Loss maps of physics debris protons around ATLAS

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AFP proposal

AFP = Atlas Forward Physics

In addition to Roman Pots at 240 m (ALFA project, installed, run with special optics at low luminosity-low emittance), the AFP collaboration is proposing to install detectors at **220 and 420 m on both sides of ATLAS**

Proposed physics: mainly forward proton tagging, with nominal optics, both at intermediate and high luminosity

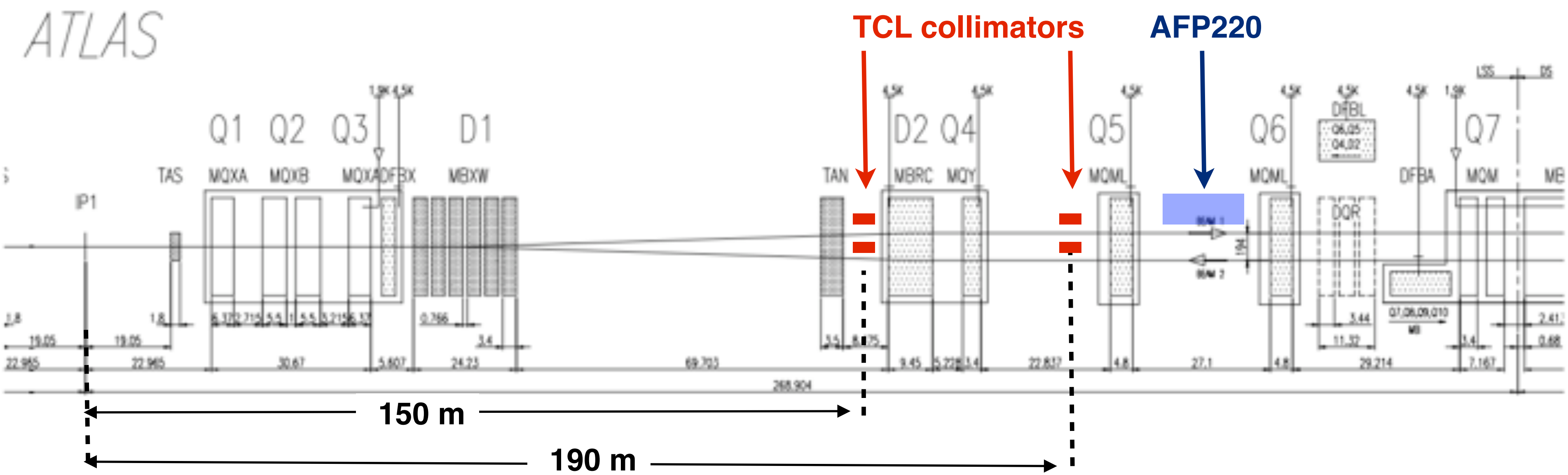
Proposed schedule: be ready for installation in 2010-2011 in compatibility with LHC sectors warm up

ATLAS internal review took place in February

Referees rose up many questions including impact of collimation system on proposed physics

AFP is supposed to answer the questions in the next few weeks in order to have ATLAS approval for a TDR (= funding from different institutes and good chances of approval by ATLAS and LHC)

TCL Collimator at 190 m from IP1



TCL4 and TCL5 are designed to protect D2, Q4, Q5, Q6 (and possibly other downstream elements down to the beginning of the arc) and RR regions from physics debris particles during high luminosity runs (L > 2e33)

- setting of both TCLs is negligible on AFP420 acceptance (Dx very small at TCL) and backgrounds from secondary showers(TCL are very far)
- setting of TCL4 has little impact on AFP220 acceptance
- impact of TCL5 on AFP220 is not negligible

Physics debris particles downstream ATLAS (and CMS)

Any p-p interaction has a probability to generate a forward proton with momentum offset dp/p. The protons will be intercepted (with a good approximation) by the first aperture restriction for which

$$x(s_a) \leq D_x(s_a) \cdot \frac{\delta p}{p_0}$$

1- All protons with dp/p > ~0.25 are intercepted by the TAN at 140 m

2- All protons with dp/p < ~0.01 potentially remain in the beam envelope and will be intercepted by IR3 collimators

3- (In between **1** and **2**) protons with 0.01 < dp/p < 0.25 are likely to be lost in the region from 150m to the first arc included and need to be cleaned to avoid quenches

TCL5 available studies

LHC-Project Note 208 (Jeanneret-Baichev, 2000), Using LHC optics V6.1

Need for protecting Q5 (at ~190 m) + MB.B8 (at ~ 280m)

they proposed the installation of TCL5 between Q4 and Q5, and looked at losses on Q5, MB.B8 and all the region downstream (up to ~ 700 m)

QUENCH LIMIT: 8e6 p/s/m (in reality it's difficult to assess a value valid for all magnets)

	WITHOUT COLLIMATORS	TCL5 AT 15 SIGMAS
1st highest peak [p/s/m]	4.2e7 in front of Q5	1.7e6 in front of Q5
2nd highest peak [p/s/m]	4.4e6 at MB.B8	0.8e6 at MB.B9
all other peaks well below quench limit		
losses integral (in p/s) for s>280 m (DS + ARC)	6.60E+07	1.70E+07

Later they discovered that also D2 and Q4 needed protection and the TCL4 was proposed (I did not find documentation

TCL5 available studies

LHC-Project Note 208 (Jeanneret-Baichev, 2000), Using LHC optics V6.1

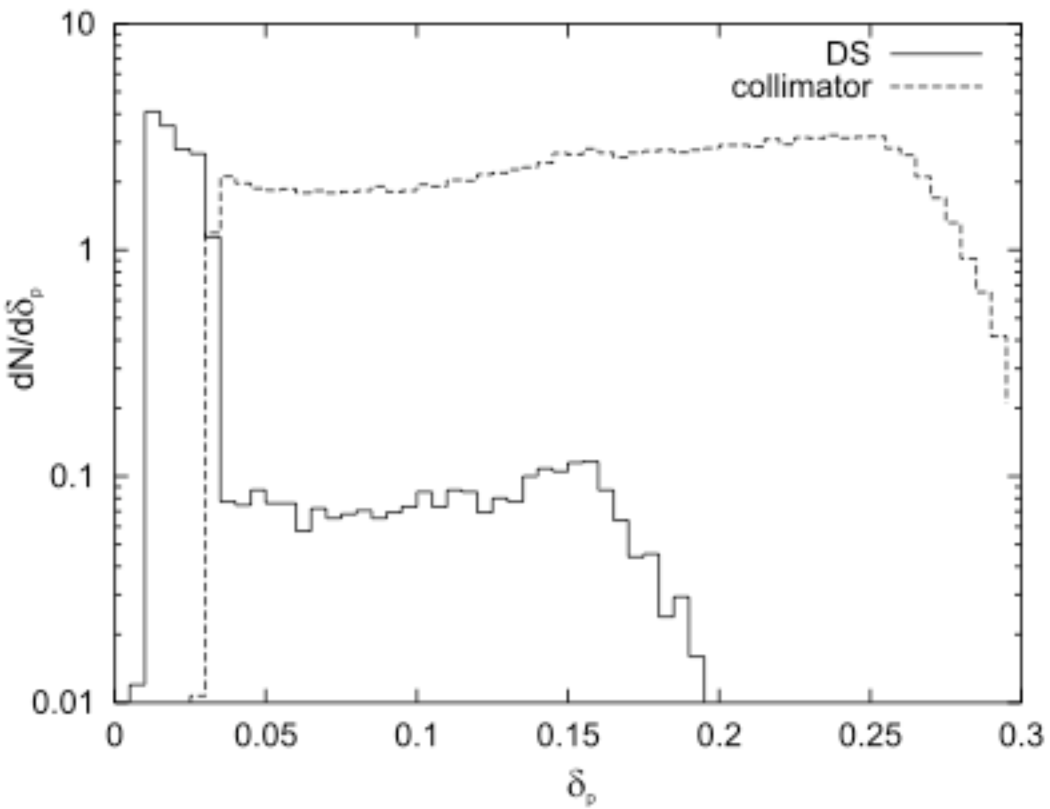


Figure 3: The momentum distributions of the lost protons. Dashed histogram - the protons intercepted by the collimator, solid one - those one lost in the dispersion suppressor and in the arc cells, including the protons which are reemitted by the collimator.

To me this says: less than 10% of protons scattered on collimator are lost in DS

My tracking simulations (2 weeks)

Loss maps of forward protons for different TCL4-TCL5 settings

I'm working on a cross-check between

1. **THINTRACK**
2. **PTCTRACK**
3. **On purpose tracking with a SECTORMAP**

In any case: I'm quite confident of results for dp/p<10%

Differences from available studies mentioned above:

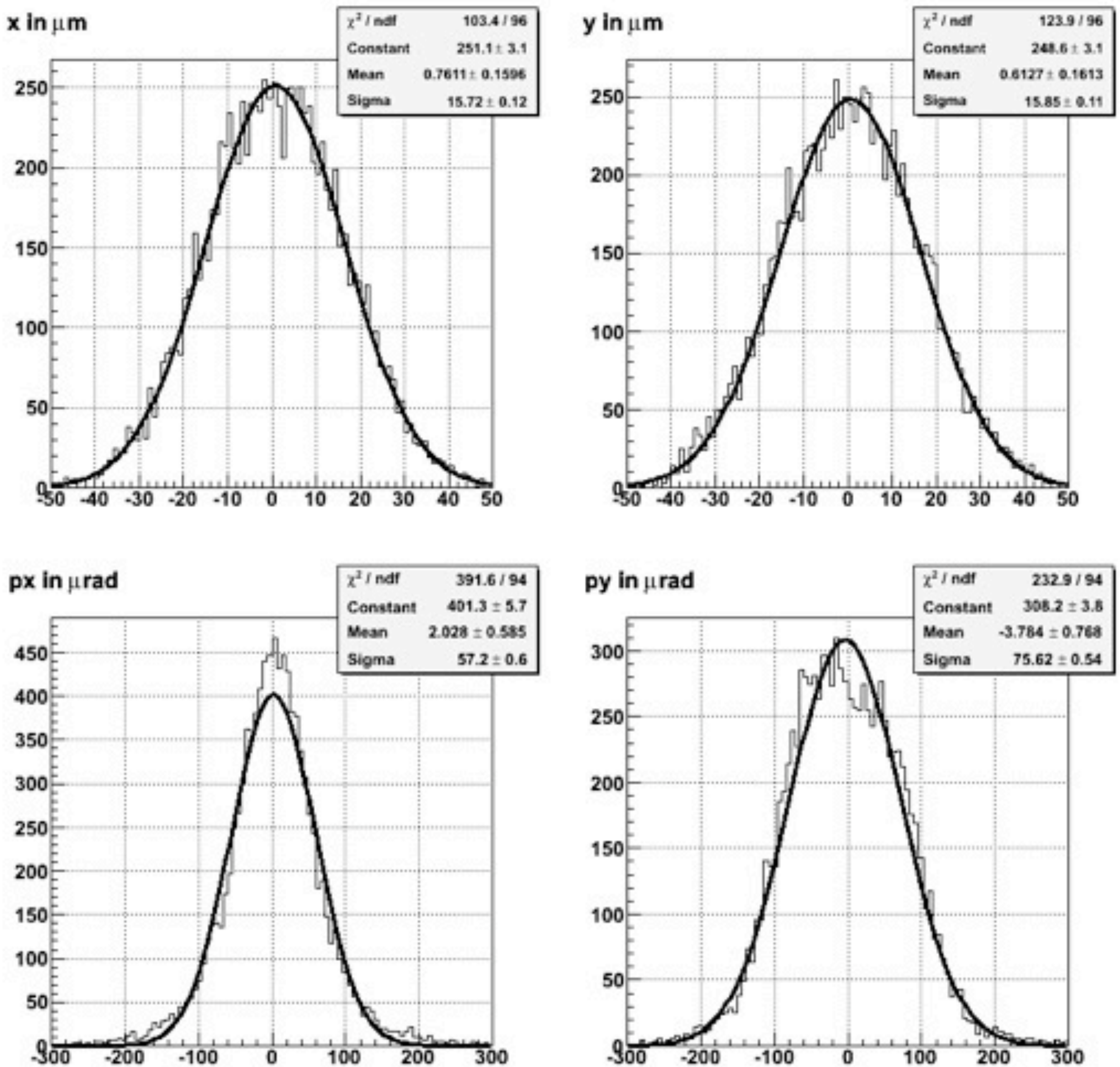
- new LHC optics : was 6.2, I'm using the last 6.503
- I only have collimators as black absorbers (they had scattering routine)
- p-p interaction source file:

