

- The following techniques have been used in the past:
  - Calibration of SEM's (and/or activation foils) with ring BCT and fast extracted beams using a BCT in the extraction line with ≈1% accuracy
  - Calibration of SEM's with activation foils, measuring integrated dose with known reaction cross-section with ≈10% accuracy
  - Calibration of SEMs and BLMs normalised with extracted intensity measured on the ring BCT:
    - Systematics make it hard to estimate accuracy… as you will see!

Measurement Concept: recap

M. Tanaka et al, AGS Studies Report 229, March 1987



Measurement Concept: recap

$$\frac{\sum BLM}{BCT}$$

RLM / XCBM

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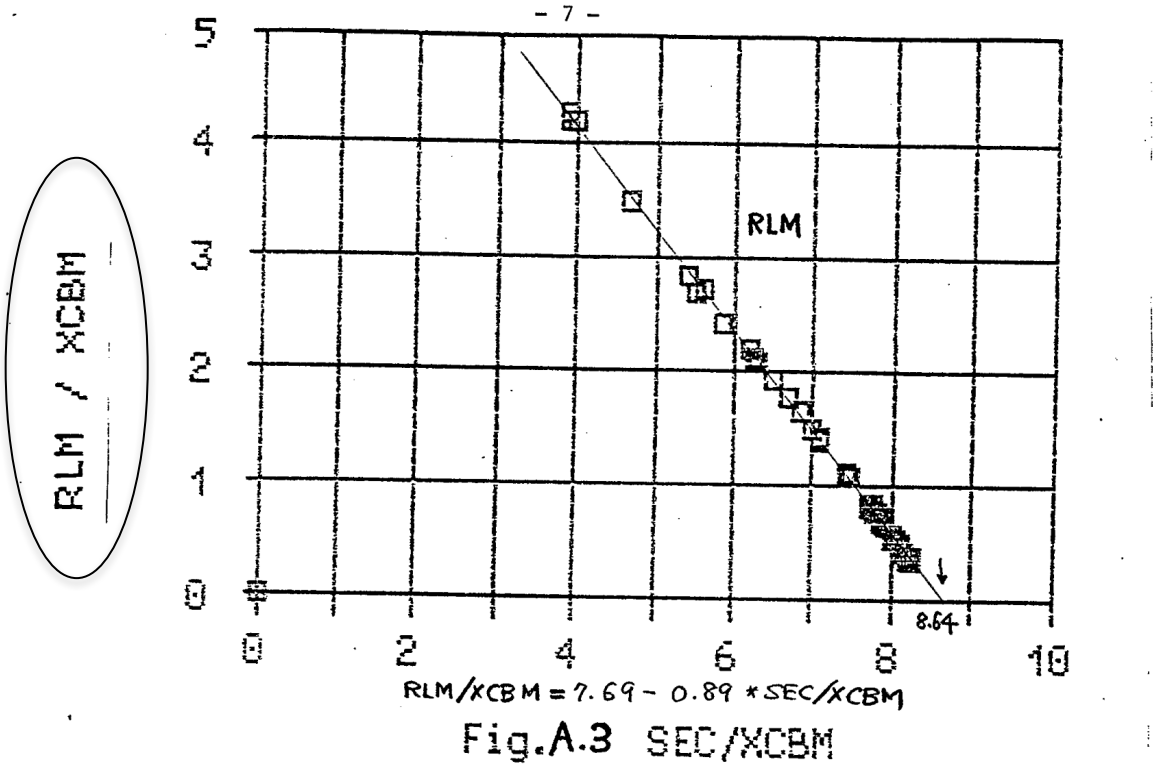

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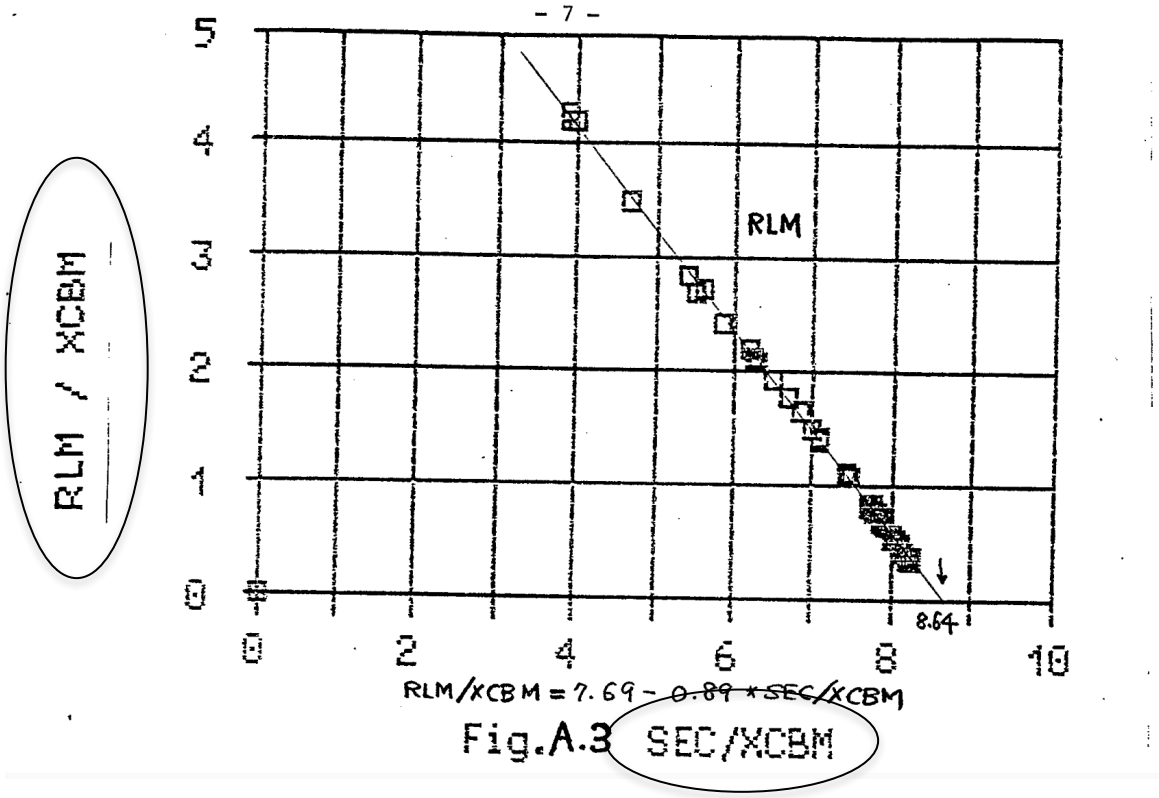

$$\frac{BSI}{BCT}$$ (in extraction line)

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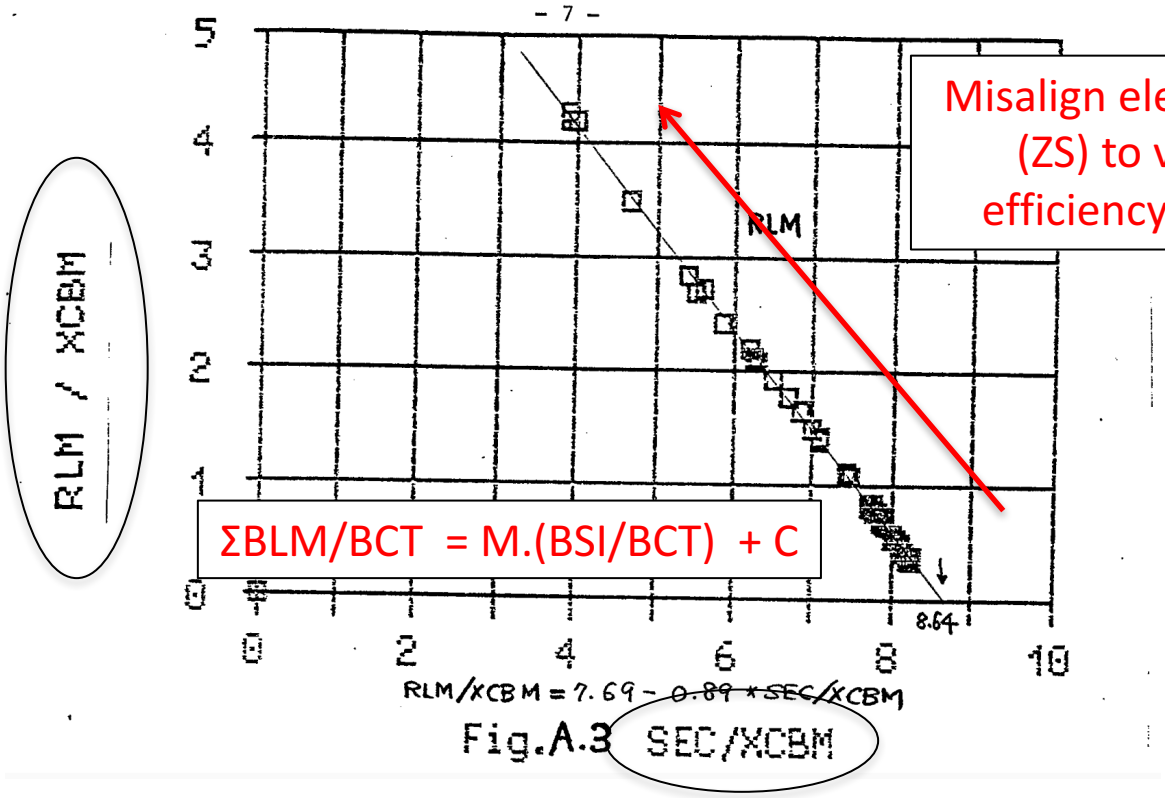

