Error models

Outline

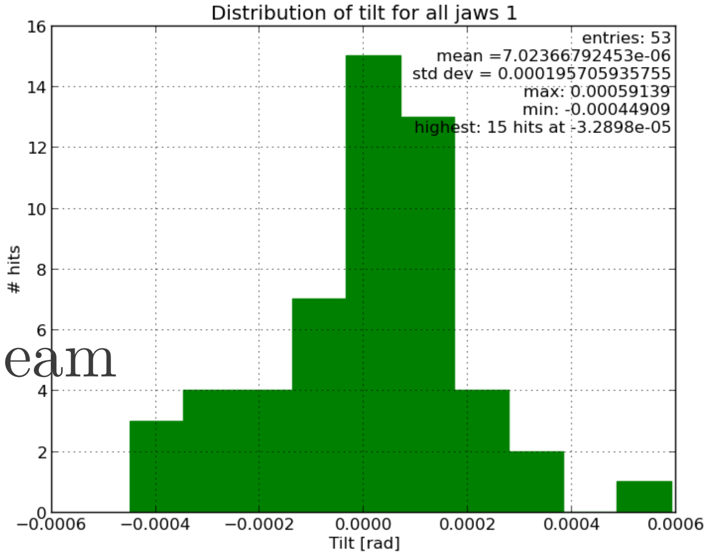
- Introduction
- Presentation of the different error models
  - Independent effects on simulations
- Combined error models
  - Combined effects on simulations
  - Emphasis on TCLD IR7
  - Non-flatness
- Conclusion

Introduction

- Collimation cleaning simulations of ATS, Beam 1
- Loss clusters downstream IR7
- Can be cured by 11 T dipoles + TCLD collimators
- Add error models of collimator alignment to simulations...

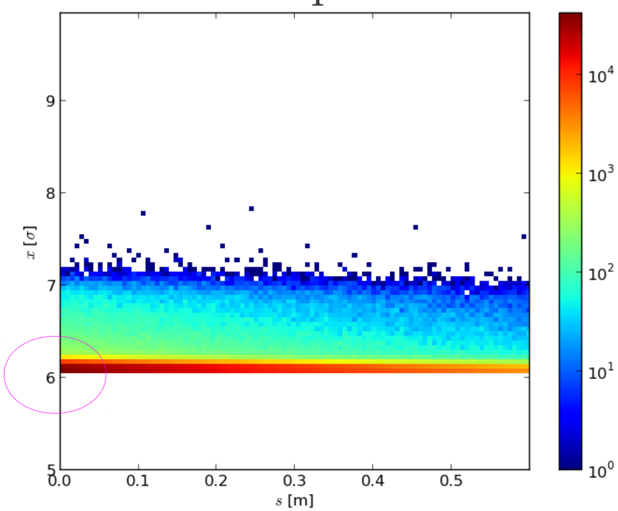
Error models in simulation
(from C. Bracco's PhD thesis)

- Gap: error on the size of the collimator gap
  - Standard deviation: 0.1σ
- Offset: error on the position of the beam centre
  - Standard deviation: 50 µm
- Slices: error on the flatness of the jaw
  - 2^{nd} order polynomial: $4\cdot10^{-4}\left(\frac{s^2}{l}-s\right)$
  - fitted linearly by 4 slices
- Tilt: error on the angle between jaw and beam
  - Standard deviation: 200 µrad



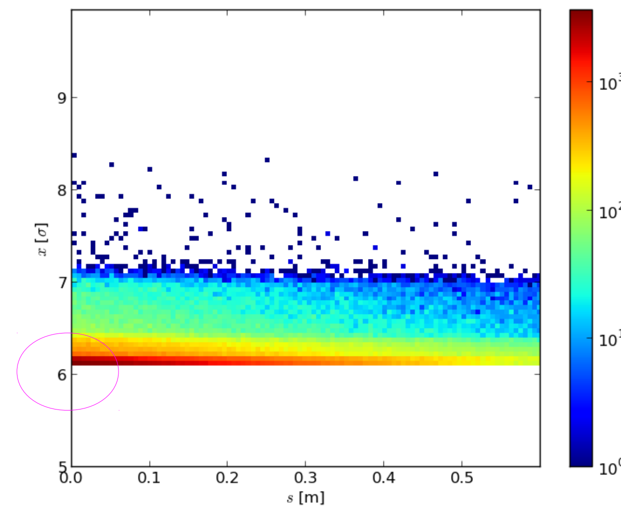
Impacts on the left jaw of the TCP
Setting: 6 σ