I used DPMJET with 100mb cross section, that I transform to ~ 12 forward protons / bunch crossing

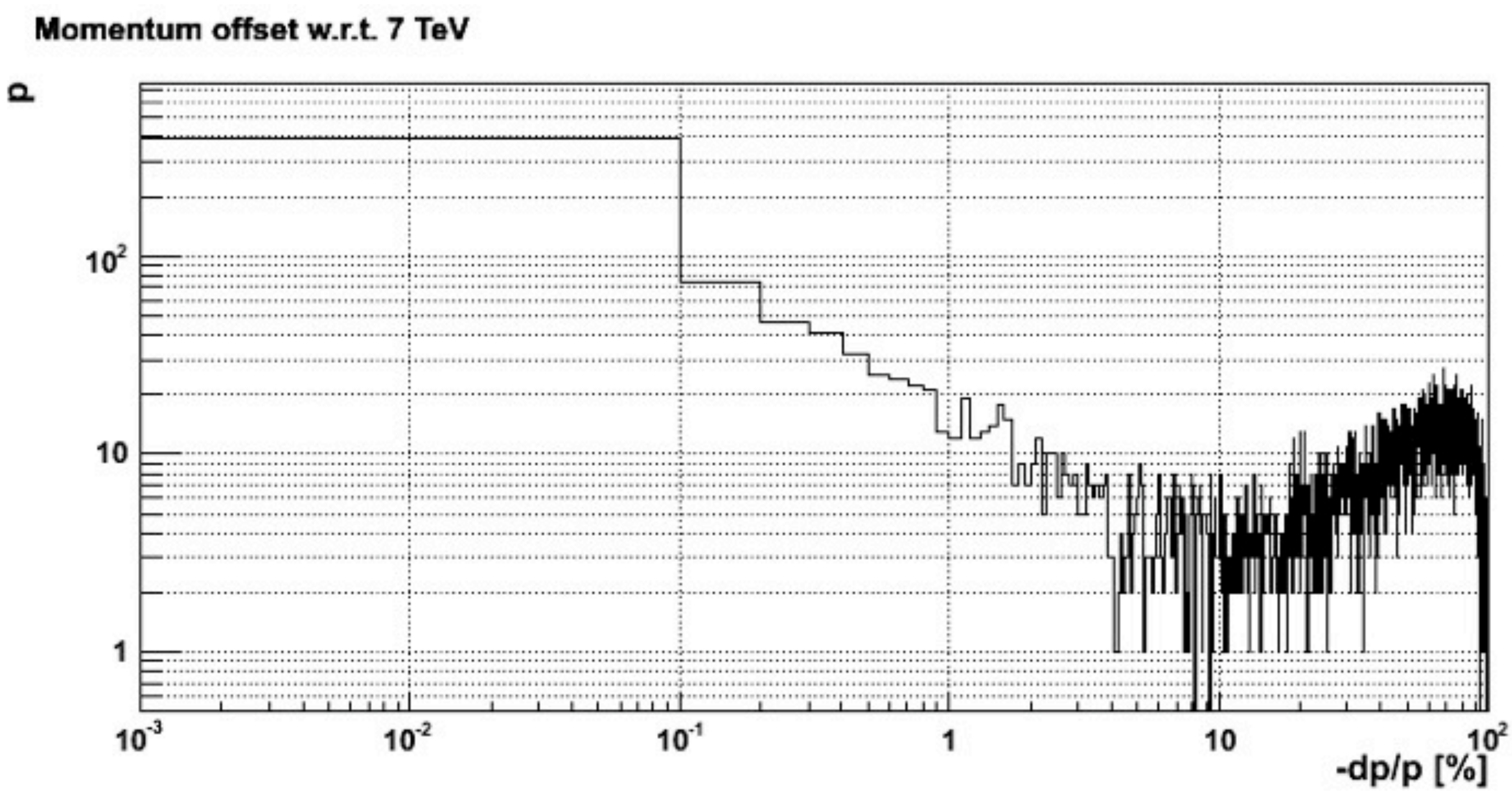
They quoted a rate of 3.5e8 inelastic events per sec that I assume gives 8.75 events/bunch crossing