$\frac{\sum BLM}{BCT}$

Misalign electrostatic septum (ZS) to vary extraction efficiency at low intensity

ΣBLM/BCT = M.(BSI/BCT) + C

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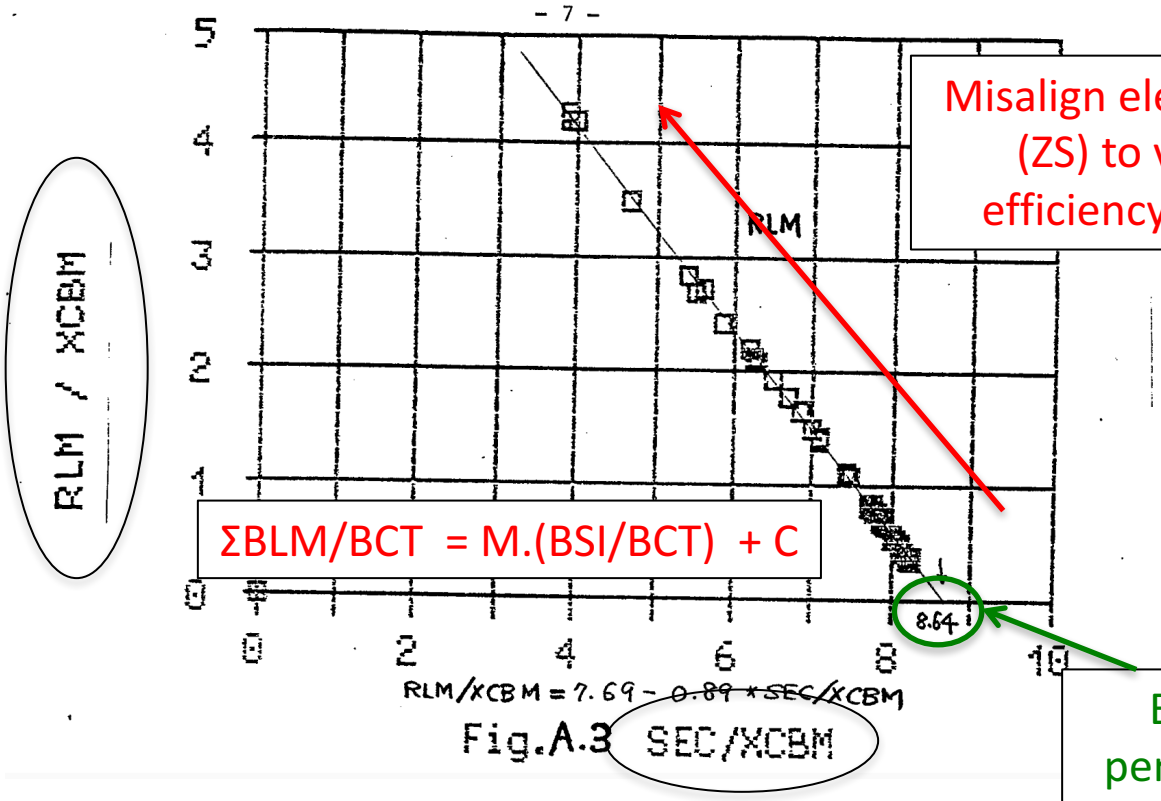


Fig.A.3

Misalign electrostatic septum (ZS) to vary extraction efficiency at low intensity

ΣBLM/BCT = M.(BSI/BCT) + C

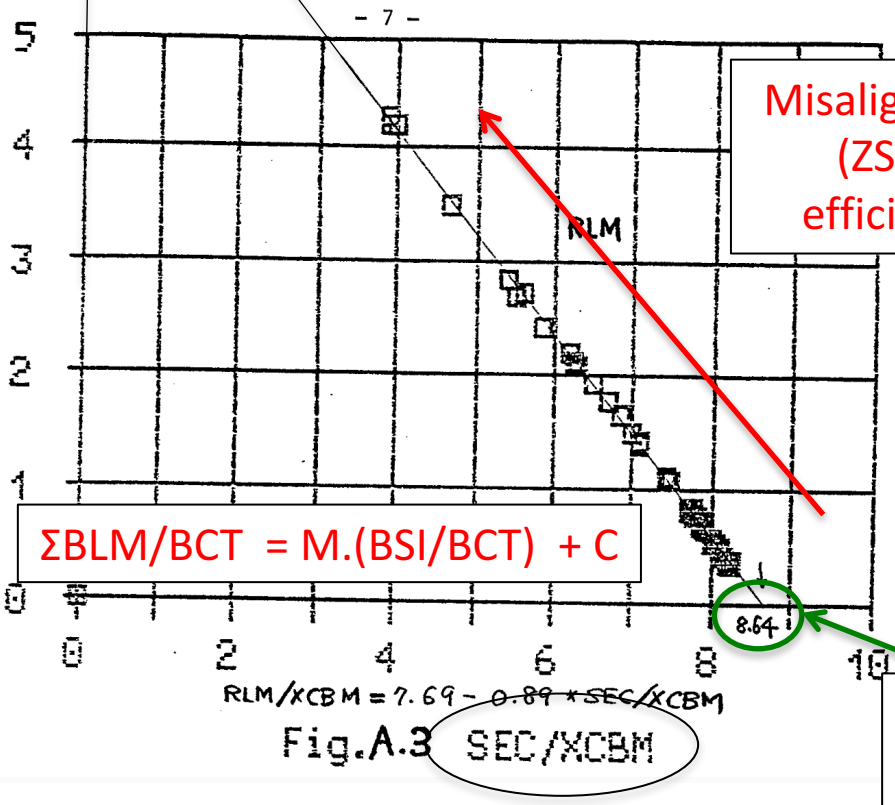
Extrapolation to perfect efficiency for **BSI calibration**:
ΣBLM/BCT = 0
BSI/BCT = -C/M

$$\frac{BSI}{BCT}$$ (in extraction

Measurement Concept: reca

Extrapolation to perfect inefficiency:
BSI/BCT = 0
ΣBLM/BCT = C

M. Tanaka et al, AGS Studies Report 229, March 1987



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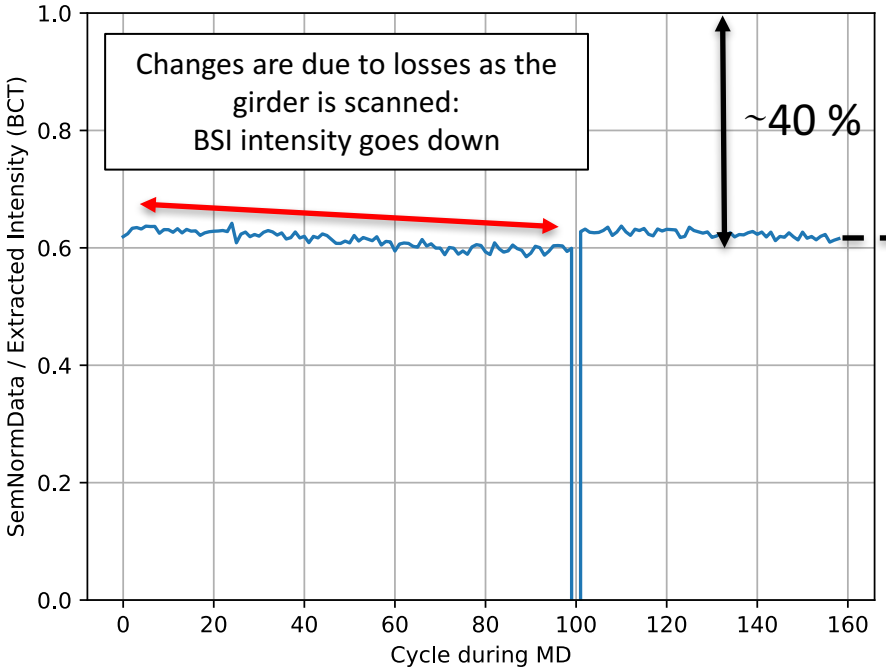
$$\frac{BSI}{BCT}$$ (in extraction