Gap

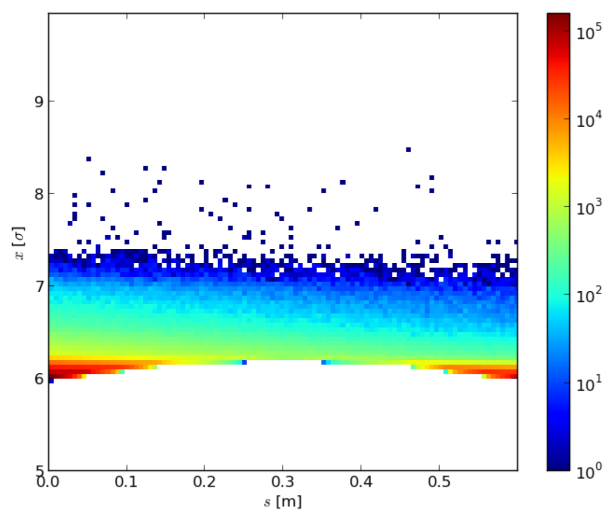


Not 6 σ any more

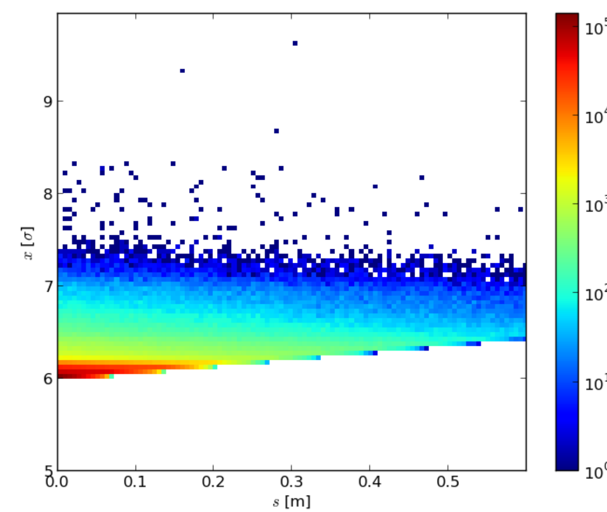
Offset



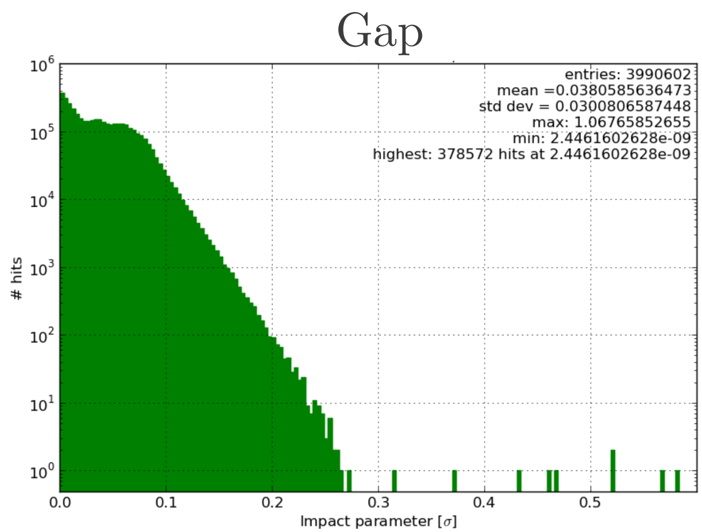
Slices

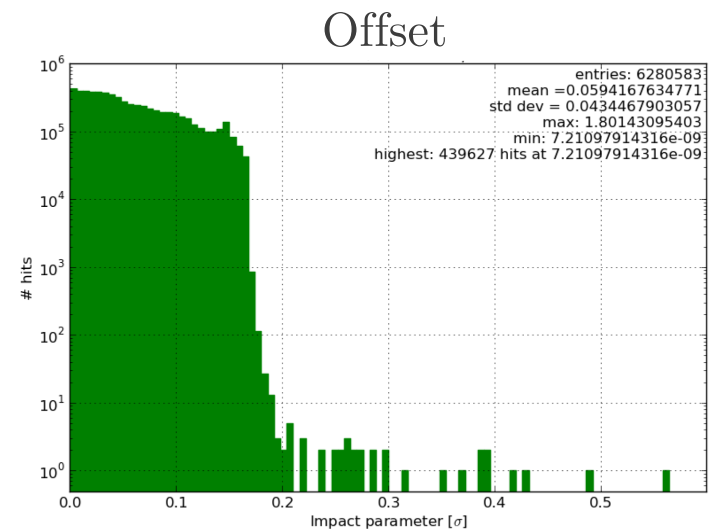


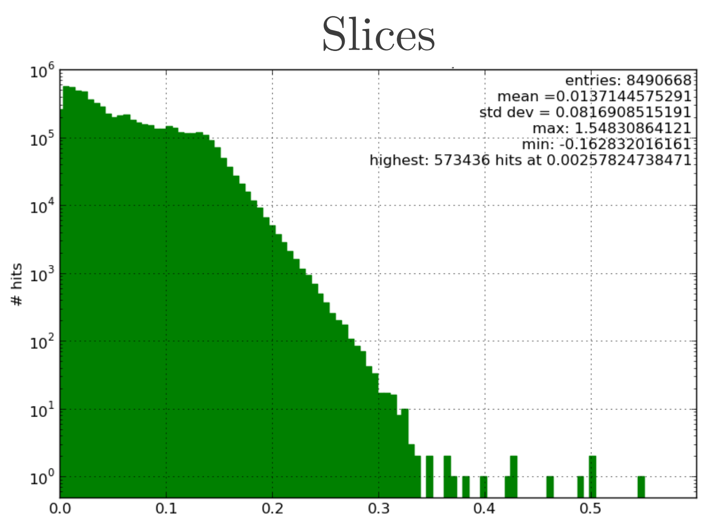
Tilt

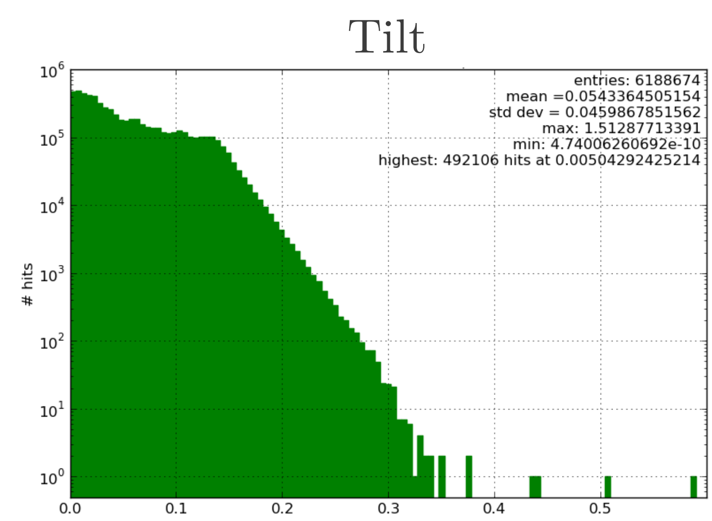


First impacts on TCP.C6L7.B1

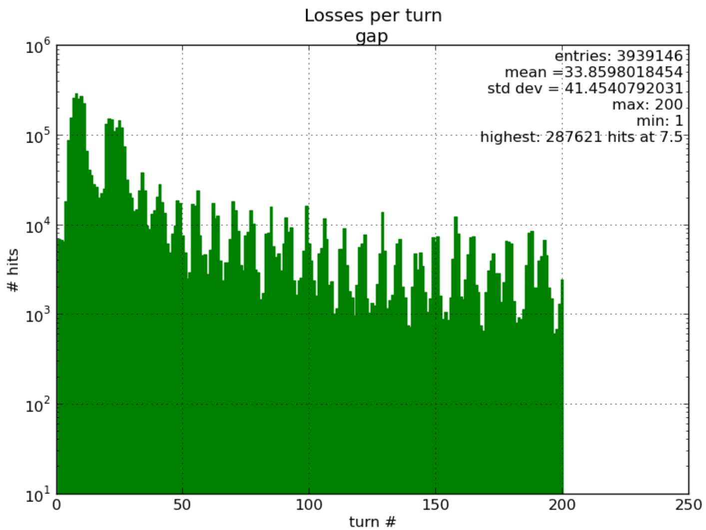




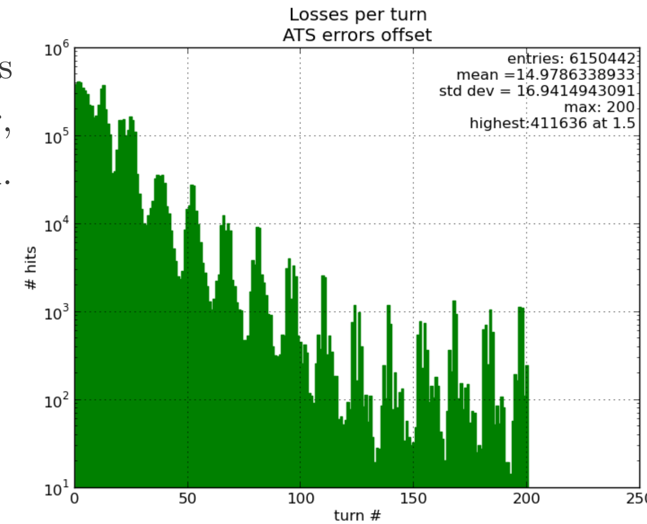