All what I present here is normalized for Lumi=10**34

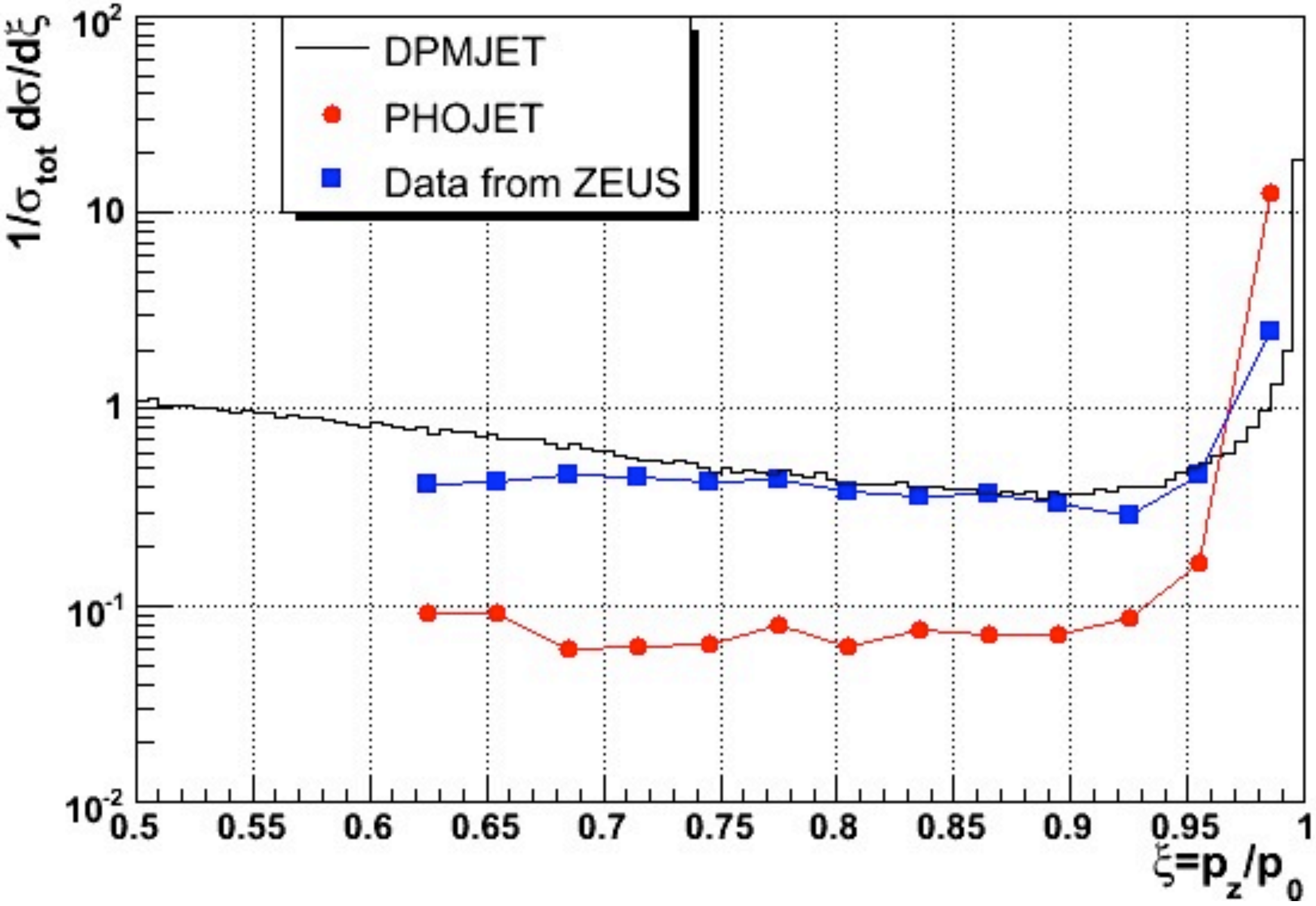
Initial distribution of protons



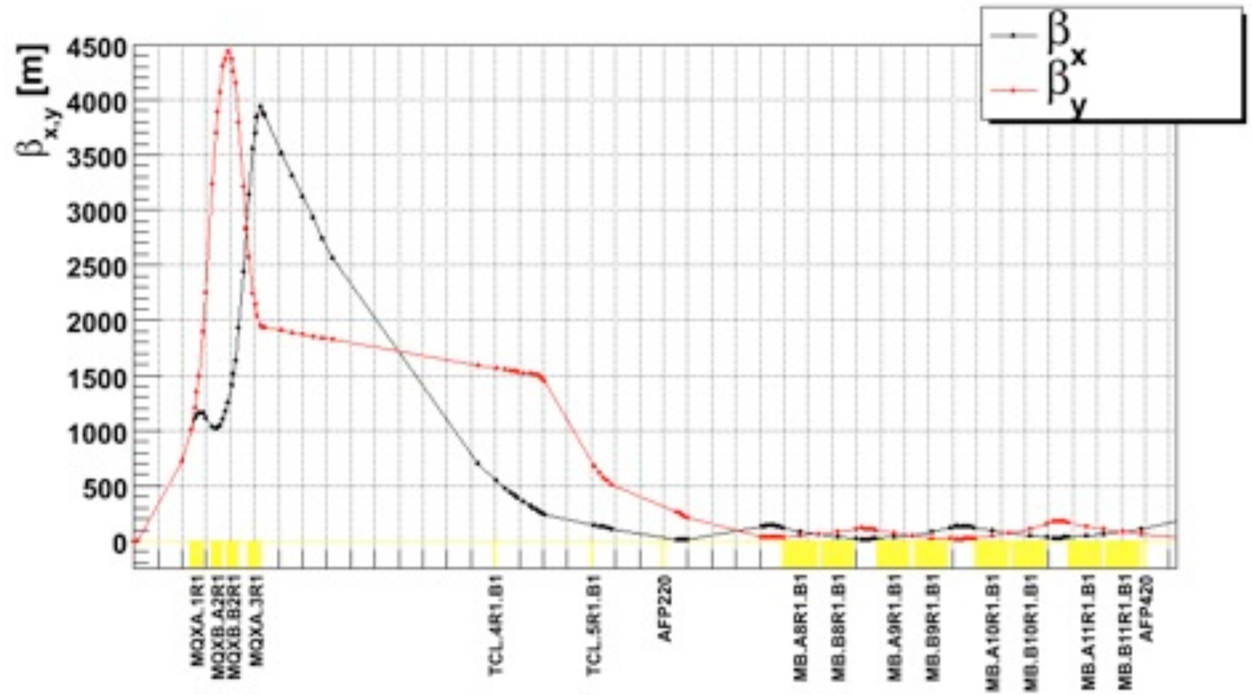
Initial distribution of protons

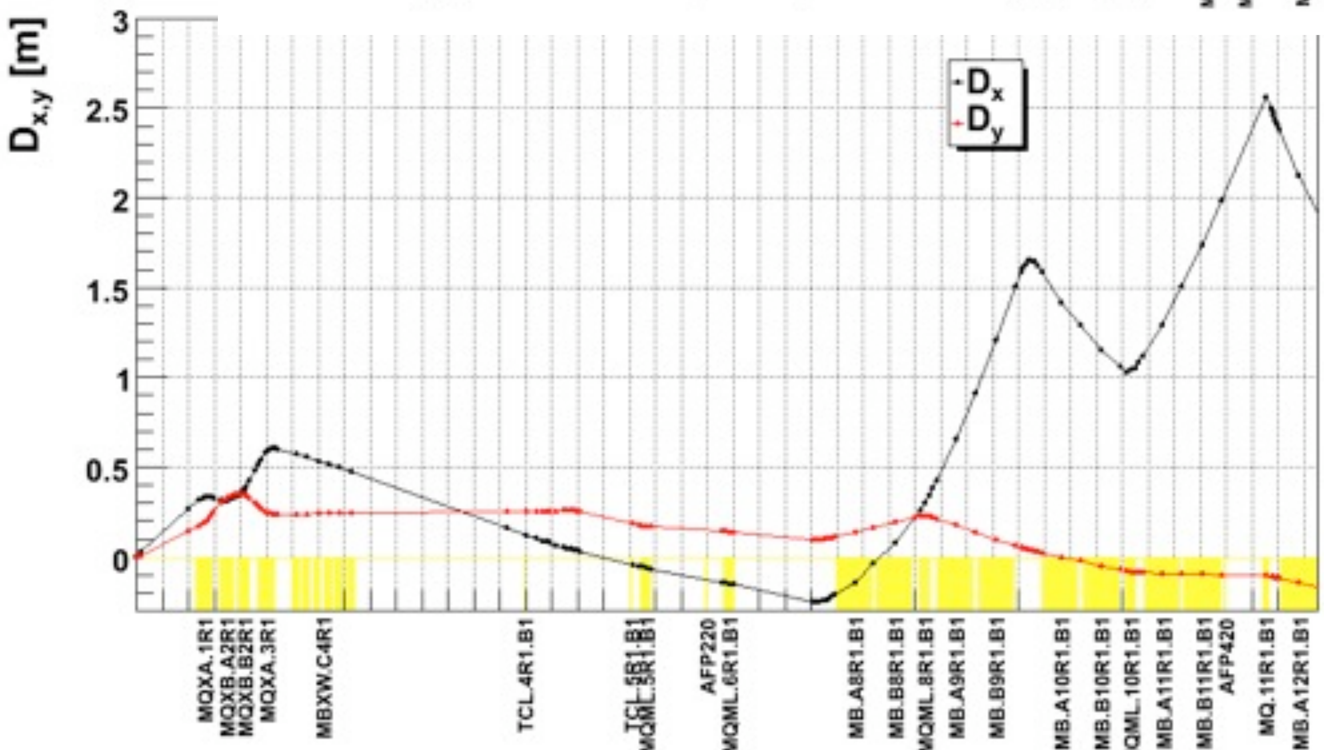


Initial distribution of protons: DPMJET reliability



Optics


$\beta_{x,y}$ [m]
β_x
β_y
4500
4000
3500
3000
2500
2000
1500
1000
500
0
MQXA.1R1
MQXB.A2R1
MQXB.B2R1
MQXA.3R1
TCL.4R1.B1
TCL.5R1.B1
AFP220
MB.A8R1.B1
MB.B8R1.B1
MB.A9R1.B1
MB.B9R1.B1
MB.A10R1.B1
MB.B10R1.B1
MB.A11R1.B1
MB.B11R1.B1
AFP420


$D_{x,y}$ [m]
D_x
D_y
3
2.5
2
1.5
1
0.5
0
MQXA.1R1
MQXB.A2R1
MQXB.B2R1
MQXA.3R1
MBXW.C4R1
TCL.4R1.B1
TCL.5R1.B1
MQML.5R1.B1
AFP220
MQML.6R1.B1
MB.A8R1.B1
MB.B8R1.B1
MQML.8R1.B1
MB.A9R1.B1
MB.B9R1.B1
MB.A10R1.B1
MB.B10R1.B1
MQML.10R1.B1
MB.A11R1.B1
MB.B11R1.B1
AFP420
MQ.11R1.B1
MB.A12R1.B1