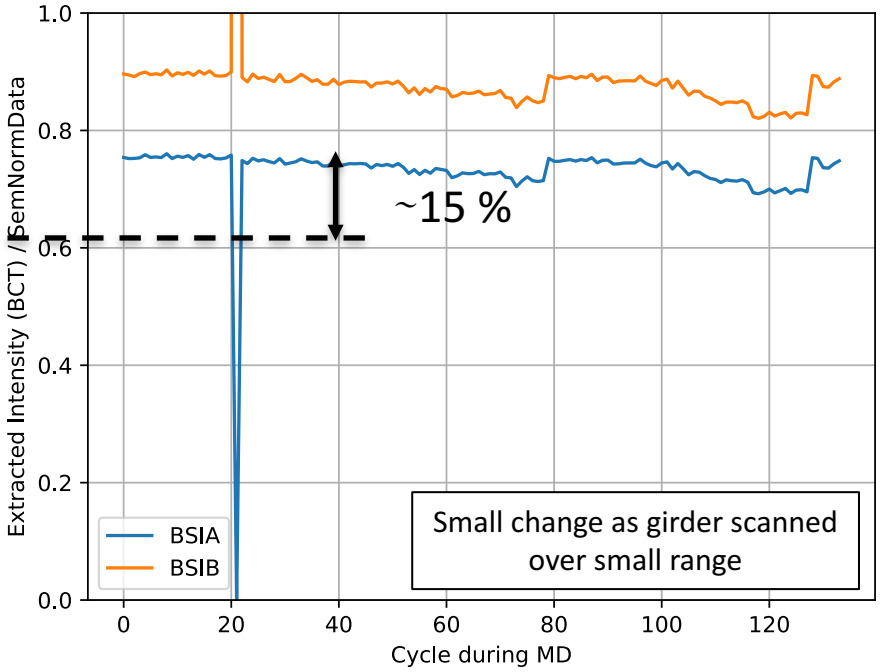
BSI vs BCT data: 2016 vs. 2017

- Using data acquired during MD's (*semNormData*) we can check change in calibration due to the change of foil:
  - BSIA foil response has increased by about 15 %

2016



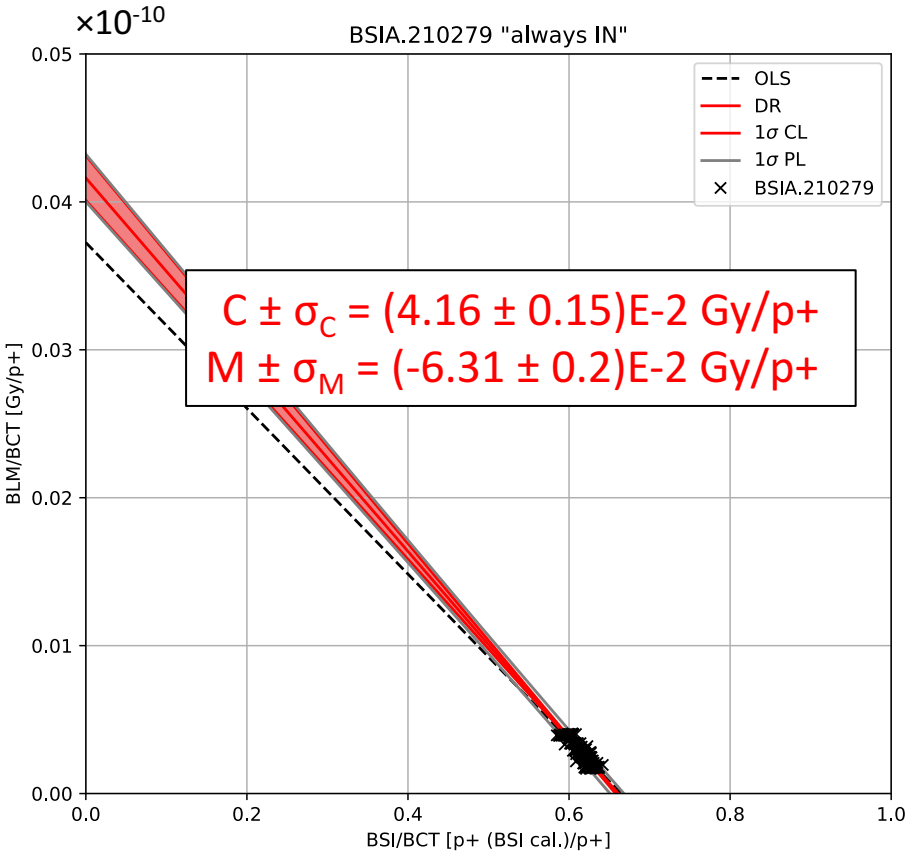
2017

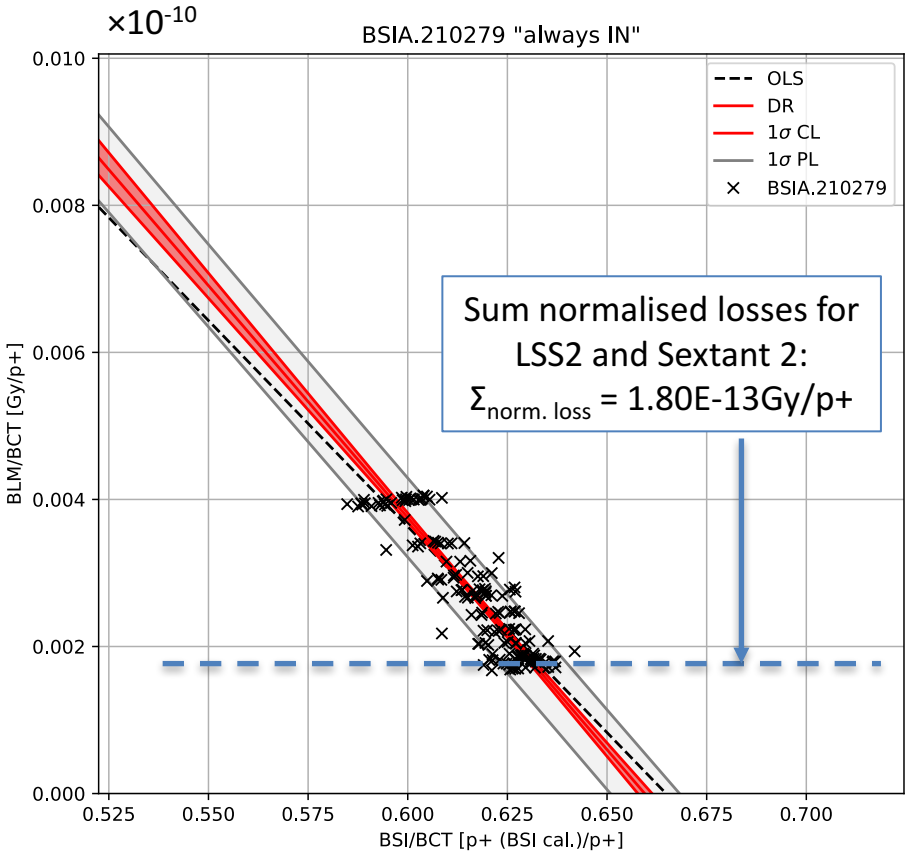


Results in 2016: BSIA 210279

- Using ***semNormData*** field published by the front-end:

$\Sigma BLM/BCT = M.(BSI/BCT) + C$

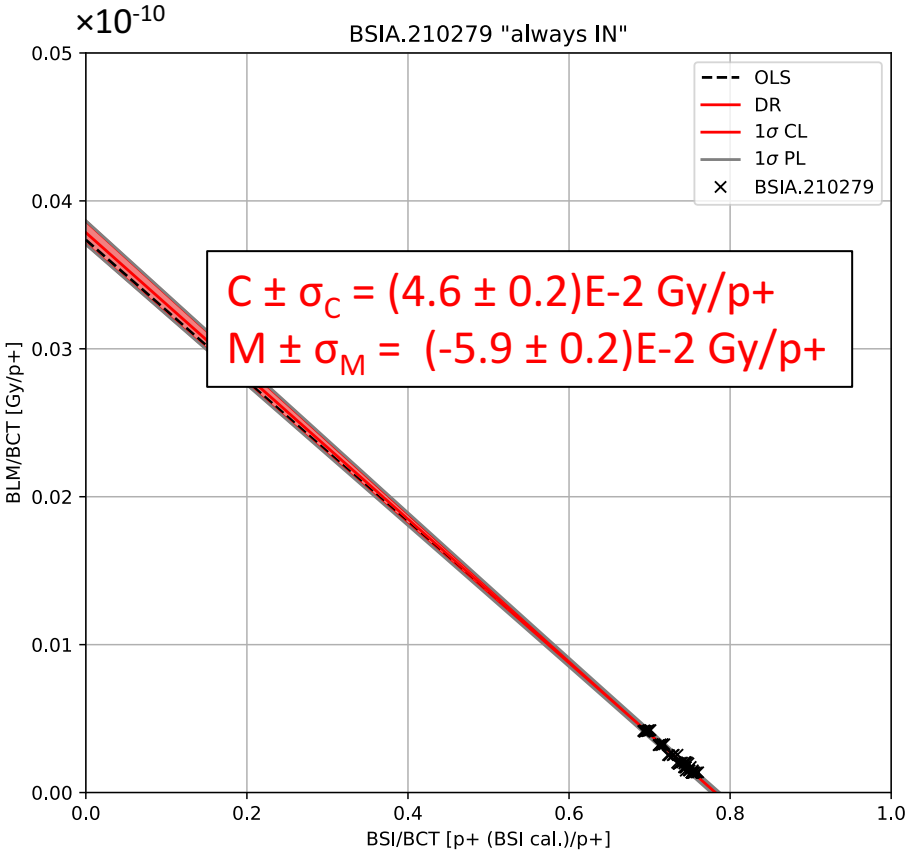




Results in 2017: BSIA 210279

- Using ***semNormData*** field published by the front-end:

ZS girder scanned **towards circulating beam**:
42.7 mm to 41.2 mm



ZS girder scanned **towards extracted beam**:
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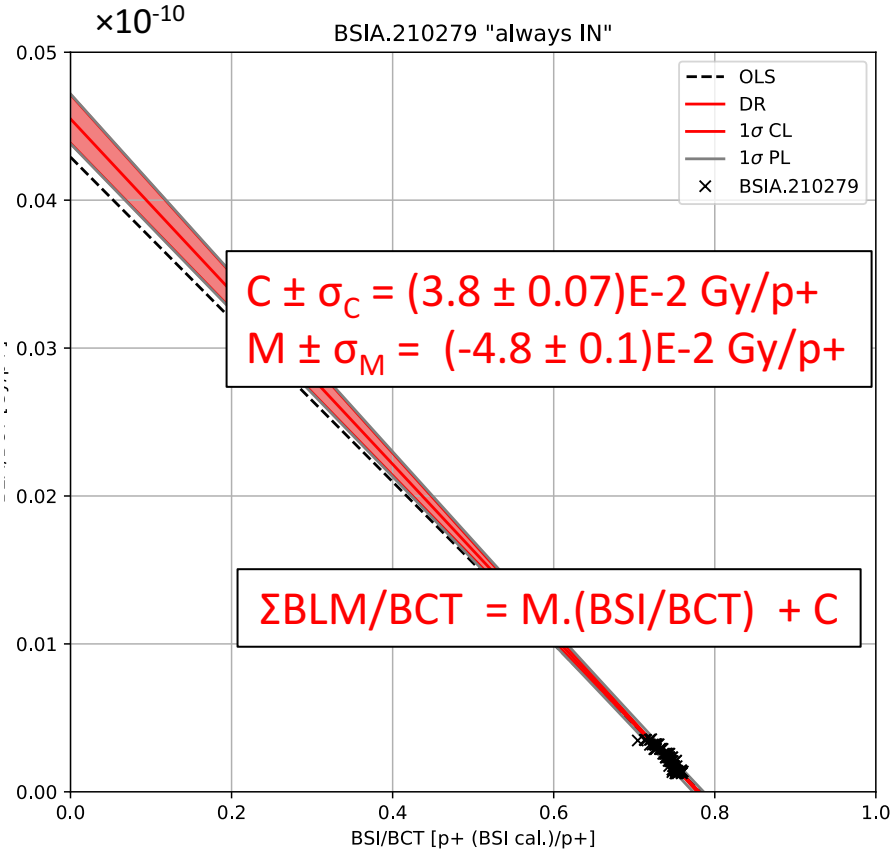
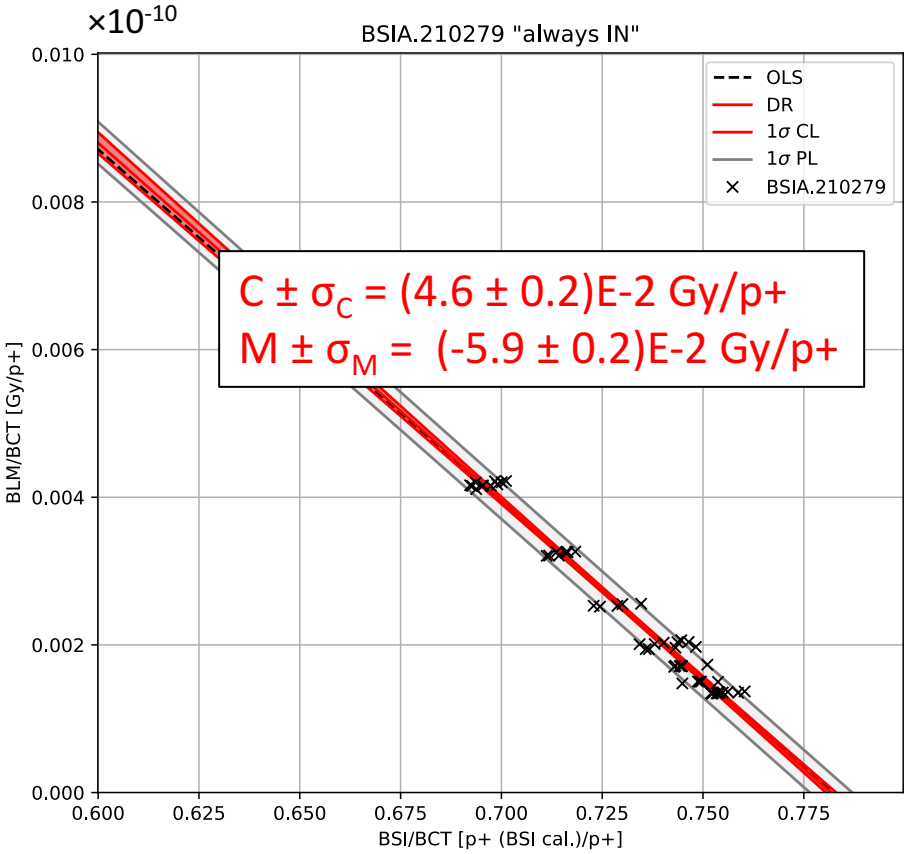


Results in 2017: BSIA 210279 (zoom)

- Using ***semNormData*** field published by the front-end:

ZS girder scanned **towards circulating beam**: 42.7 mm to 41.2 mm



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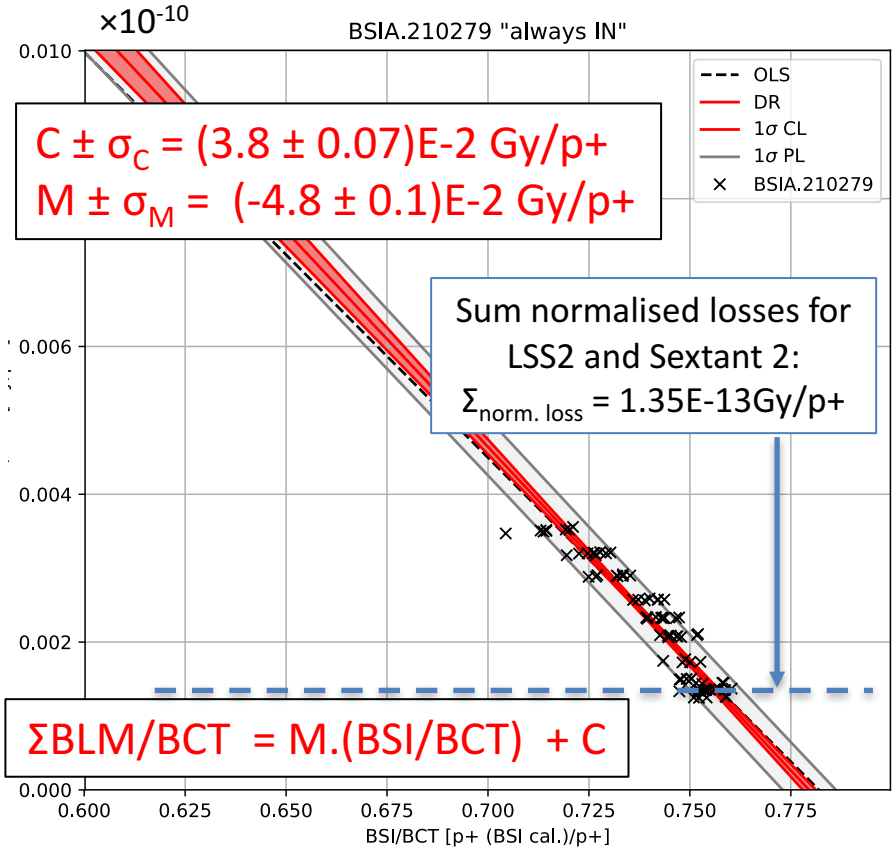