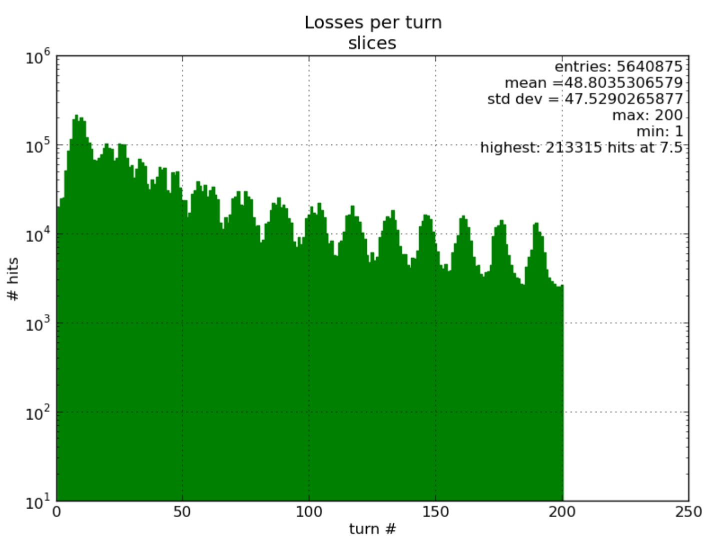


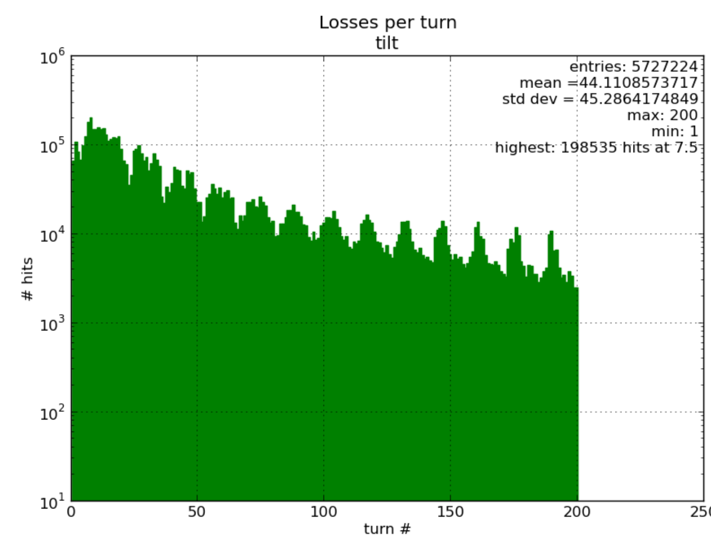
Distributions of losses per turn



With offset error, one jaw is used more than the other, but cleaning is still good.

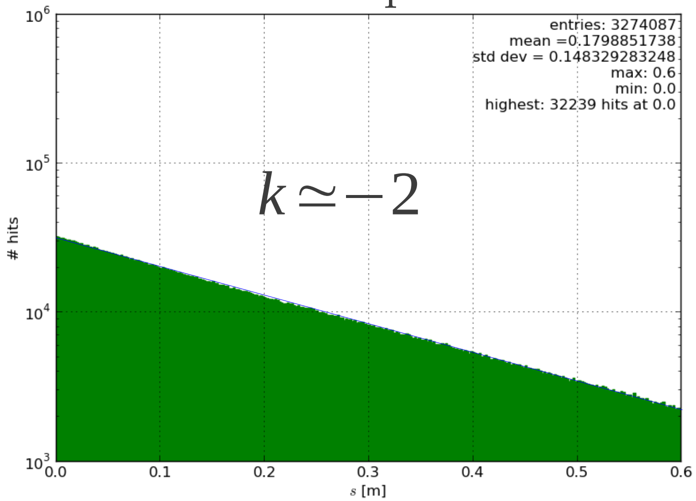






Longitudinal distribution of particles absorbed in TCP.C6L7.B1

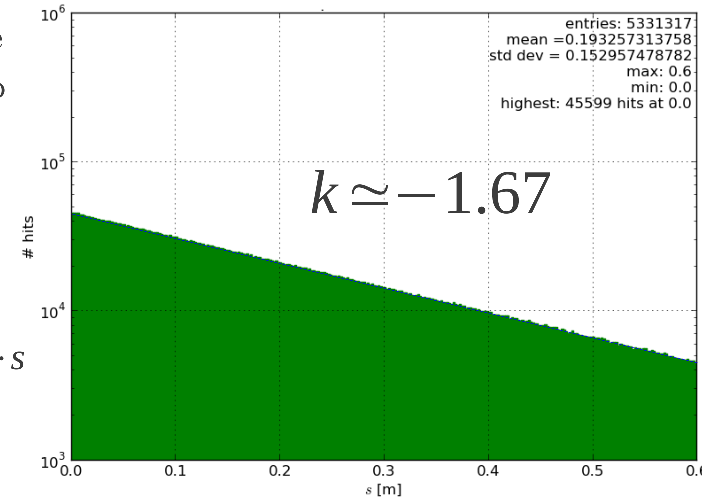
Gap



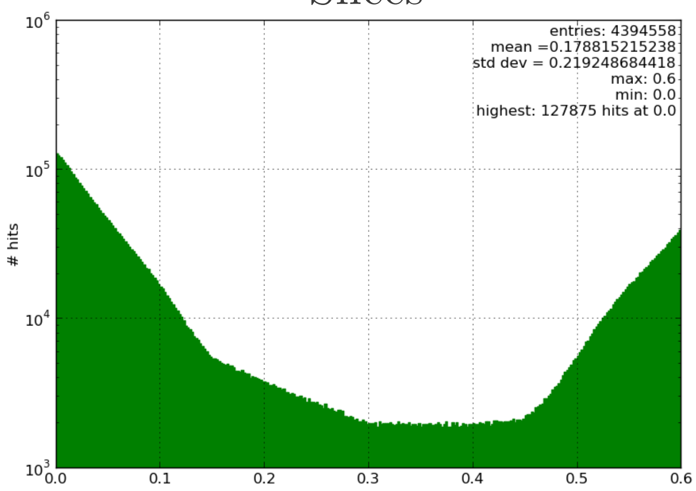
More particles are absorbed with gap than with offset