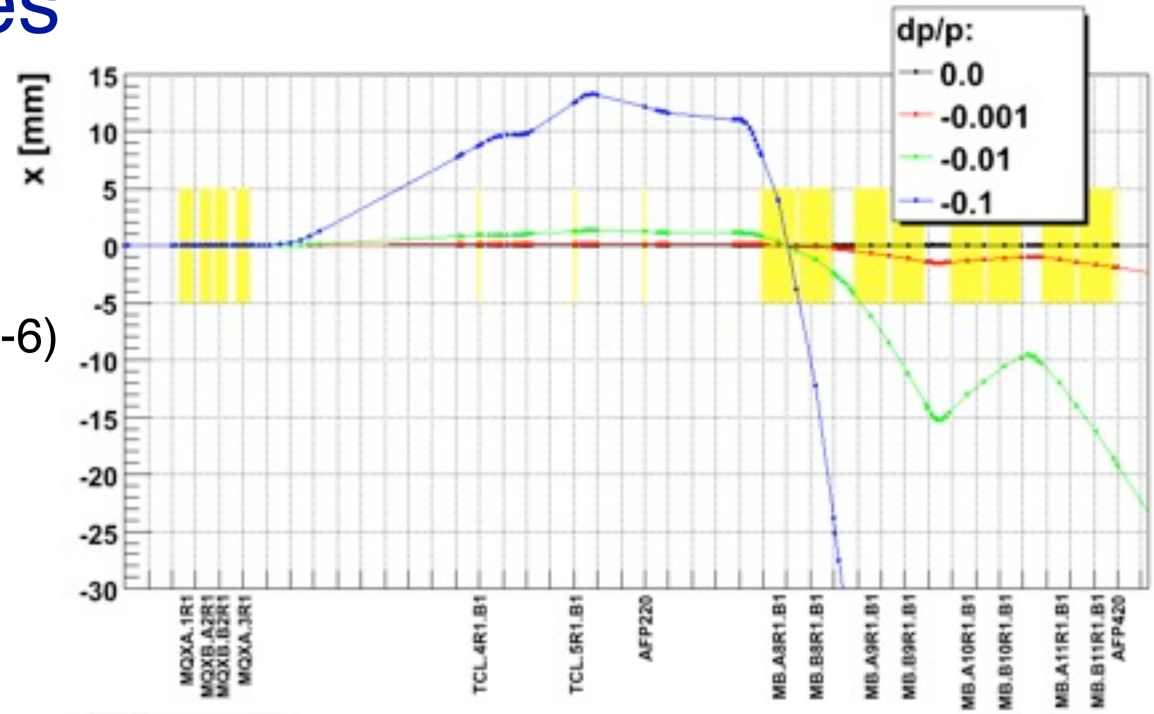
Some more optics

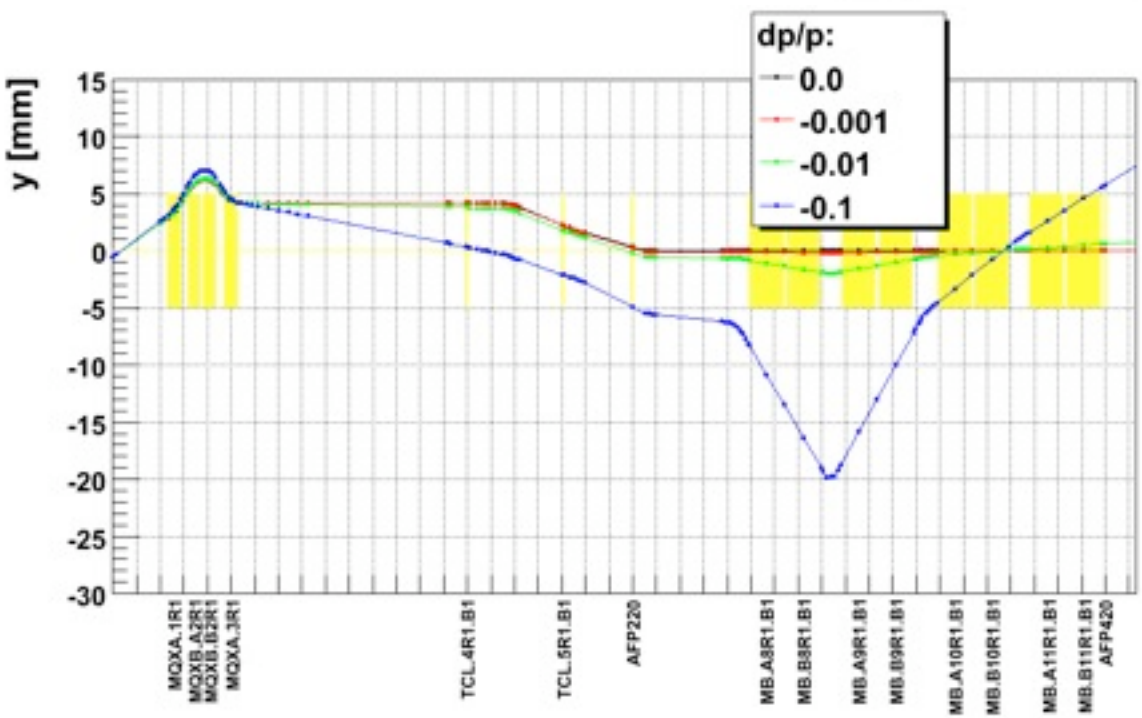
V6.503

NAME	S	SX	SY	SXBETA	SYBETA	BETX	BETY
%s	%le	%le	%le	%le	%le	%le	%le
IP1	0	0.000017	0.000017	0.000017	0.000017	0.55	0.55
TAS.1R1	20.02	0.000606	0.000605	0.000605	0.000605	728.91	728.91
TASB.3R1	45.34	0.001109	0.001272	0.001107	0.001271	2439.7	3216.1
TANAR.4R1	142.75	0.000593	0.000895	0.000593	0.000895	700.02	1592.33
TCL.4R1.B1	149.9	0.000529	0.000888	0.000529	0.000887	556.31	1566.29
TCL.5R1.OLD.B1	184.45	0.000294	0.000673	0.000294	0.000673	171.87	900.21
TCL.5R1.B1	190.82	0.000270	0.000590	0.000269	0.000589	144.53	691.54
AFP220	220	0.000092	0.000388	0.000091	0.000387	16.54	298.57
AFP420	420	0.000331	0.000170	0.000242	0.000169	116.12	57.02

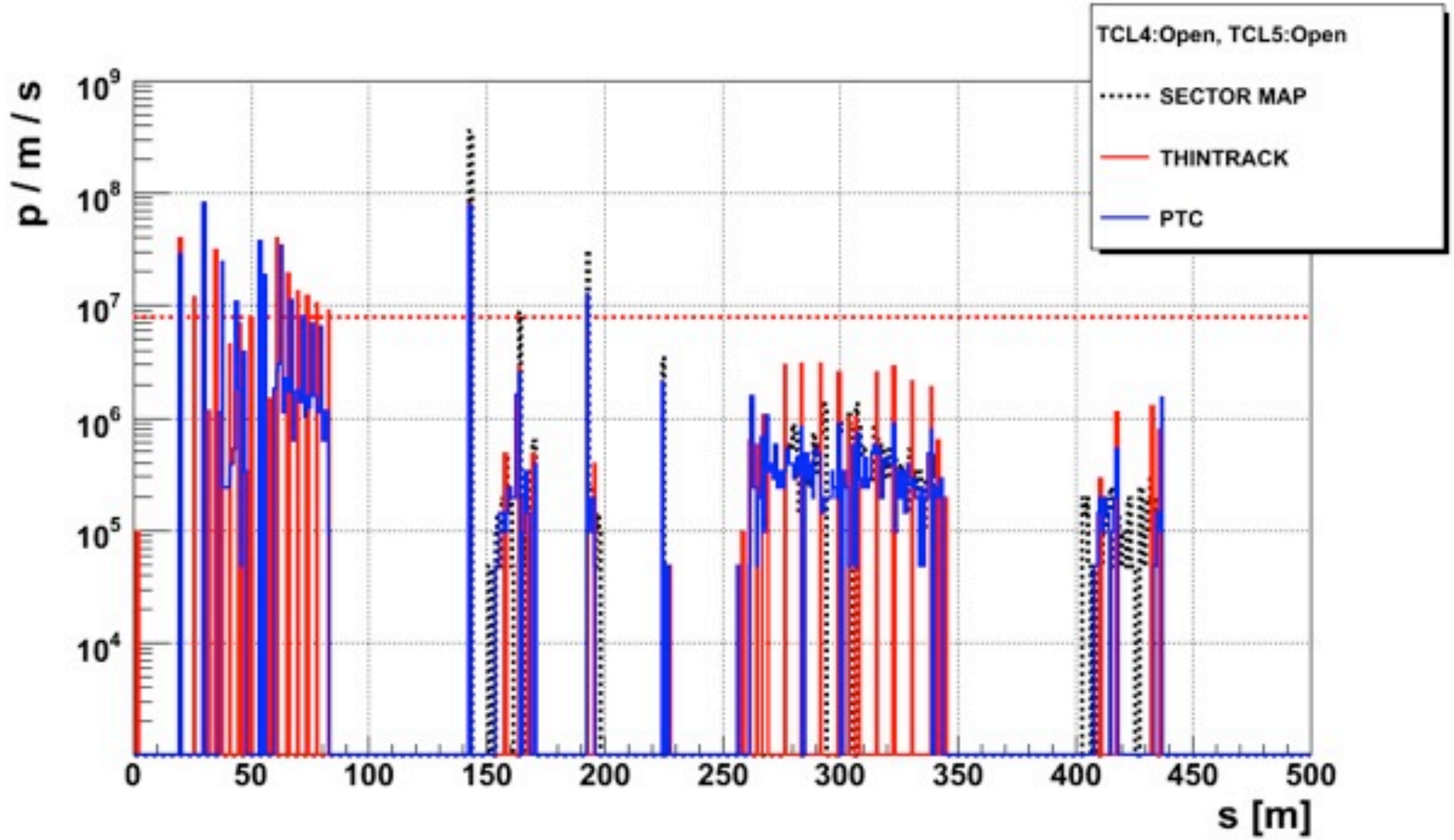
Reference trajectories

Protons starting with
(x,x',y,y') = (0,0,-0.0005,142.5e-6)
and different off-momentum





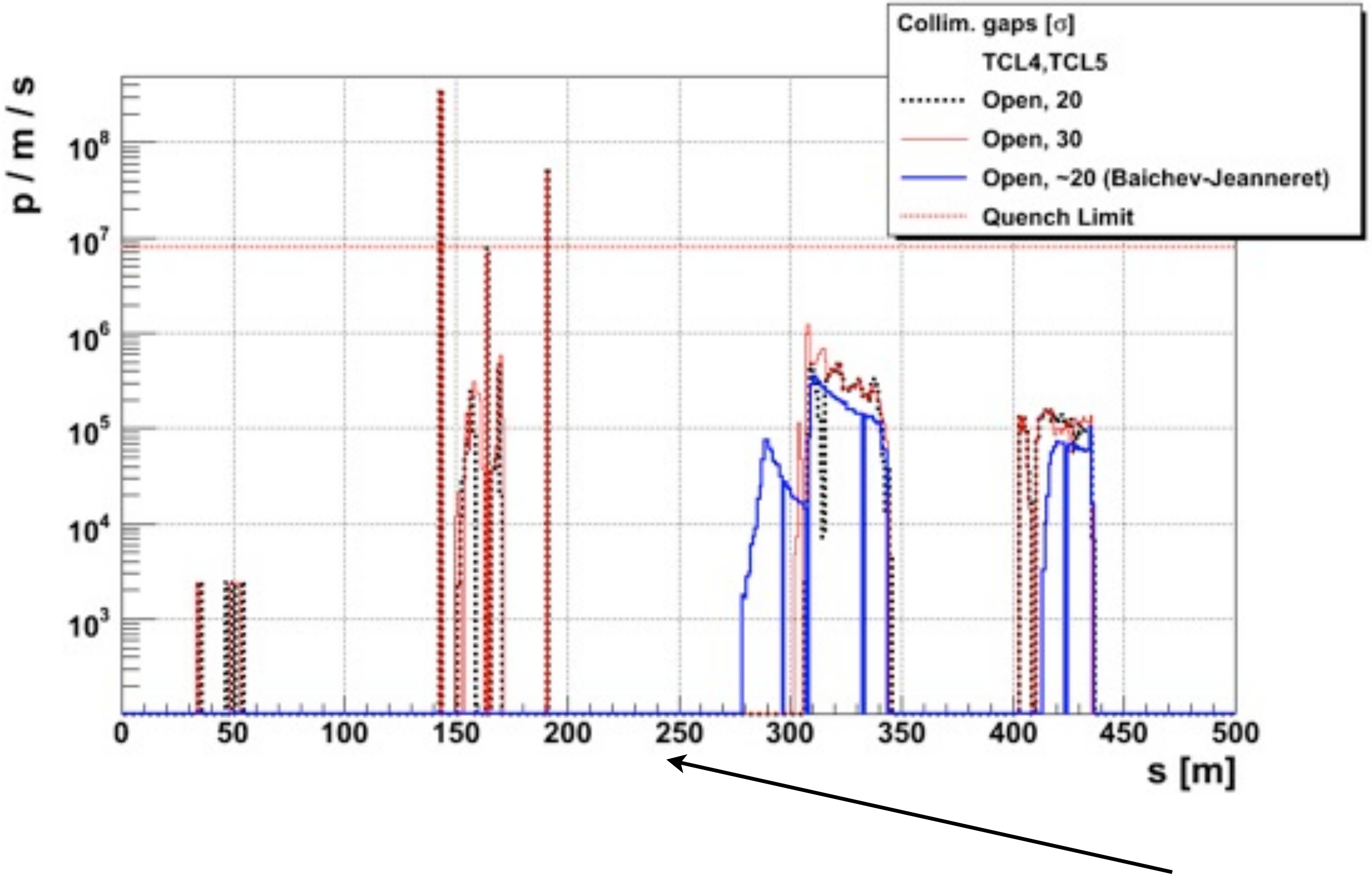
SECTORMAP-THINTRACK-PTC Comparison



N.B: with THINTRACK I score only at the centre of elements (-->higher peaks)

With SECTORMAP I don't see losses before the TAN (140m) ....