Summary of results: BSIA vs. BSIB

- Same analysis repeated for the second foil BSIB.210279 read-out on channel 46 of the FEC (BSIA = ch. 45), see extra slides for all data:

Year	SEM Foil	Scan Direction	Extraction Inefficiency [% ± 1σ]
2016	BSIA.210279	**All data**	**4.3 ± 0.2**
2017	BSIA.210279	Towards extracted beam	3.0 ± 0.1
		Towards circulating beam	3.6 ± 0.07
		All data	**3.4 ± 0.09**
	BSIB.210279	Towards extracted beam	2.9 ± 0.1
		Towards circulating beam	3.6 ± 0.07
		All data	**3.4 ± 0.1**

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0.9% reduction corresponds to a 21% improvement in the extraction inefficiency in 2017

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Year	SEM Foil	Scan Direction	Extraction Inefficiency [% ± 1σ]	BSI to BCT Calibration Error [% ± 1σ]
2016	BSIA.210279	**All data**	**4.3 ± 0.2**	**-34.1 ± 0.2**
2017	BSIA.210279	Towards extracted beam	3.0 ± 0.1	-22.0 ± 1.1
		Towards circulating beam	3.6 ± 0.07	-21.8 ± 0.6
		All data	**3.4 ± 0.09**	**-21.6 ± 0.8**
	BSIB.210279	Towards extracted beam	2.9 ± 0.1	-7.5 ± 0.4
		Towards circulating beam	3.6 ± 0.07	-7.1 ± 0.2
		All data	**3.4 ± 0.1**	**-6.9 ± 0.3**

BSIA has increased its SEM yield by 12.5%

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		Towards circulating beam	3.6 ± 0.07	-7.1 ± 0.2
		All data	**3.4 ± 0.1**	**-6.9 ± 0.3**

BSIB measures 14.7% higher than BSIA: similar phenomenon observed on BSI's in TT10

Conclusions

- BSIA.210279 has increased its SEM yield by 12.5% since its foil was replaced in EYETS16-17
- BSIB reads 15% higher intensity than BSIA:
  - BSIB foil located immediately downstream of BSIA
  - Similar discrepancies between foils installed in TT10… tbc
- The extraction inefficiency between the ring and BSI.210279 is measured at 3.4 ± 0.1 %:
  - …let's be cautious here, it's extremely hard to quantify the systematic error: large extrapolation!
- The sum of the normalised losses in LSS2 and Sextant 2 has been reduced by 25% in 2017… great news!
- This is more-or-less consistent with the 21% improvement of the extraction efficiency measured on BSIA.210279

Follow-up and open questions

- As we skew the septum far we see non-linearity:
  - Some losses may not be detected by the BLMs, or rather, the loss distribution is changing shape: seen in MADX
  - FLUKA to checks BLM response
  - When losses are missed a lower intercept is measured: as a result we over-estimate the relative number of protons lost
  - i.e., our measurement is probably an over-estimation…
- What effective septum thickness does 3.4% losses imply in simulation?
  - 200 um: losses expected are about 1.5 % up to TPST, still need to track to BSI
- Different BLM loss profiles were measured this year?
  - ZS1 and ZS2 response strange this year, see extra slides
- If we only lose 3.4% in the extraction, where are the other ≈25% of protons going before the targets:
  - Splitting, transmission losses in TT20, BSI calibration?

Extra slides

Results in 2017: BSIA 210279 all data

- Using **semNormData** field published by the front-end, using all data (both ZS downstream girder position moved towards circulating and extracted beams):

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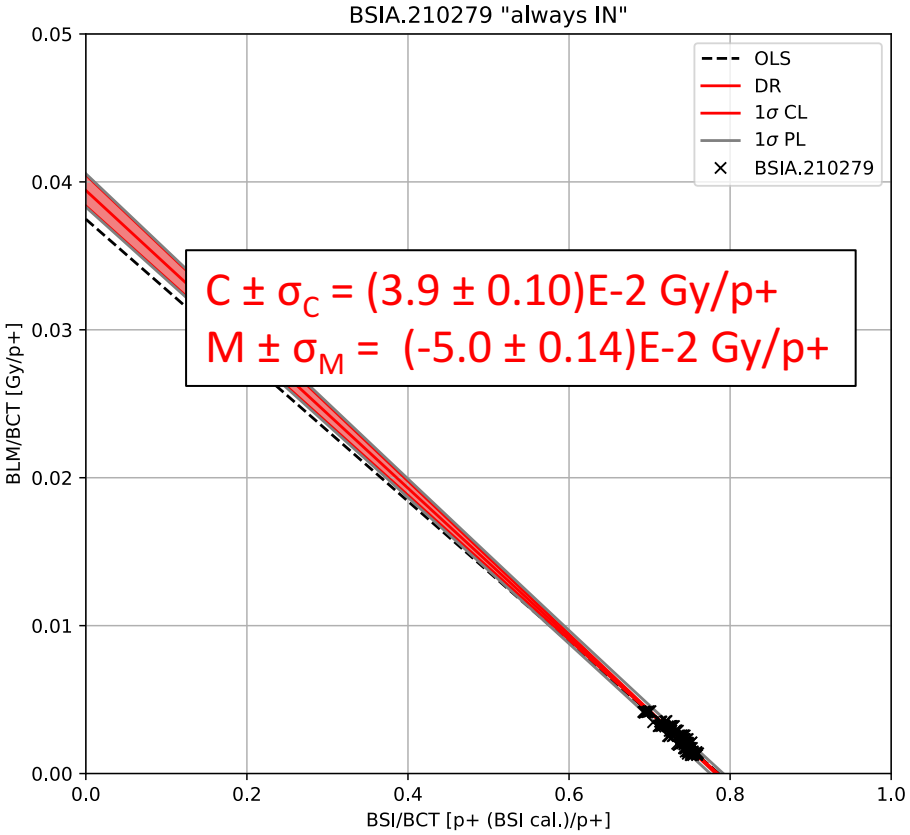