$$N \simeq N_0 \cdot 10^{k \cdot s}$$

Offset



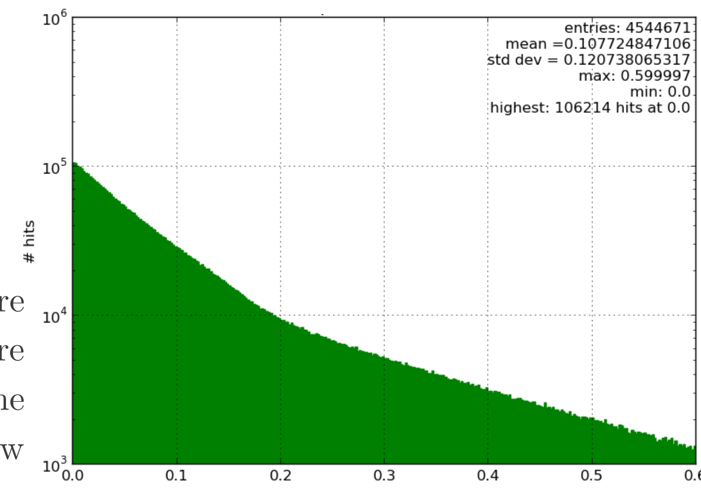
Slices



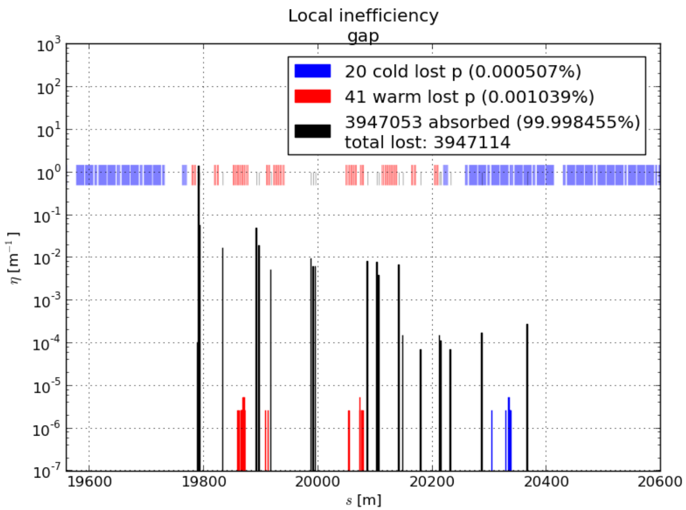
Slices are clearly visible

With tilt, more particles are absorbed at the beginning of the jaw

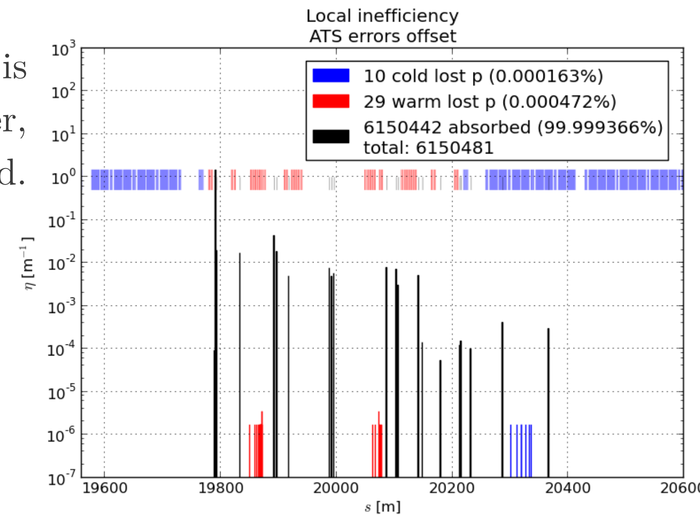
Tilt

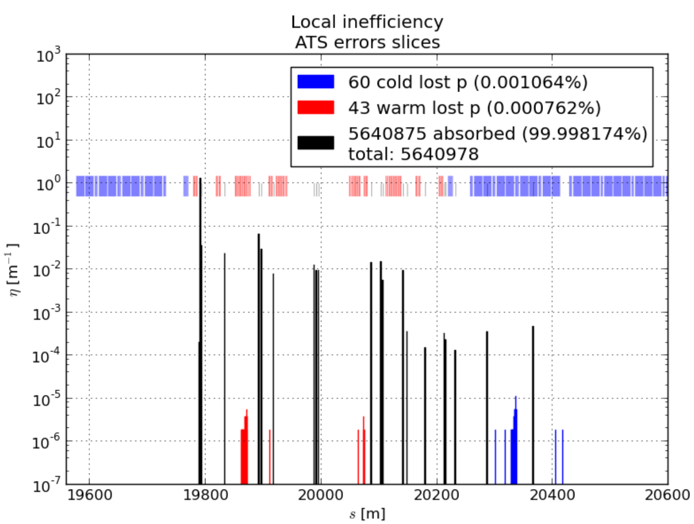


Loss maps of IR7

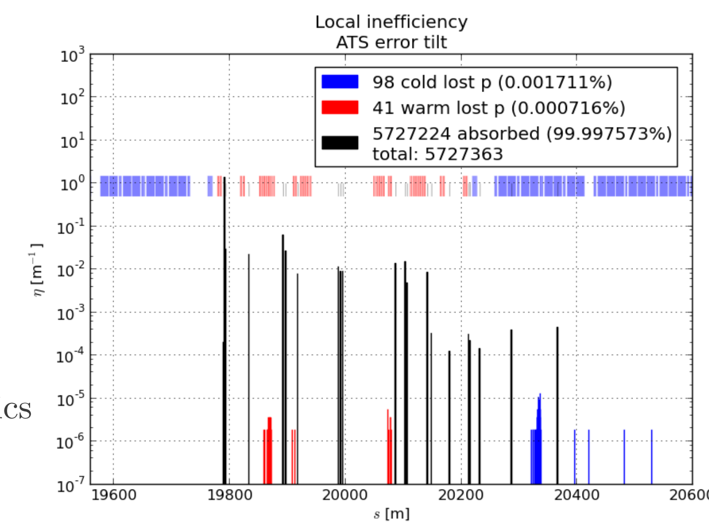


With offset error, one jaw is used more than the other, but cleaning is still good.

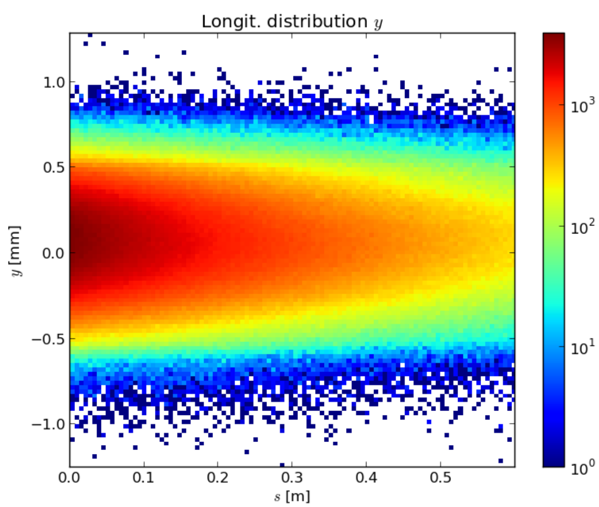


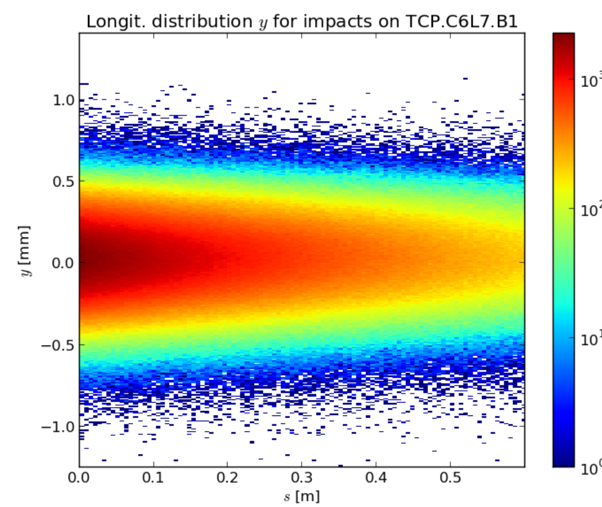


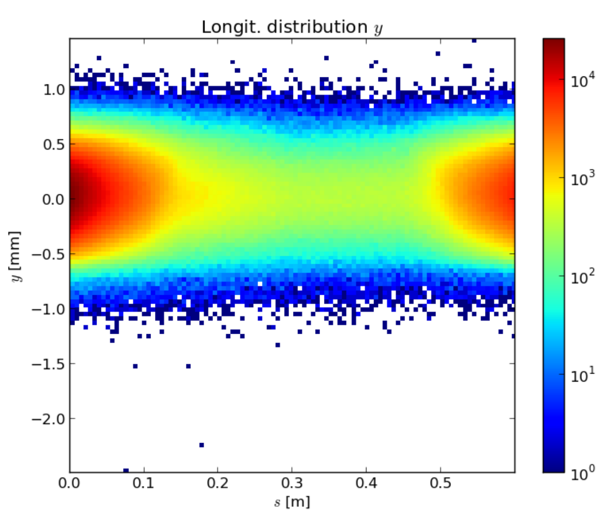
(Could do with more statistics or without TCRYO)



Impacts on the TCP (vertical plane)