SECTORMAP Comparison with published results

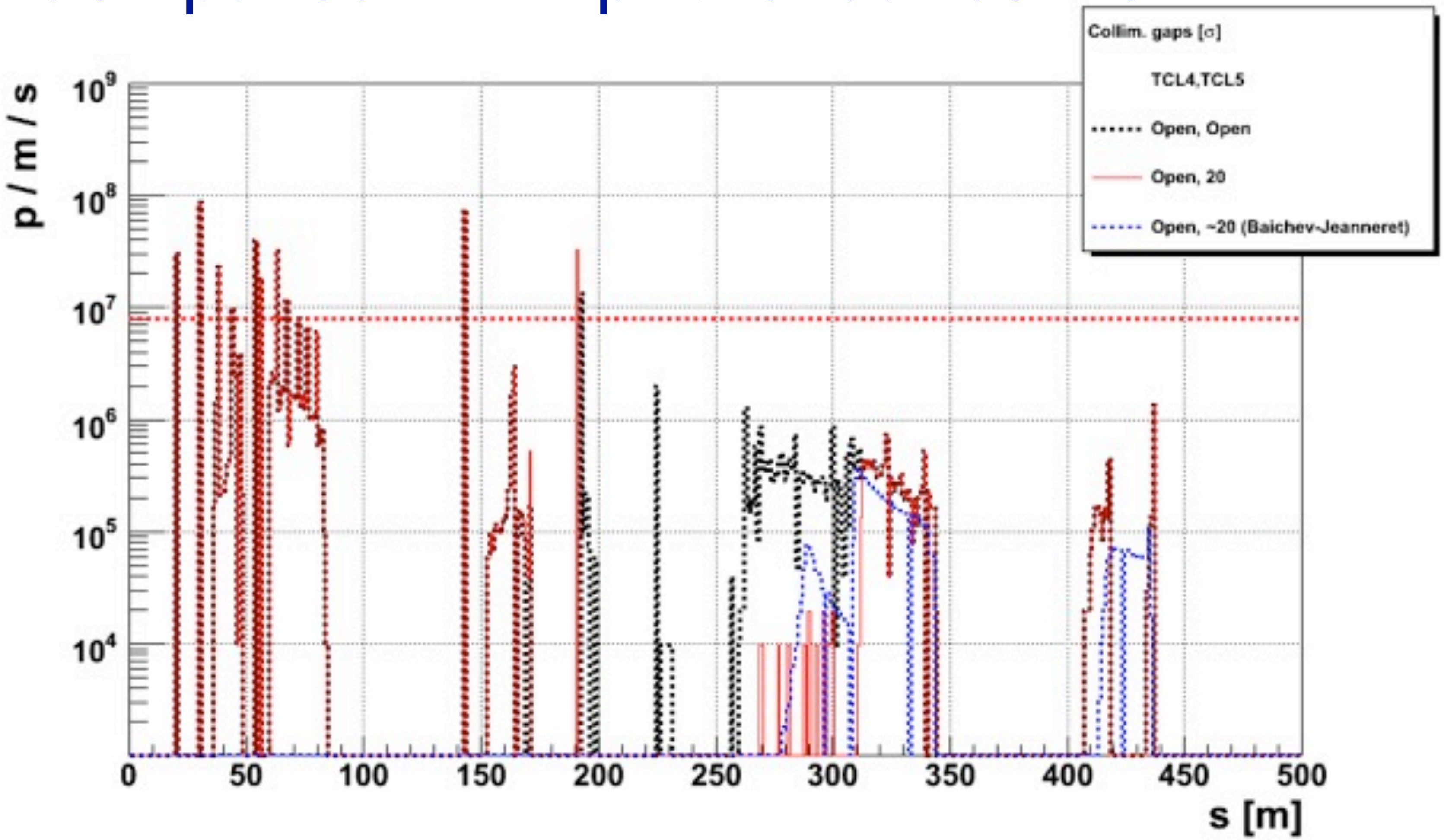


In the case I managed to rebuild, Baichev-Jeanneret did not score losses before 350 meters.

I'm more pessimistic from 300 to 350 m but I don't see losses from 280 to 300m

Remember differences in LHC optics, tracking model, p-p protons model

PTC Comparison with published results



In the case I managed to rebuild, Baichev-Jeanneret did not score losses before 350 meters.

I do see losses from 280 to 300m

Remember differences in LHC optics, tracking model, p-p protons model

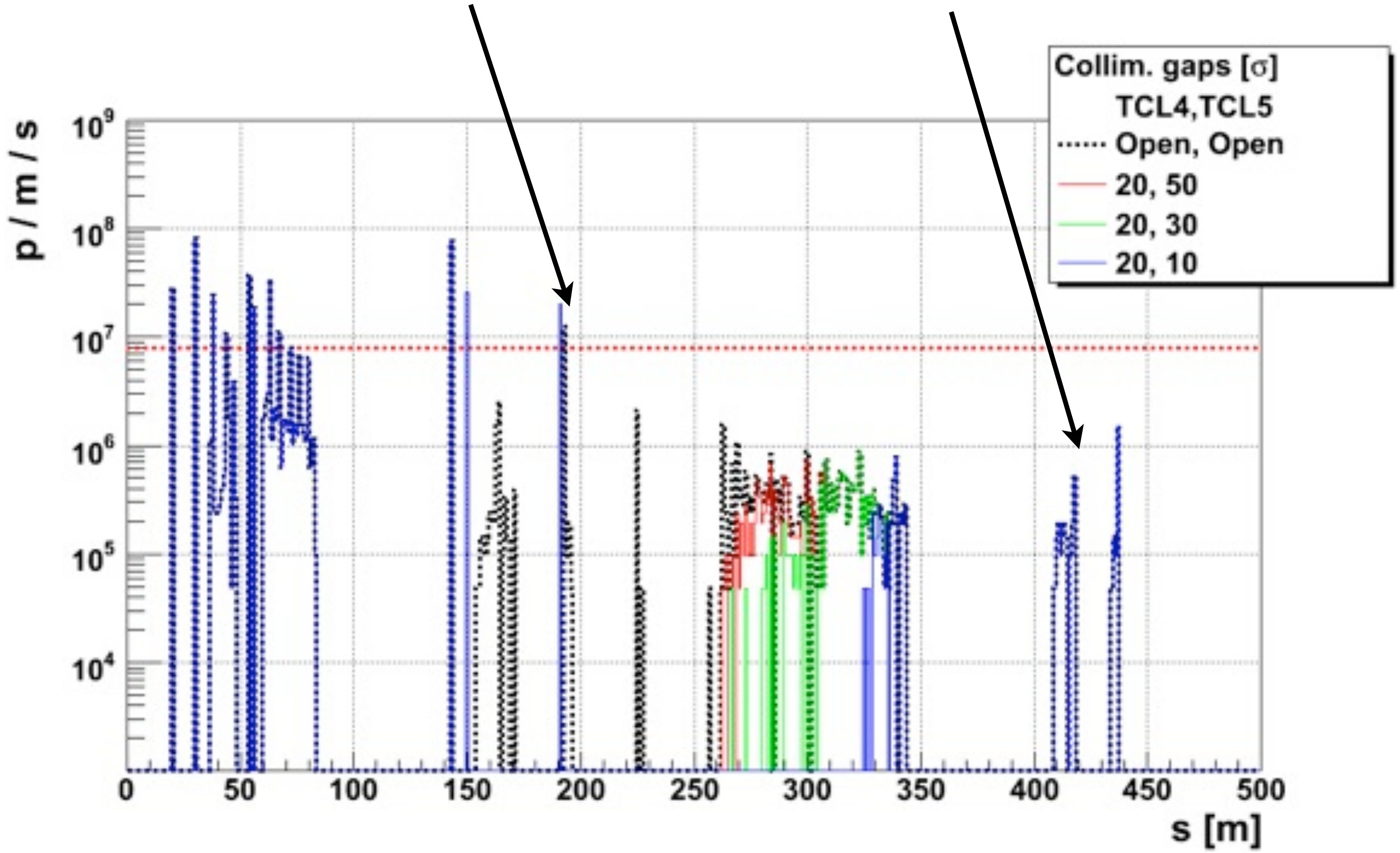
Scan of different collimator settings (PTC)

TCL4 at 20 sigma, TCL5 at 10,30,50 sigma

I will zoom on the results on the next slides. Here juste note 2 issues:

as mentioned by Baichev-Jeanneret in published paper: without collimators loses at Q5 exceed quench limit

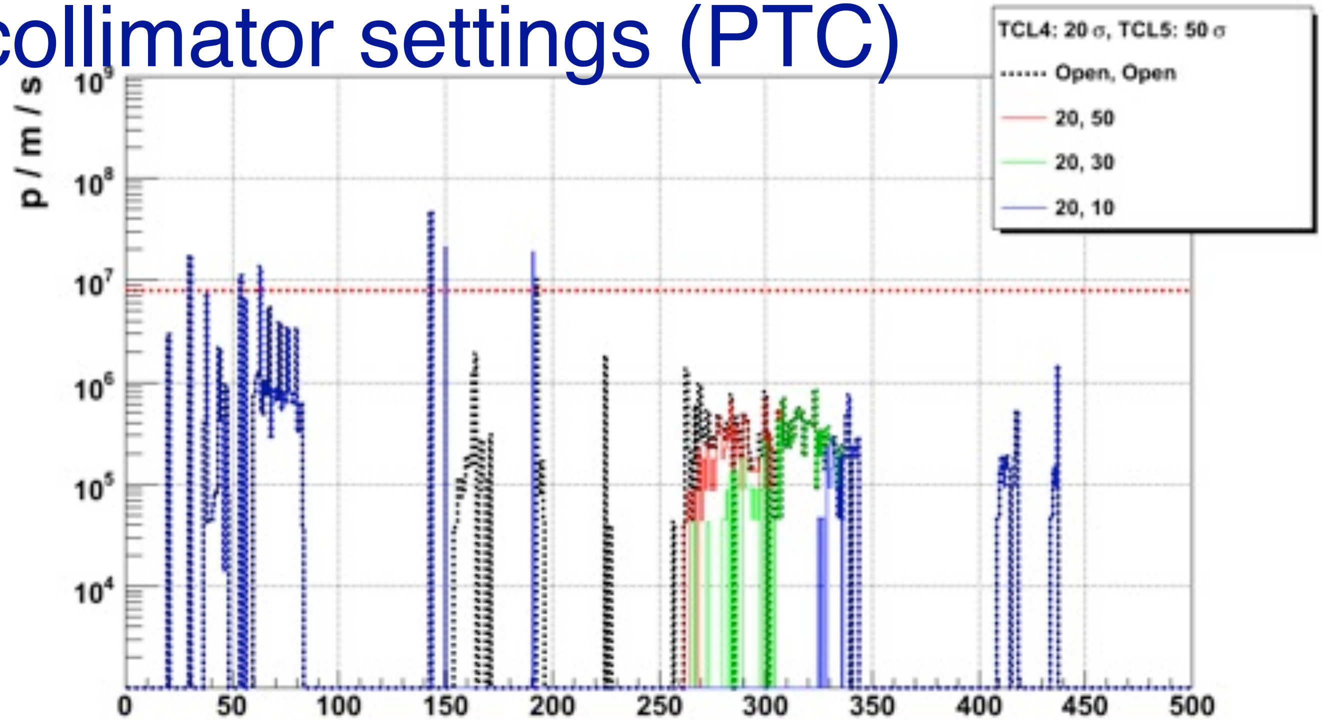
after 450m both collimators doesn't have any effect !