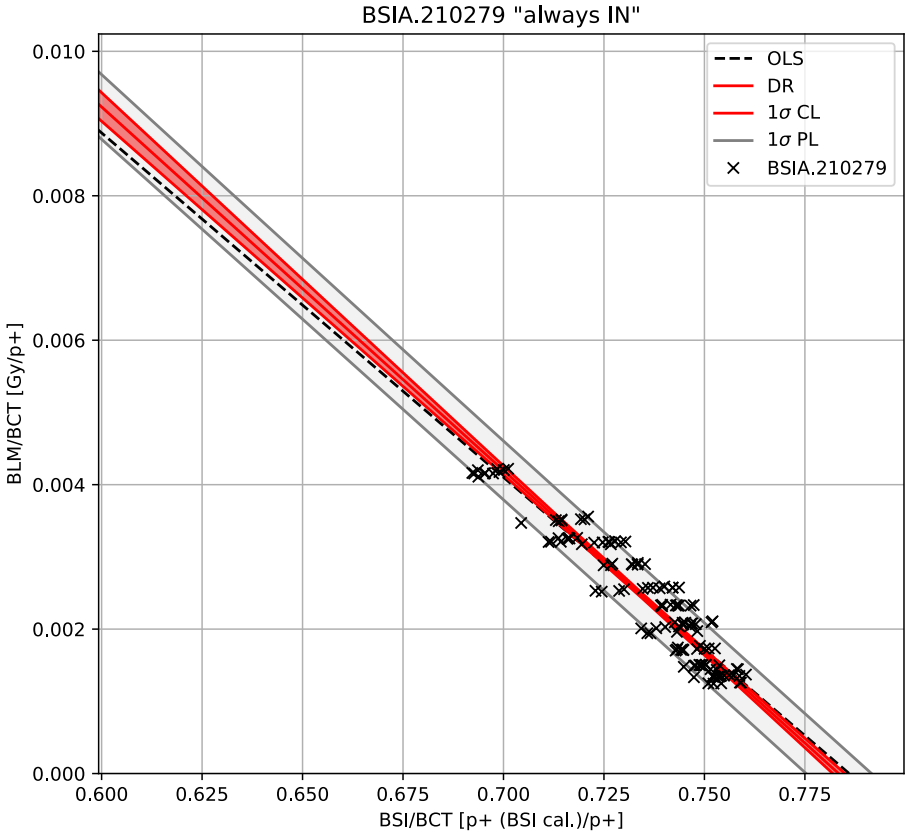

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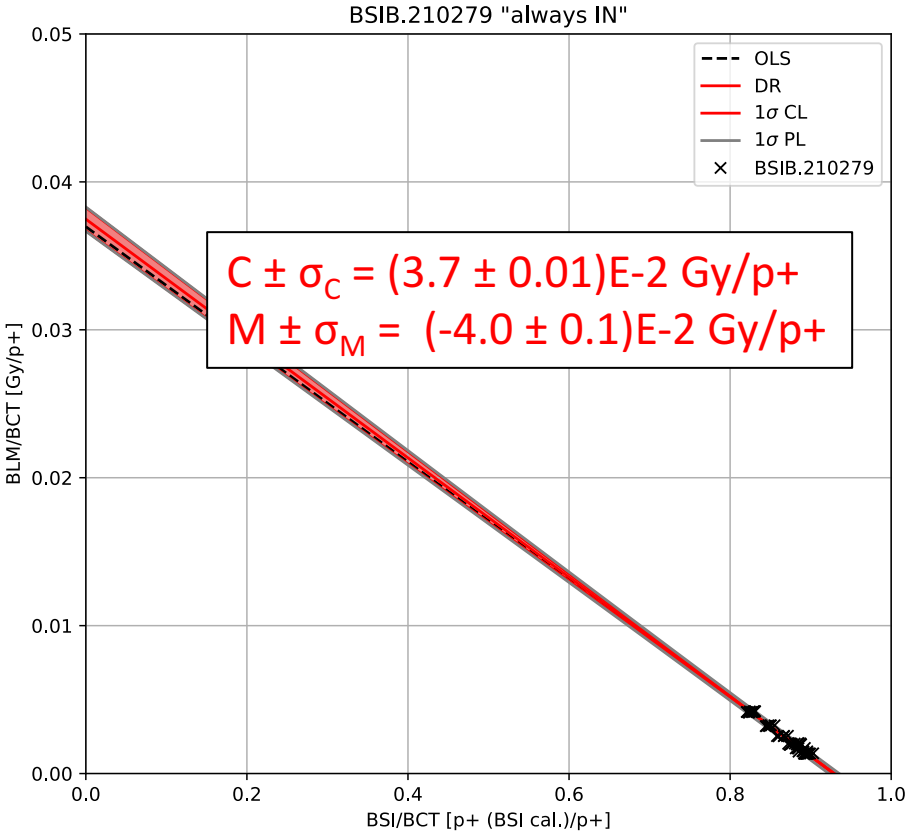

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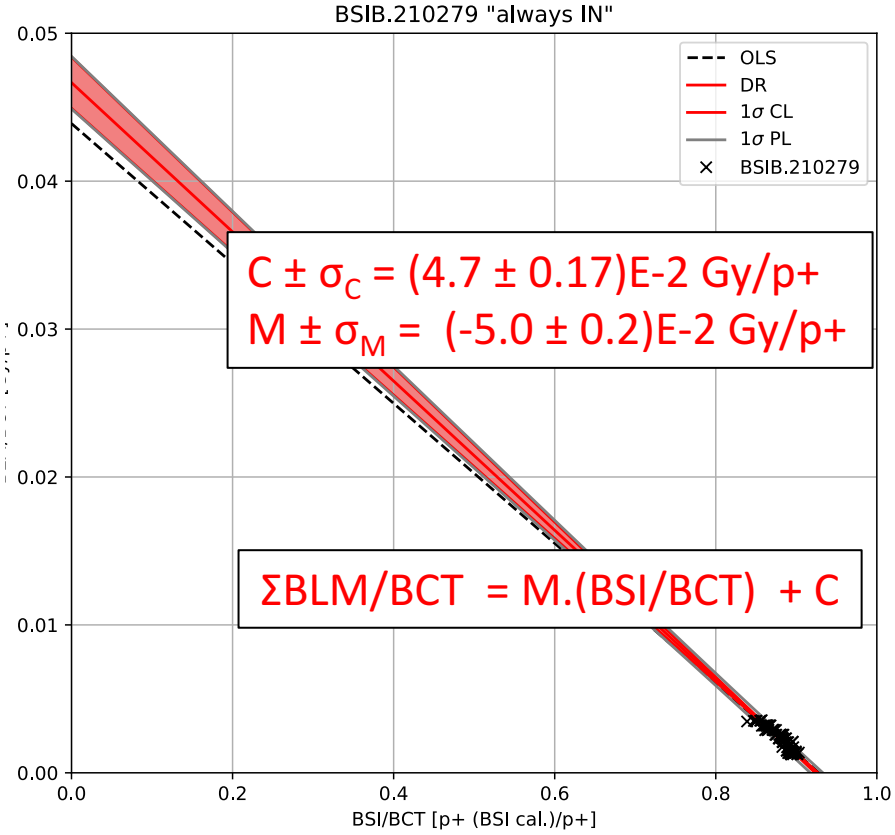

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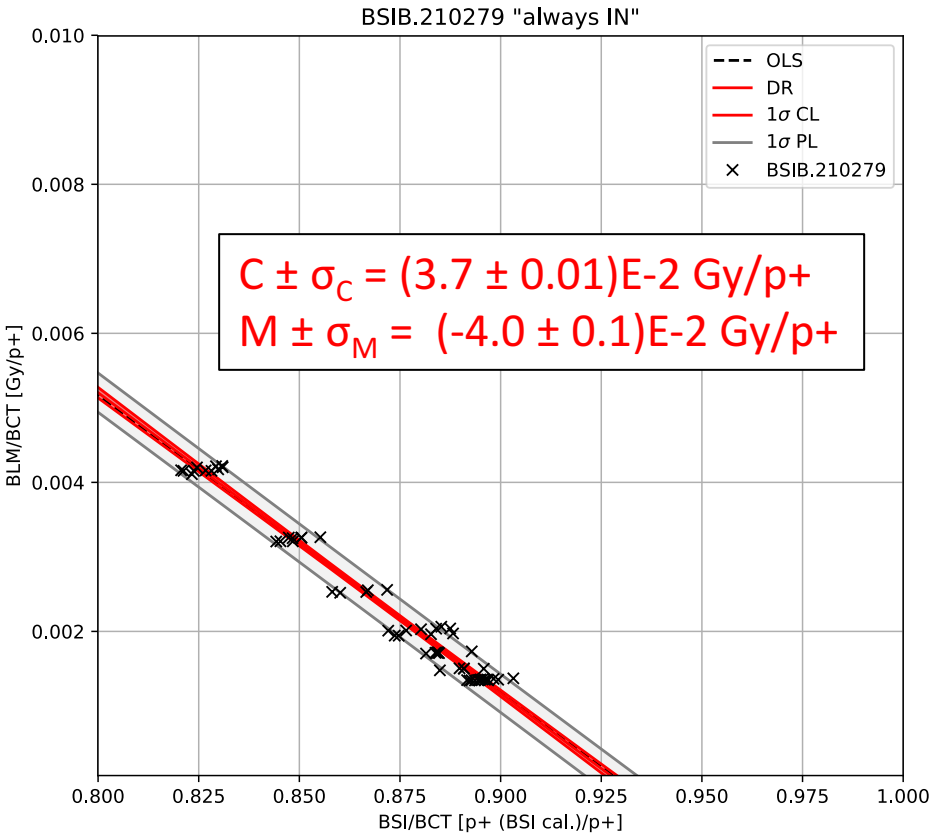

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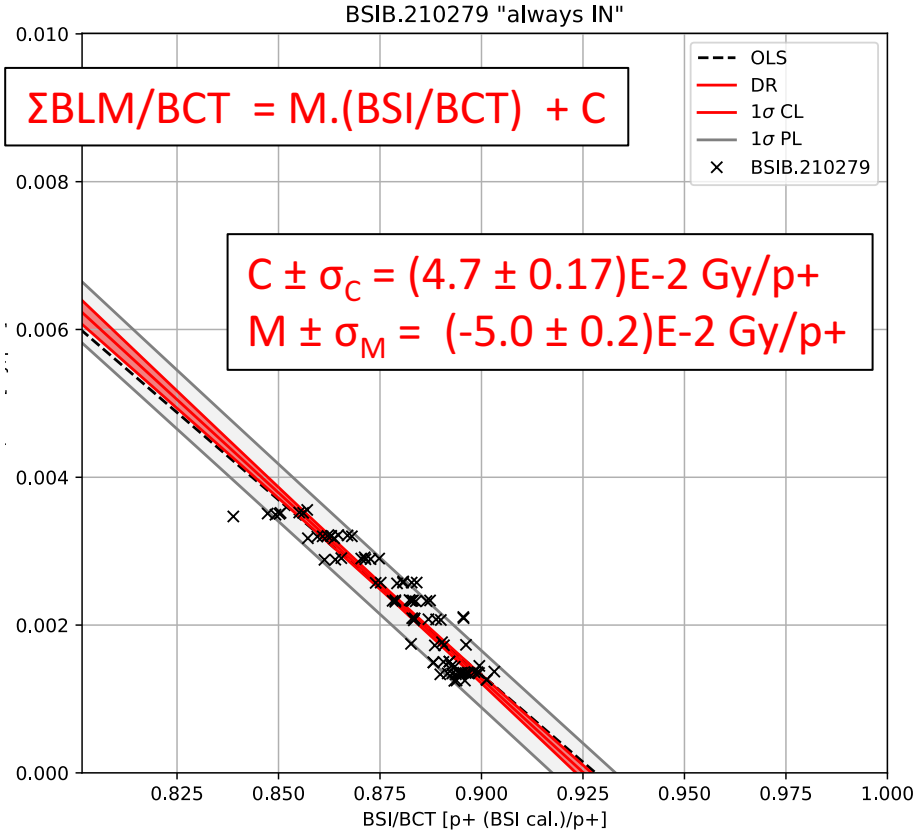