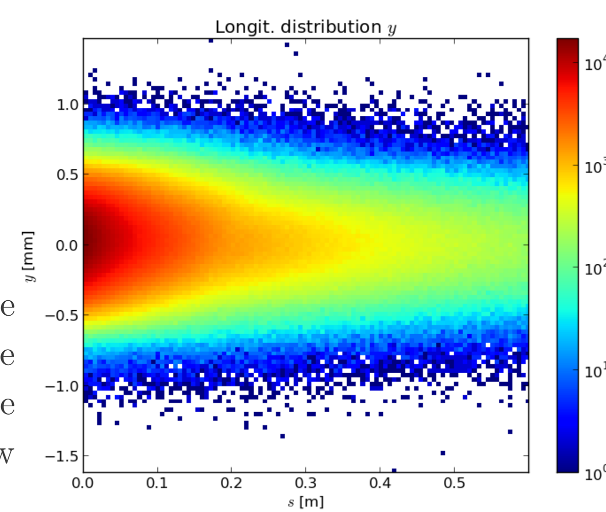




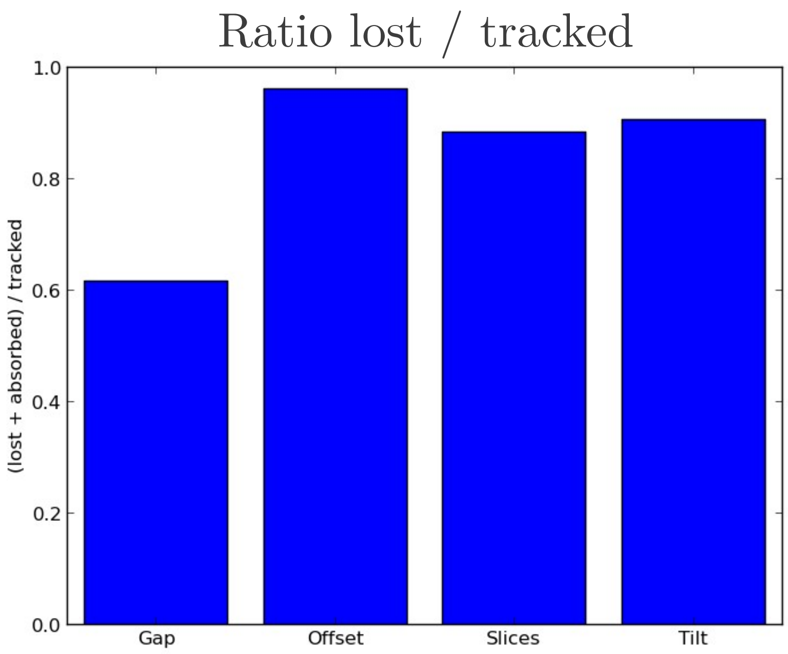


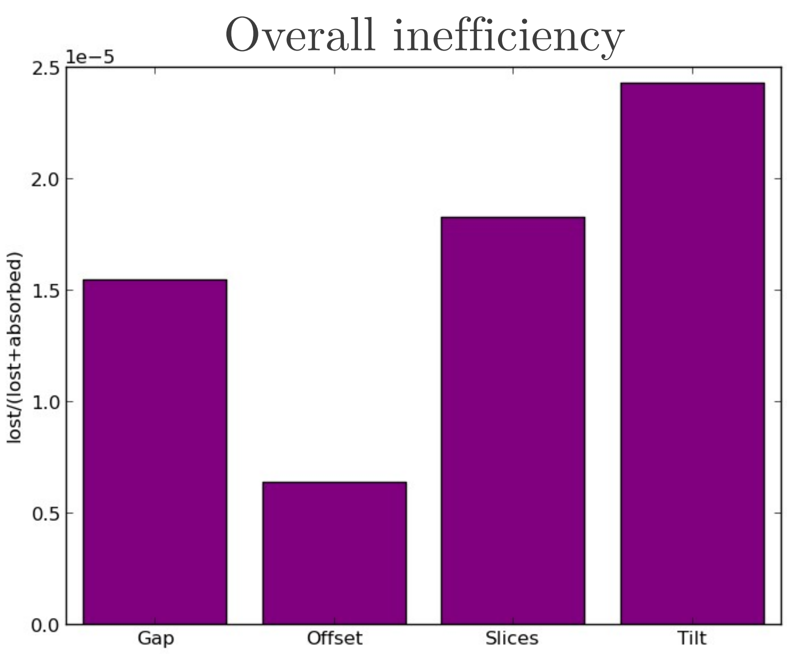
Slices are clearly visible

With tilt, more particles are absorbed at the beginning of the jaw



Statistics





- Error on gap = bigger collimator setting
- Offset = favouring one jaw
- Slices and tilt have similar effect: less material

- Offset gives best cleaning
- Tilt gives worst cleaning
- Slices = higher order of tilt (better cleaning)

Realistic error models for LHC collimators

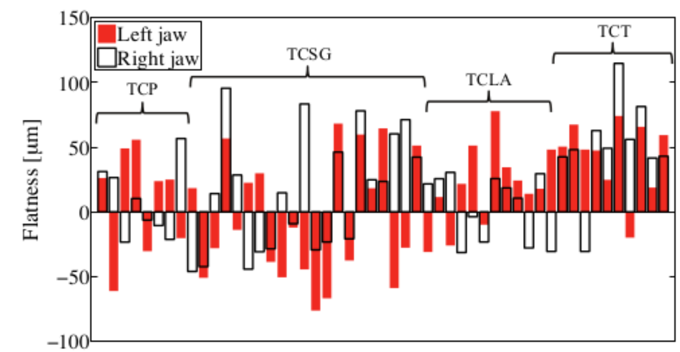
TCLD
Other collimators

- Open, or set at 15 σ
- Worst case situation, to compare with the no-error case (10 and 15 σ)
- Reality should be in between two cases
- Simulations: 100 cm jaws
  - current model is 80 cm
  - both values give similar results (FLUKA)
- Global inefficiency strongly dependent on the presence of the TCLD

Type	Setting
TCP IR7	6
TCSG IR7	7
TCLA IR7	10
TCP IR3	12
TCSG IR3	15.6
TCLA IR3	17.6
TCL	10
TCSTCDQ	7.5
TCDQ	8
TCT IR1/5	8.3
TCT IR2/8	12.0

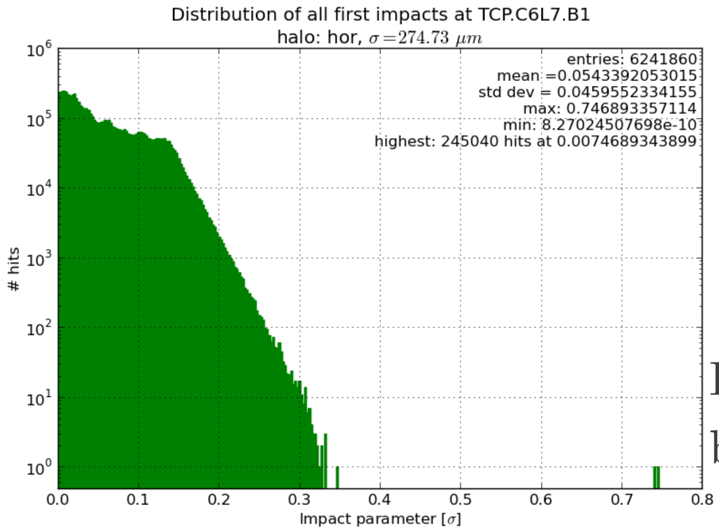
Combined error models

- Based on experimental data (C. Bracco, PhD thesis)

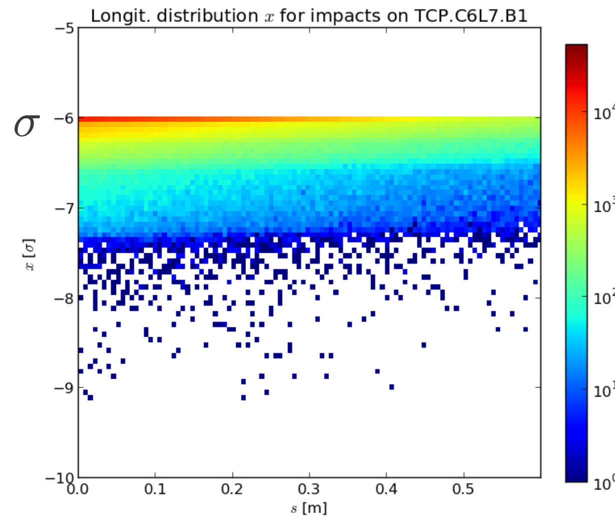


- Error on flatness:
  - Mostly deformed towards the beam (2/3)
  - Average absolute flatness: 40.3 ± 22.2 µm
  - Modelled as parabola with maximum: 10 ppm (worst case scenario)
- Error on gap: 0.1σ
- Offset (beam centre): 50 µm
- Jaw angle: 200 µrad
- Different seeds for the random errors