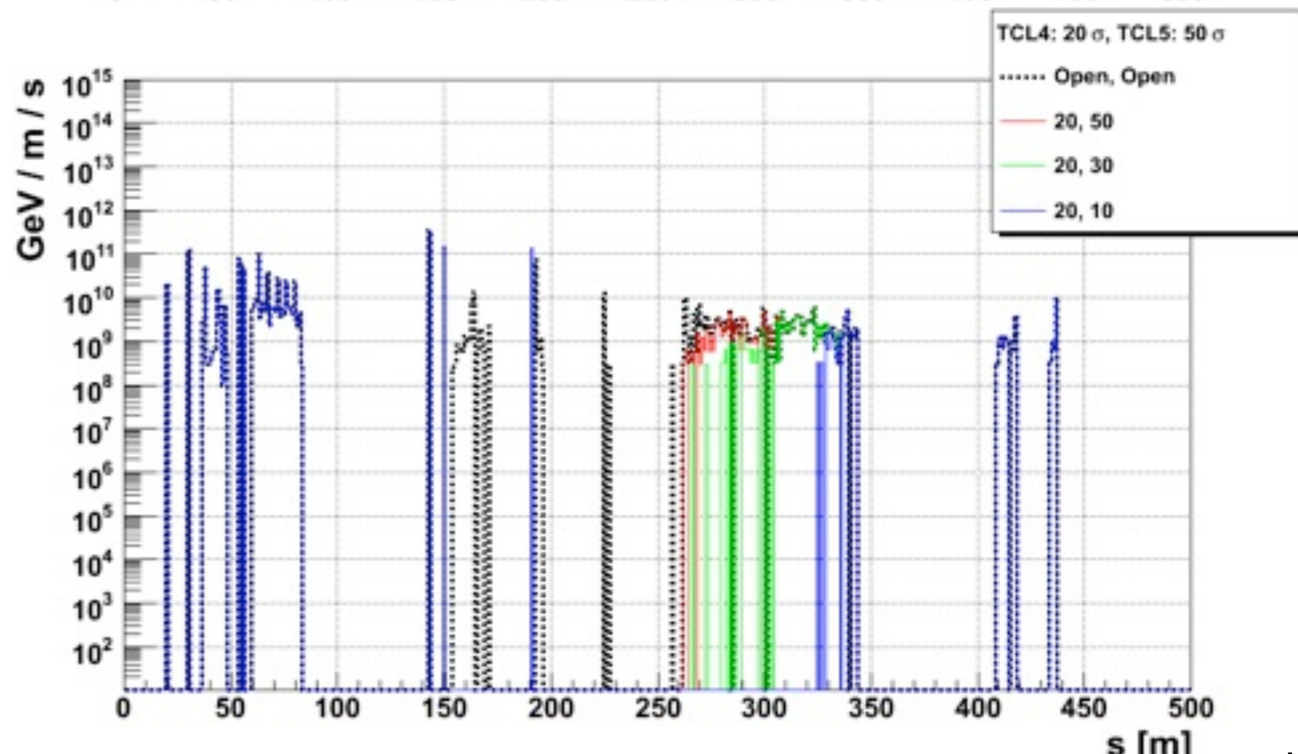
Scan of different collimator settings (PTC)

TCL4 at 20 sigma, TCL5 at 10,30,50 sigma

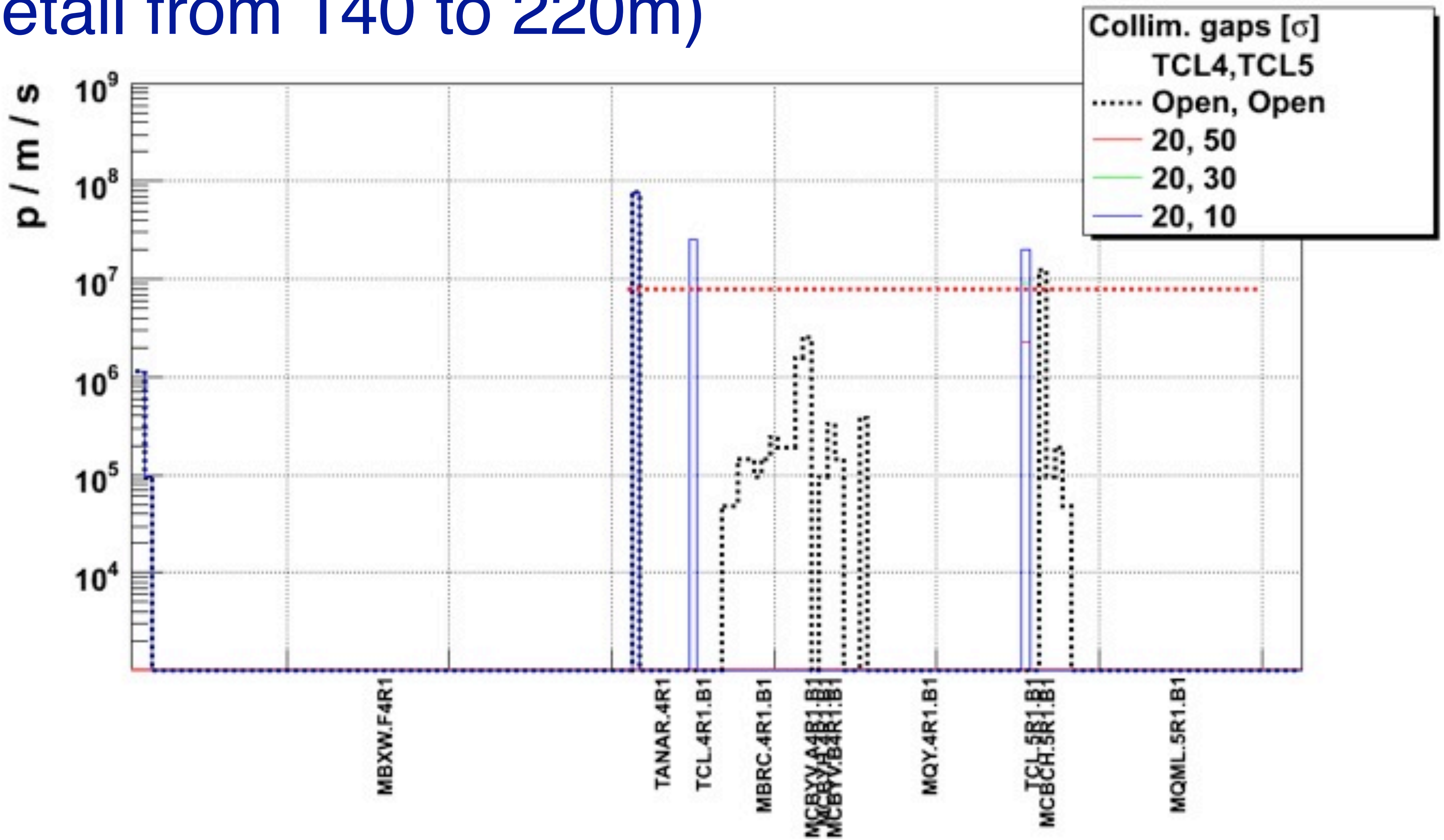
Losses weighted for proton energy



Energy deposition



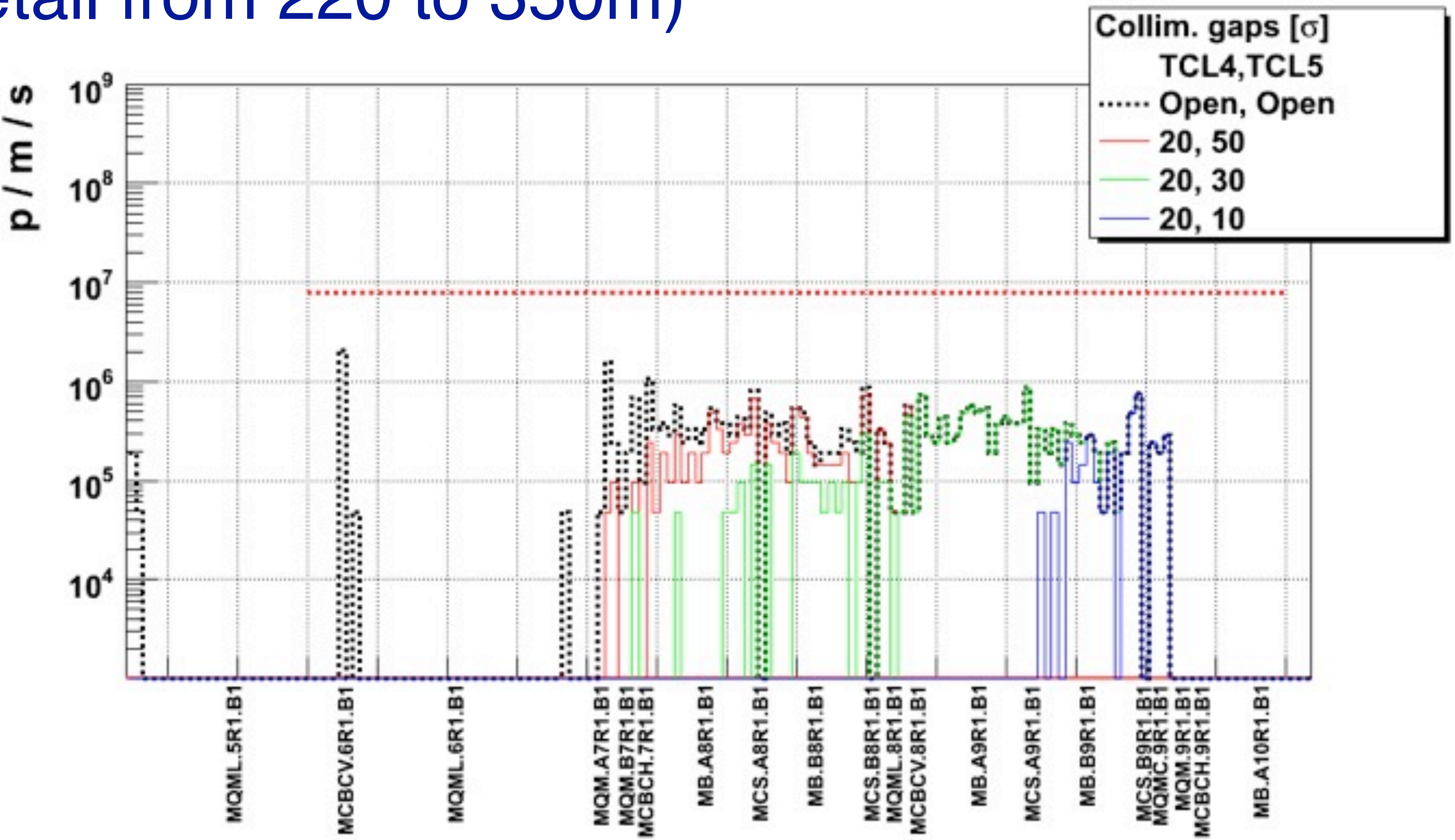
Scan of different collimator settings (detail from 140 to 220m)