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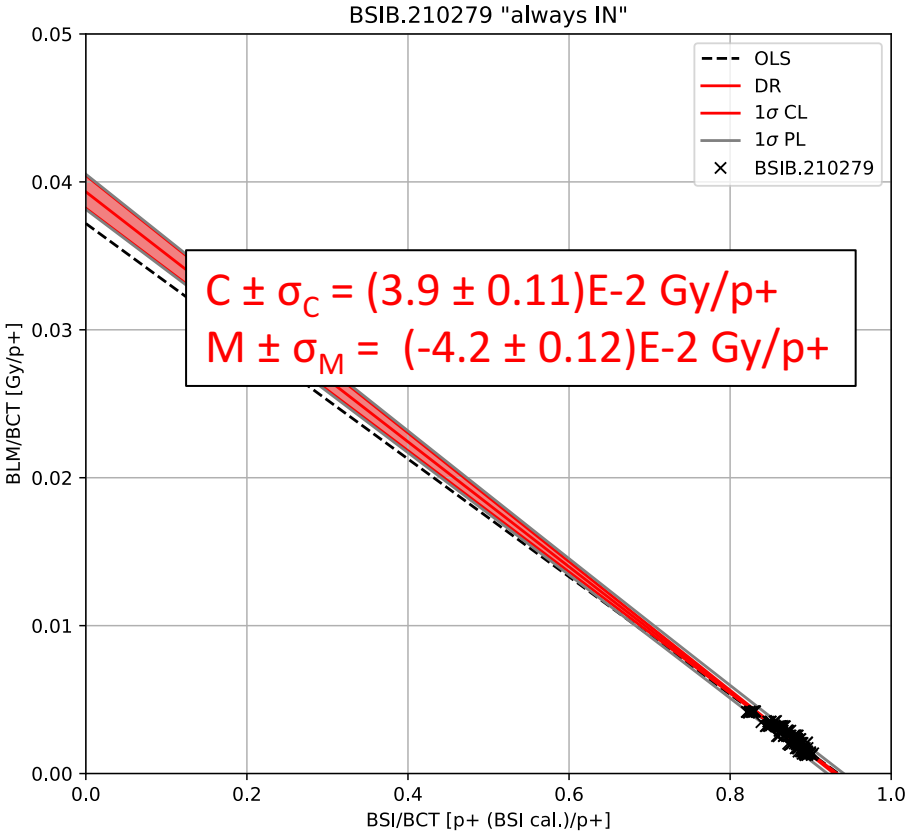
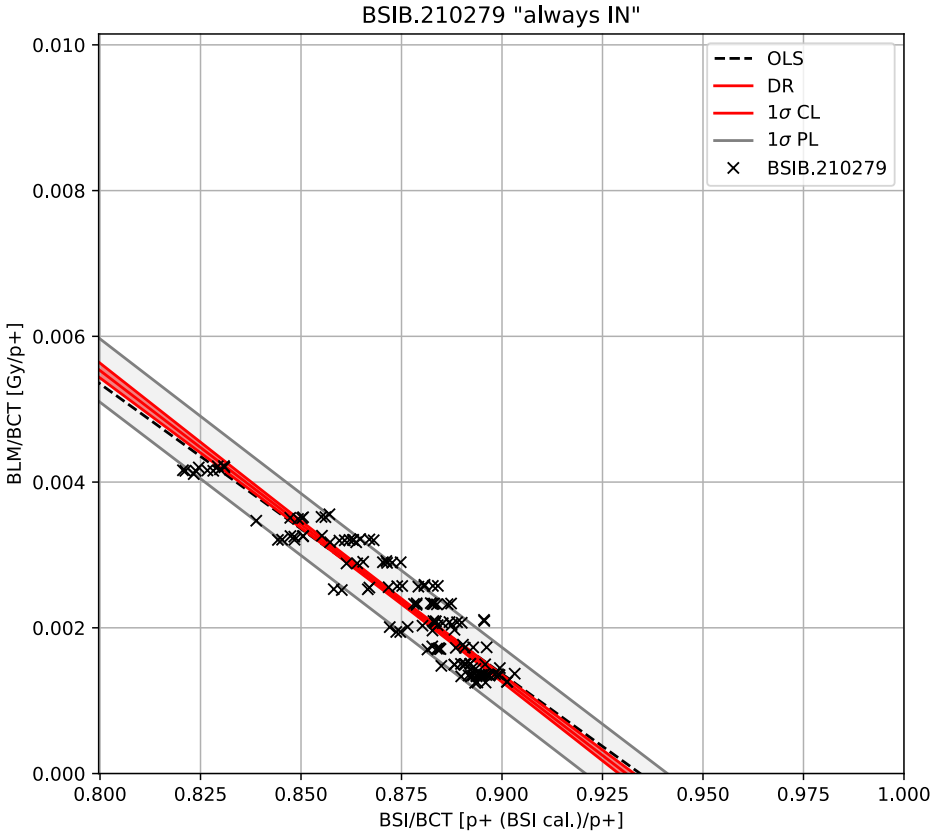
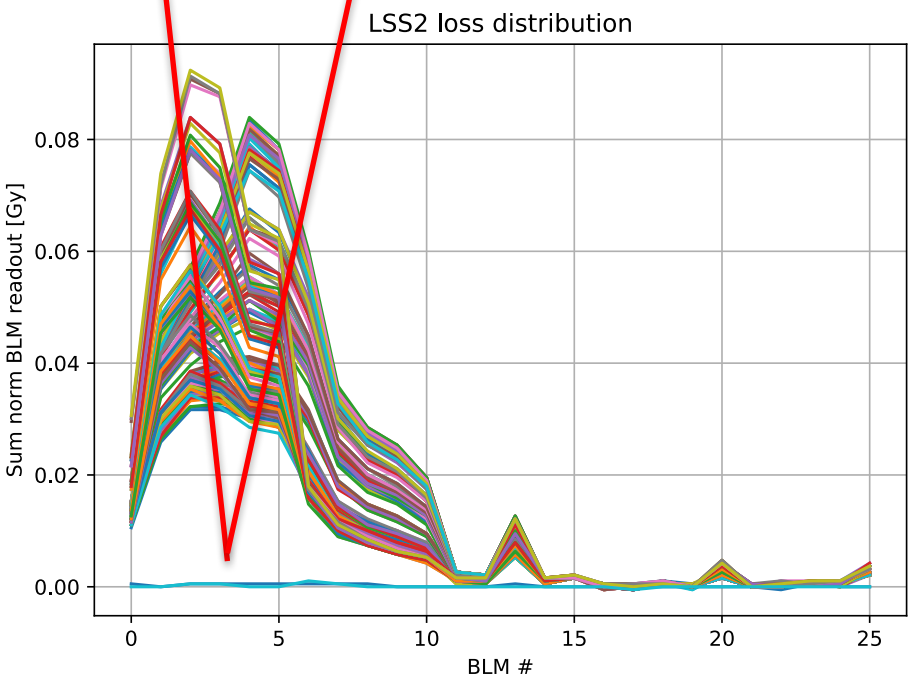