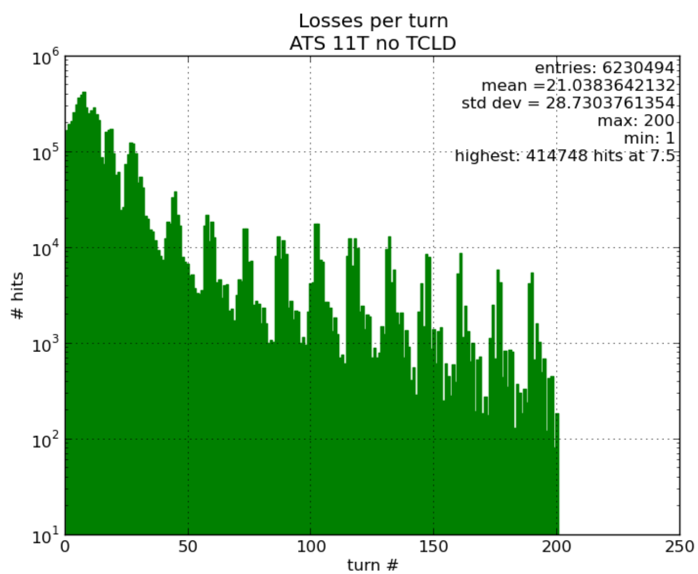
No error, Horizontal B1 (for reference)

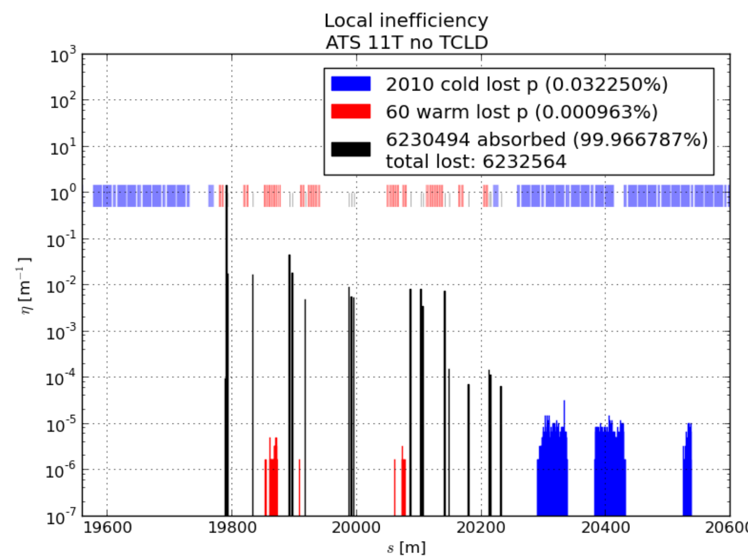


Flat jaw at exactly 6 σ

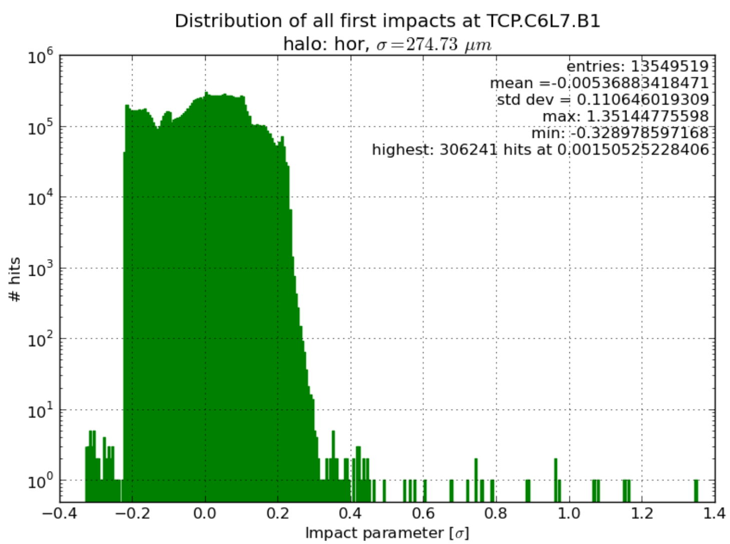


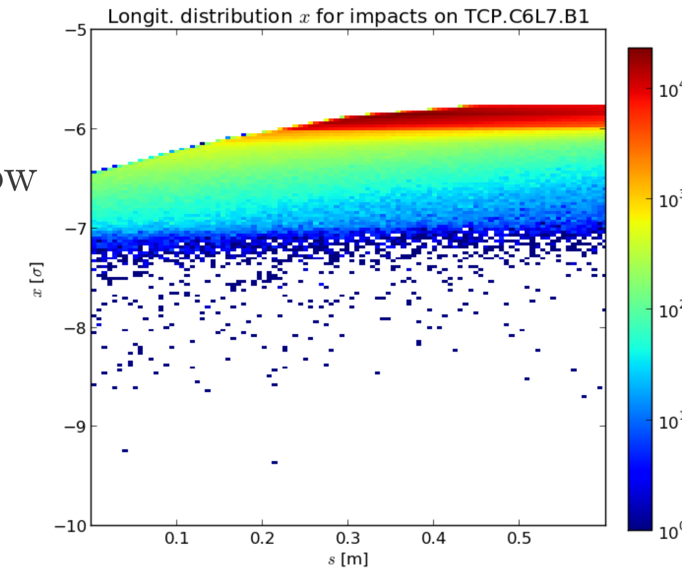
First impacts are high between 0 and 0.15 σ