Important: **TCL4 at 20 sigma** and **TCL5 at 50 sigma** are **enough to protect Q5** (**all the job is done by Q4 actually**)

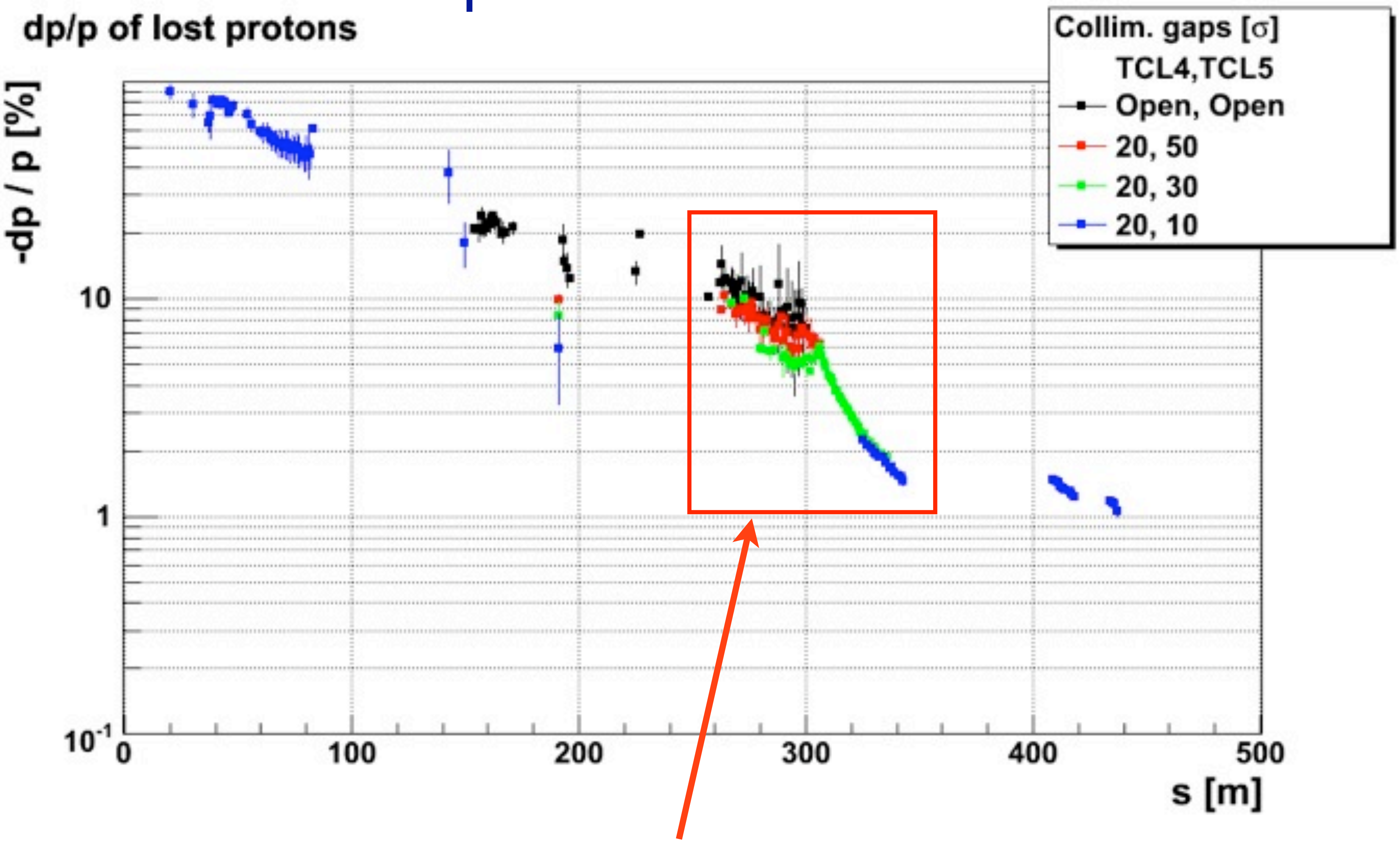
TCL4 at 20 sigma protects D2 and Q4

Scan of different collimator settings (detail from 220 to 350m)



Indeed TCL5 at 10-20 sigma reduces the losses, but even at 30 and 50 sigma losses at B8 (concern for Baichev-Jeanneret) are reduced(remember log scale)

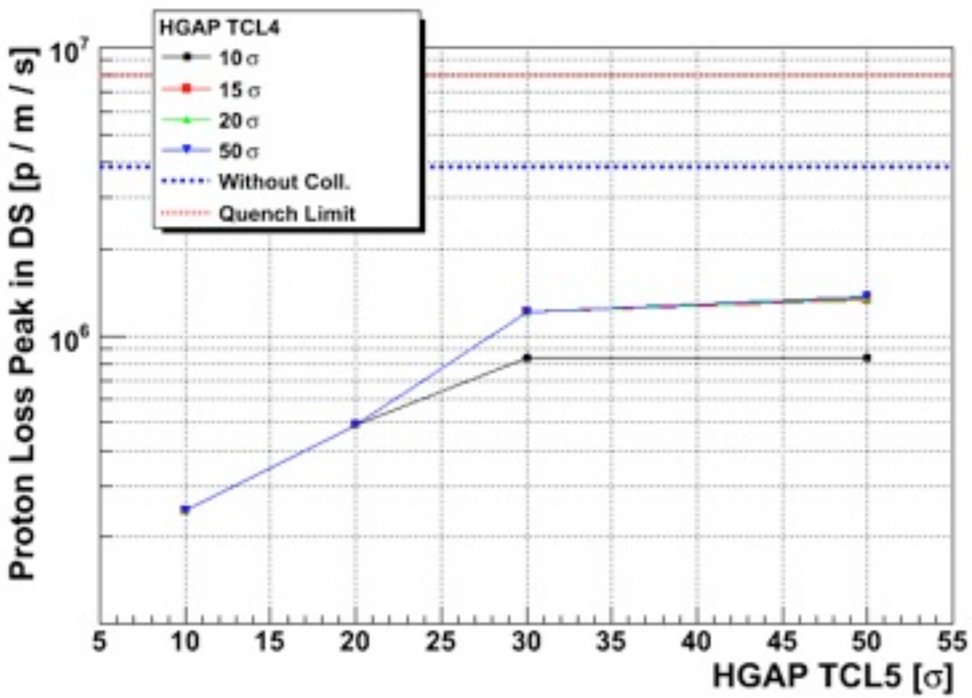
Scan of different collimator settings
Momentum of lost particles

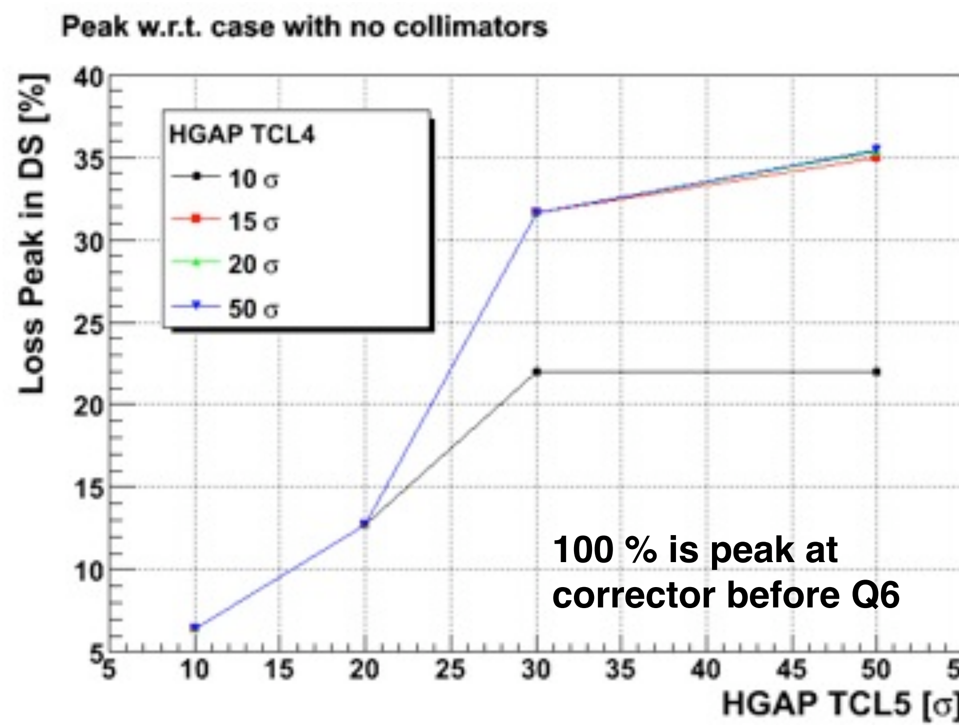


This is the region for which one can argue that TCL5 needs to stay very closed

Scan of different collimator settings PEAKS

All peaks well below quench limit





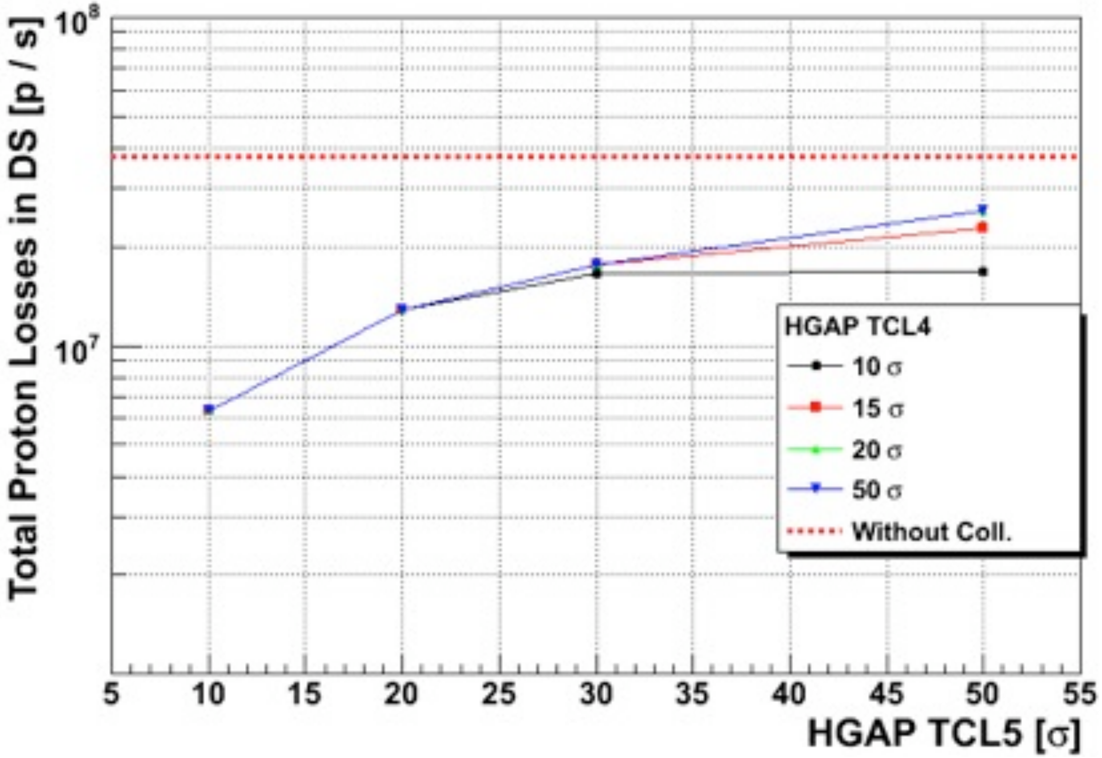
For TCL4 at 20 sigma:

loose a factor 2.5 changing TCL5 from 20 to 30 and then little change for 30 and 50 sigma

another factor 2.5 chaging TCL5 from 20 to 10

Scan of different collimator settings INTEGRAL LOSSES

Integral for s > 220 m



In good agreement with Baichev-Jeanneret:

6.6e7 with no collimators

1.7e7 with TCL5 at 15sigma

TCL4 has very little effect on integral losses in Dispersion Suppressor

For TCL4 at 20 sigma:

gain “only” a factor 2 changing TCL5 from 50 to 10 sigma

Optimal collimator settings

Basic constrains:

- collimator gap can't be smaller than 8-10 sigma: to avoid interfering with primary collimators at 6-7 sigmas

- collimator operation must avoid quenches on the downstream magnets due to secondary showers (the smaller the gap the larger the showers)

- collimator operation must avoid excessive irradiation of downstream electronics due to secondary showers (the smaller the gap the larger the showers)

Favorable locations for cleaning are where

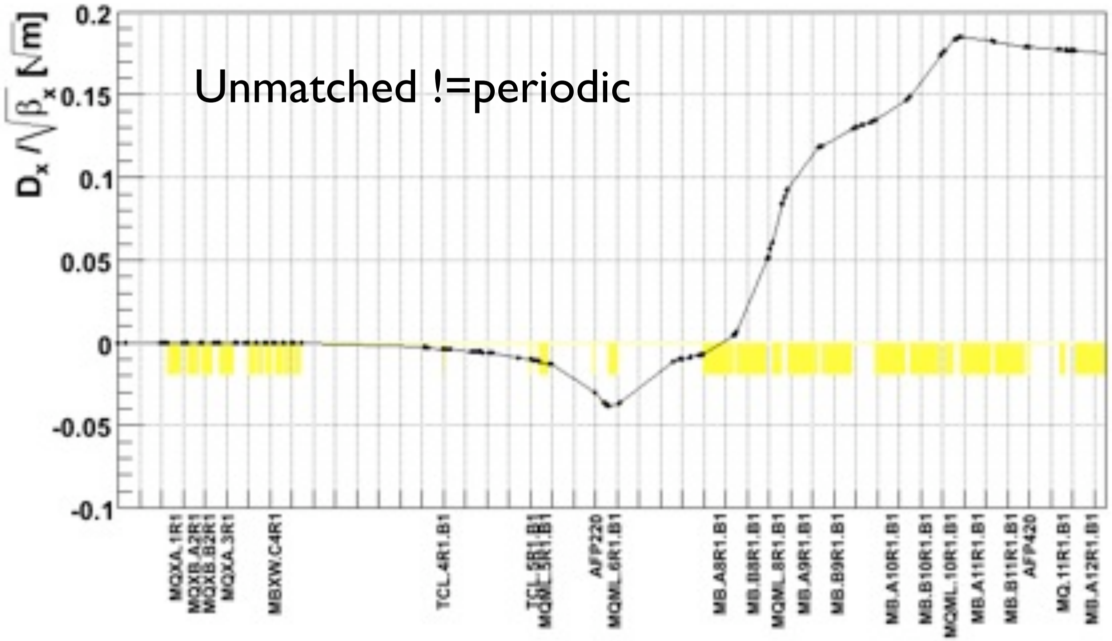
- Dx large : to enhance the off-momentum orbit excursion and therefore minimize relax the collimator gap

- Betax is small : to have a collimator gap in mm that corresponds to a larger number of betatron sigmas

Optimal collimator settings

For the reasons mentioned in the previous slide, it is often convenient to look for locations where there is a maximum normalized dispersion

$$D_x^n(s) = \frac{D_x(s)}{\sqrt{\beta_x(s)}}$$



Similarly, willing to clean particles for a certain dp/p, one can look at the necessary collimator gap (in terms of sigma) at different locations s:

Collimator hgap necessary to clean all particles with momentum offset >= dp/p0

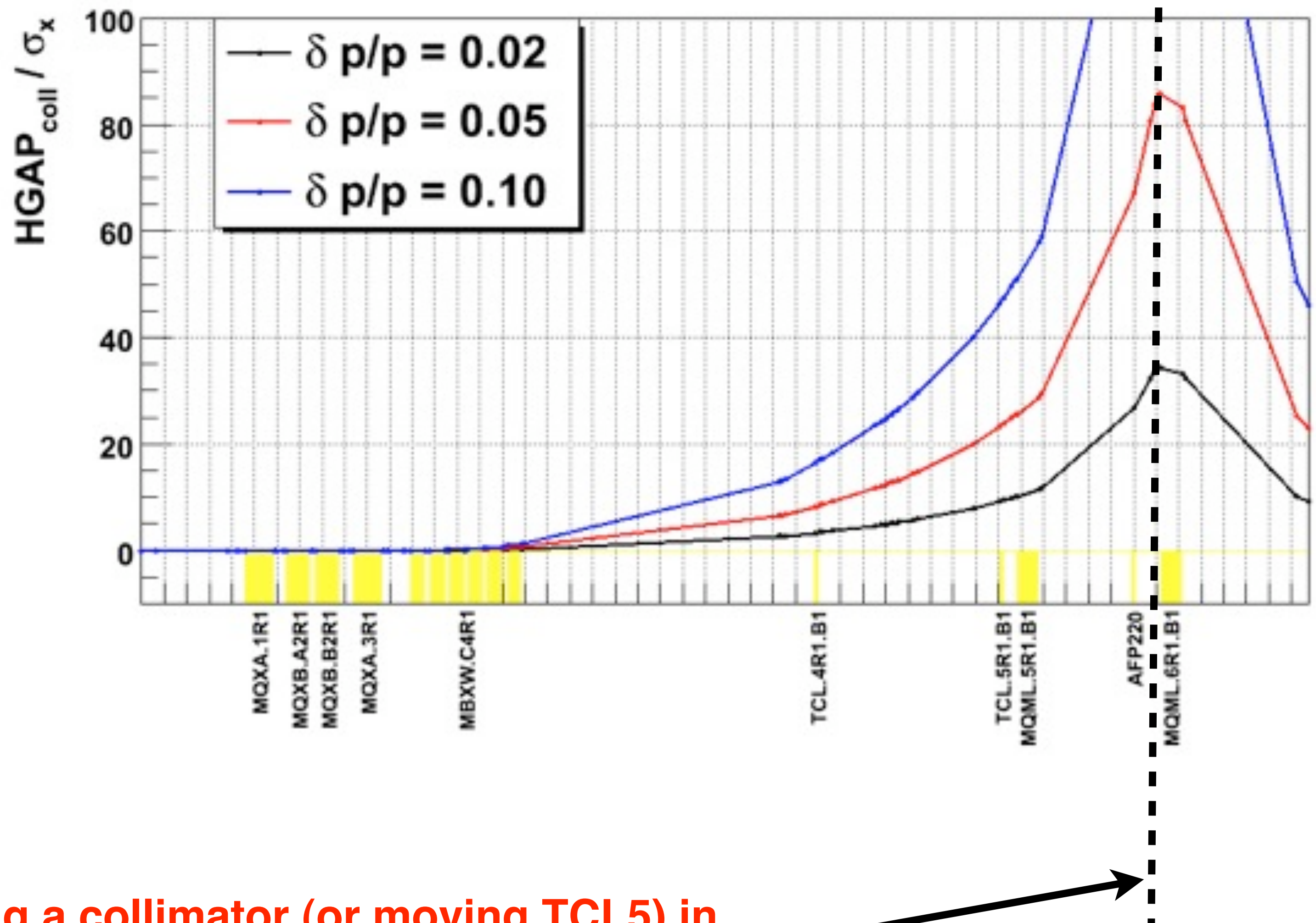
$$\frac{x_c(s)}{\sigma_x(s)} = \frac{D_x(s)}{\sigma_x(s)} \cdot \frac{\delta p}{p_0} \equiv \frac{D_x(s)}{\sqrt{\beta_x(s)\varepsilon_x}} \cdot \frac{\delta p}{p_0}$$

See plot next slide

Optimal collimator location

Collimator half-gap necessary to clean all particles with momentum offset >= dp/p0, in the momentum region of losses at 250m < s < 350 m (critical region)

This is more or less consistent with the results of the tracking studies for different TCL5 settings



Could think of putting a collimator (or moving TCL5) in front of Q6 but I didn't investigate the layout in detail...

Preliminary conclusions / possible further studies

- **Q5 is always protected**, even for TCL5 at 50 sigma
- If one **believes the absolute scaling** of the results (in agreement with published studies) : **there is no quench in DS even for large TCL5 gaps**
- If **one does not believe the absolute scaling**, indeed TCL5 at 10 sigma helps in the region at 220 < s < 350 m
  - **wait for LHC low luminosity data** for benchmarking the simulations?
  - study the layout+optics and **propose a new collimation scheme**?
- For the moment I did not spend time on checking validity low energy proton losses on triplets, but I guess this is of general interest (I'm aware of similar studies by FLUKA team)

Preliminary conclusions / possible further studies

Here I don’t have secondary showers:

I underestimate losses / energy deposition for s > 300m

I don’t treat ‘important’ radiation issues at Q5 + electronics in RR, for which a collimator more open can only help!

Conclusions depend on impact of collimators on acceptances (I may track signal protons if needed)

SIXTRACK to simulate scattering on collimators? (I gave Yngve DPMJET protons)