LSS2 Loss Distribution

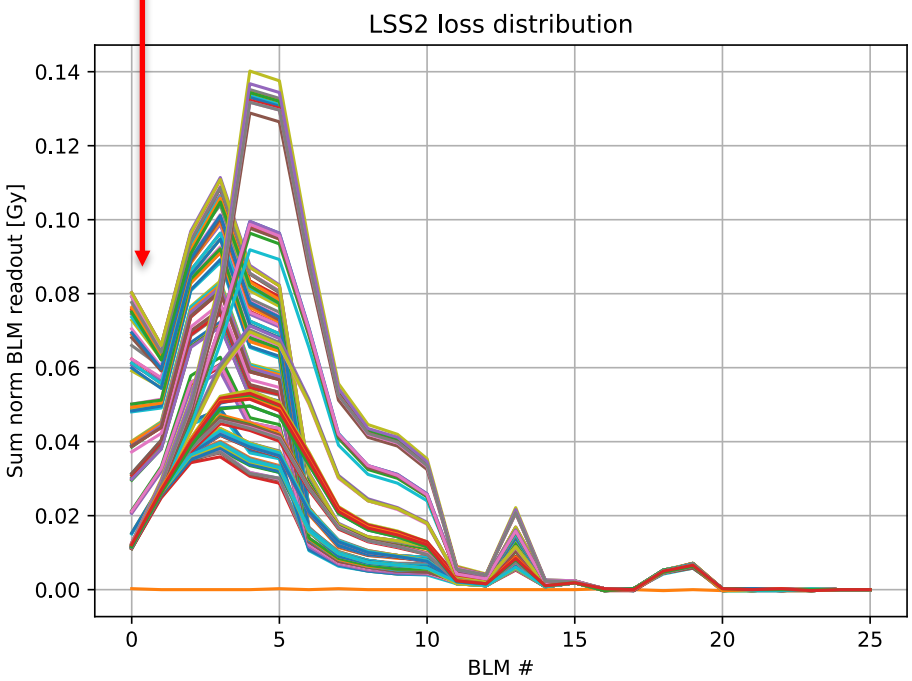
Towards extracted beam

Towards circulating beam



2016

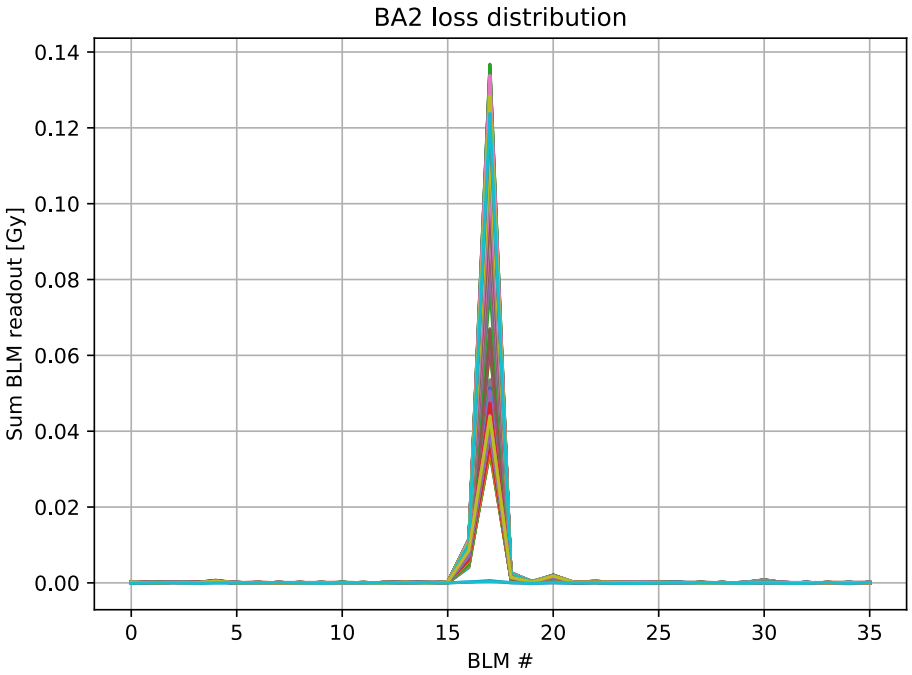
ZS1 and ZS2 BLM readings strange this year?!



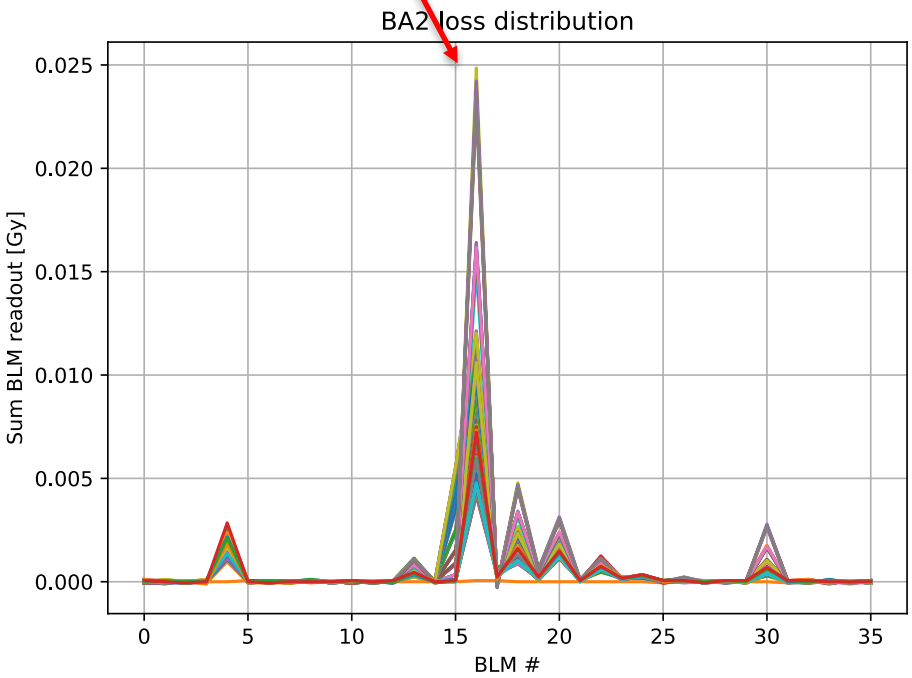
2017

Sextant 2 Loss Distribution

Far lower losses at QDA,219
(intensity roughly 2E12 ppp in both MDs)



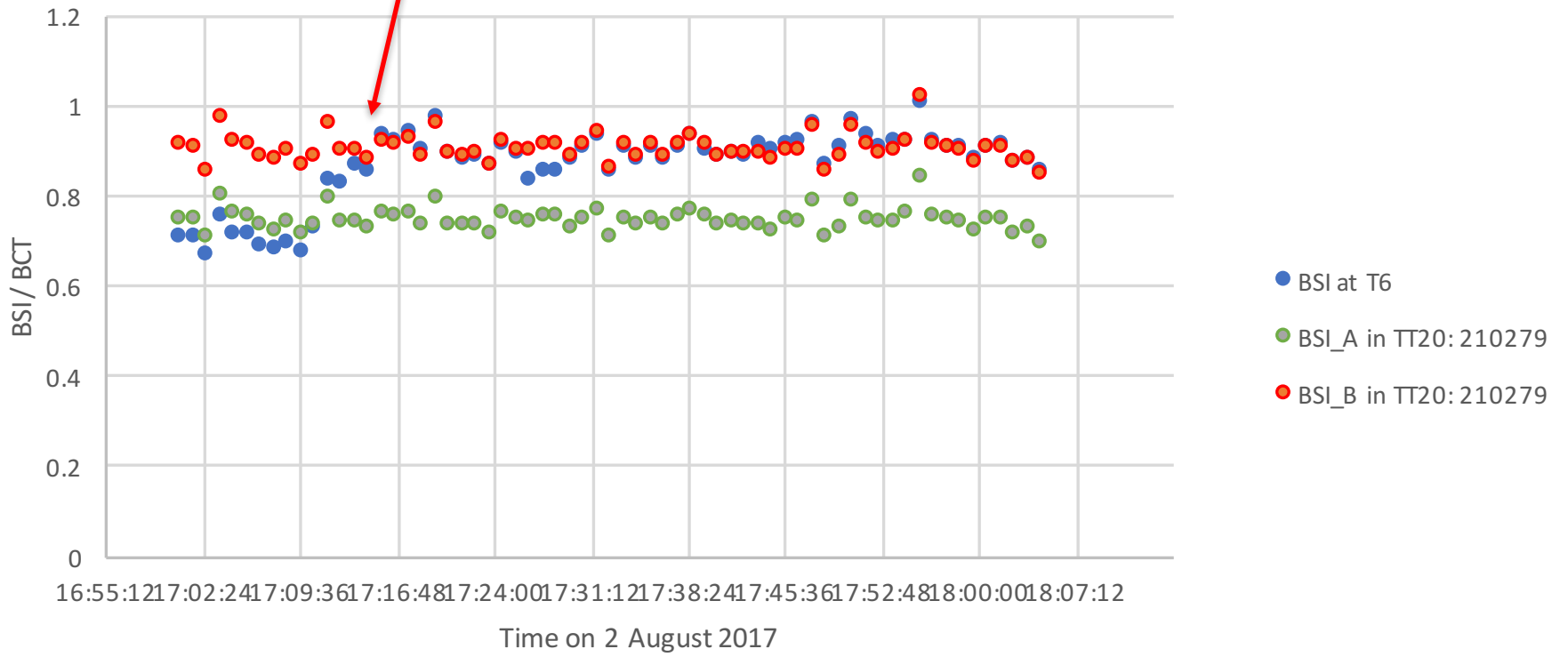
2016



2017

Steering During SHiP TT20 optics MD

TT20 transfer line steering achieved close to 100% transmission from BSIB.210279 and BSI at T6



If we assume the TT20 SHiP optics was close to lossless after steering, this might imply that the we can trust the T6 target BSI reading to the same level as BSIB.210279, i.e. to within 7%... Can we repeat this to T2 and T4?