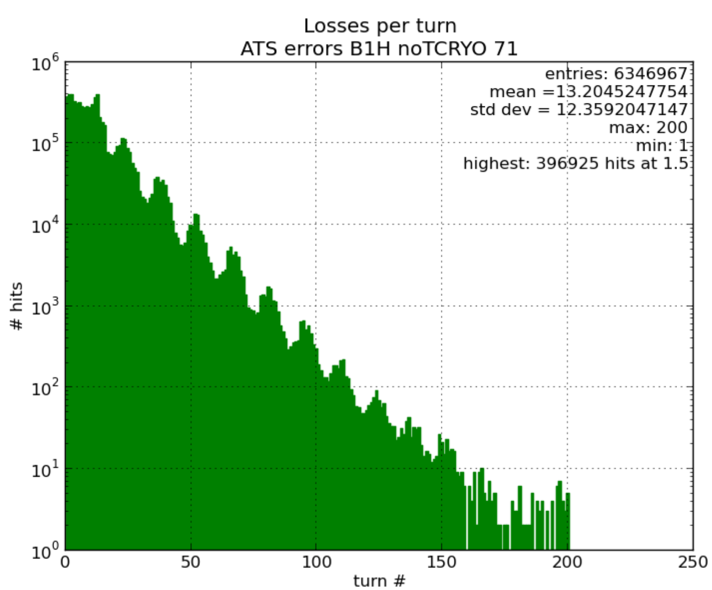


Result example:
B1 horizontal, no TCRYO

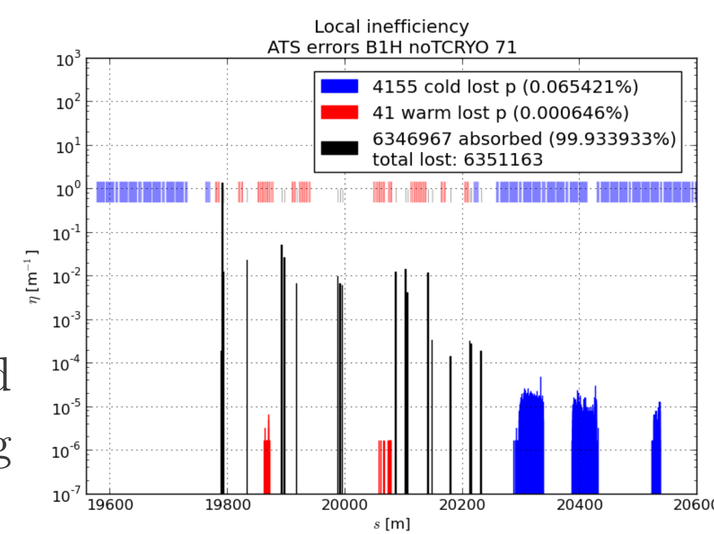




Impacts on primary show non-flatness + tilt



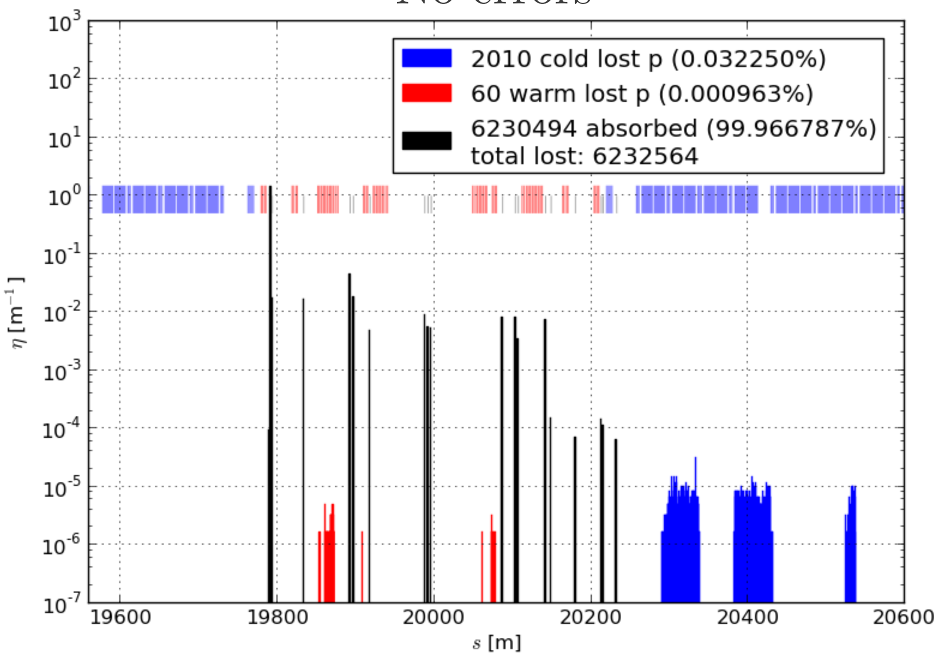
Losses per turn



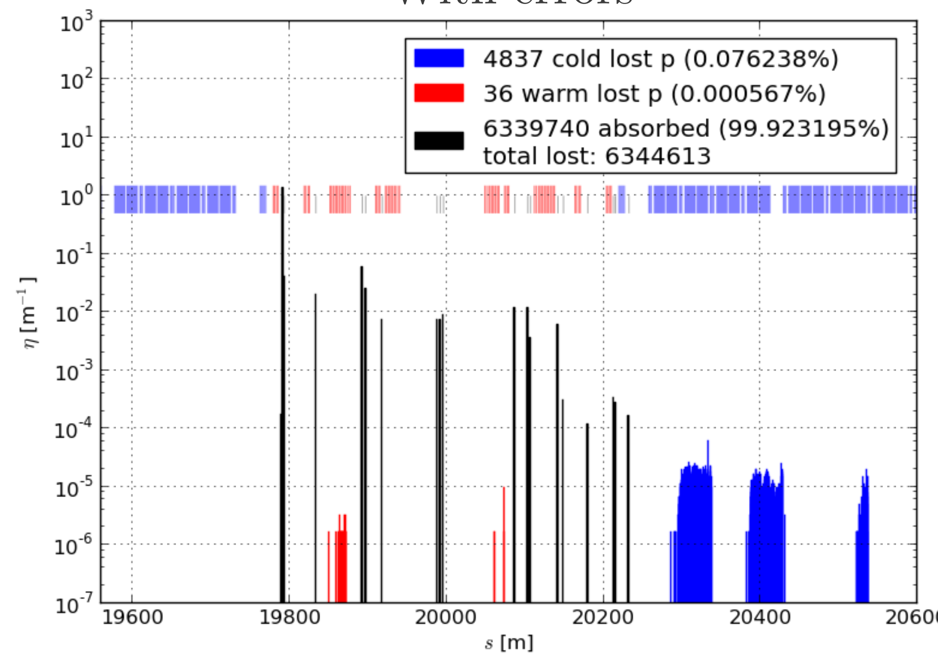
Deteriorated cleaning

Loss maps IR7, no TCRYO with and without errors

No errors



With errors



Global inefficiency: 3.225e-4

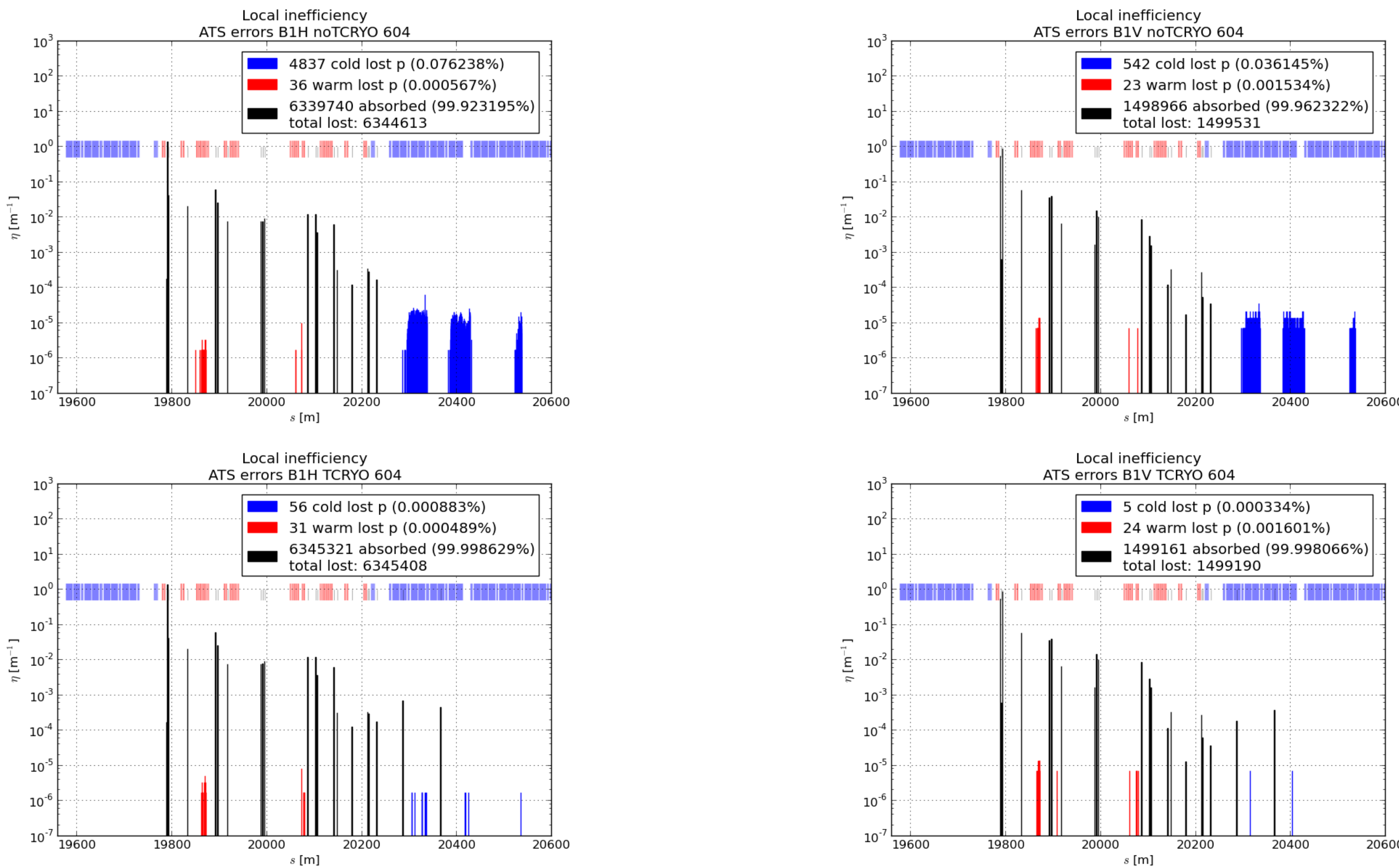
Loss clusters under 1e-5

Global inefficiency: 7.624e-4

Loss clusters above 1e-5

Cleaning deteriorates with error models

Loss maps for four cases (same seed)



Even with errors and at 15σ, the TCLD provide a good protection

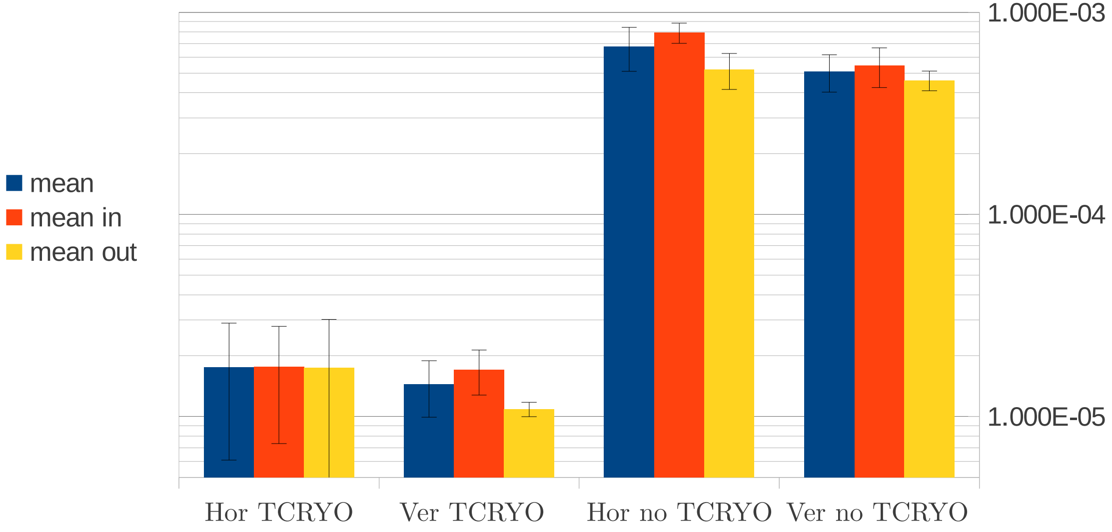
Statistics

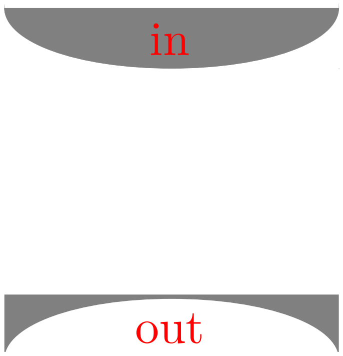
- Global inefficiency

	Hor, no TCRYO	Ver, no TCRYO	Hor, TCRYO	Ver, TCRYO
Mean	6.756e-4	5.086e-4	1.753e-5	1.441e-5
Std. Dev.	1.659e-4	1.065e-4	1.144e-5	4.497e-6
Error	6.27e-5	4.025e-5	4.326e-6	1.7e-6

Observations on non-flatness

- 2nd order polynomial, two options: towards the beam, or away.
- Half of simulations in one case, half in the other
- Same maximum deformation
- On average, the deformation towards the beam provides a better cleaning efficiency (more material than other case)





Conclusions

- Error models deteriorate cleaning efficiency
- Worst case situation: all error models + setting at 15 σ
- Even in worst case, global efficiency improves by factor 30 to 45
- Local efficiency downstream IR7 improves even more (x100)

- Error models deteriorate statistics
  (equivalent different collimator / halo setting)
- Compensate? (aligment)
- 310 000 jobs, 2e12 particles, 800 years of CPU

Thank you!

Statistics

Gap

- Tracked: 6 400 000
- Lost: 3 947 114 (61.67 %)

Offset

- Tracked: 6 400 000
- Lost: 6 150 481 (96.10 %)

Slices

- Tracked: 6 393 600
- Lost: 5 640 978 (88.23 %)

Tilt

- Tracked: 6 329 600
- Lost: 5 727 363 (90.48 %)

All results
ratio lost/sent

Horizontal		Vertical	
B1H_TCRYO_1	0.948362313675	B1V_TCRYO_1	0.99958140625
B1H_TCRYO_28	0.387117461746	B1V_TCRYO_28	0.409967397023
B1H_TCRYO_45	0.858202029936	B1V_TCRYO_45	0.995526890262
B1H_TCRYO_604	0.991569156916	B1V_TCRYO_604	0.23448292042
B1H_TCRYO_71	0.994606975843	B1V_TCRYO_71	0.994606975842
B1H_TCRYO_72	0.101252688575	B1V_TCRYO_72	0.991525985394
B1H_TCRYO_864	0.998737560012	B1V_TCRYO_864	0.96894203125
B1H_noTCRYO_1	0.94838546875	B1V_noTCRYO_1	0.999586479796
B1H_noTCRYO_28	0.387040431975	B1V_noTCRYO_28	0.410120500401
B1H_noTCRYO_45	0.858190458617	B1V_noTCRYO_45	0.995600456478
B1H_noTCRYO_604	0.991544090068	B1V_noTCRYO_604	0.234395476941
B1H_noTCRYO_71	0.994557244688	B1V_noTCRYO_71	0.999950019664
B1H_noTCRYO_72	0.10121171875	B1V_noTCRYO_71	0.991446644664
B1H_noTCRYO_864	0.99874	B1V_noTCRYO_864	0.968934310905

All results
Global inefficiency

Horizontal		Vertical	
B1H_TCRYO_1	3.52735023308e-05	B1V_TCRYO_1	1.67260310504e-05
B1H_TCRYO_28	1.21100855214e-05	B1V_TCRYO_28	1.03132477105e-05
B1H_TCRYO_45	9.47893216183e-06	B1V_TCRYO_45	2.18342806374e-05
B1H_TCRYO_604	1.37108902765e-05	B1V_TCRYO_604	1.9344153163e-05
B1H_TCRYO_71	8.64301518656e-06	B1V_TCRYO_71	1.0161609921e-05
B1H_TCRYO_72	3.55083483215e-05	B1V_TCRYO_72	1.21390772504e-05
B1H_TCRYO_864	7.98048255631e-06	B1V_TCRYO_864	1.03206413634e-05
B1H_noTCRYO_1	0.00067203027777	B1V_noTCRYO_1	0.000483655358329
B1H_noTCRYO_28	0.00092473932545	B1V_noTCRYO_28	0.000679880499836
B1H_noTCRYO_45	0.000803848992371	B1V_noTCRYO_45	0.000638847020963
B1H_noTCRYO_604	0.00076864350904	B1V_noTCRYO_604	0.000376926494664
B1H_noTCRYO_71	0.000661103169435	B1V_noTCRYO_71	0.000388870117545
B1H_noTCRYO_72	0.000410817789955	B1V_noTCRYO_72	0.000510983787218
B1H_noTCRYO_864	0.000488040197733	B1V_noTCRYO_864	0.000481025404114