L. Keller
13 June, 2008

Discussion of High Energy Proton Losses in Arc 7

Motivation: A large fraction of the energy lost in the beginning of Arc 7 is due to high energy protons leaving the primary collimators and not touching a secondary collimator. This is a fundamental limit on the performance of the collimation system.

1. This work is not an attempt to exactly reproduce the SixTrack efficiency simulations.

2. The goal of this study is to find a relatively fast method for studying properties of the near-beam-energy proton losses in Arc 7 and look for changes in the IR-7 collimation system to reduce these losses.

Analysis Steps

1. **Start with a TRANSPORT/TURTLE model of IR-7 and the first part of Arc 7.**

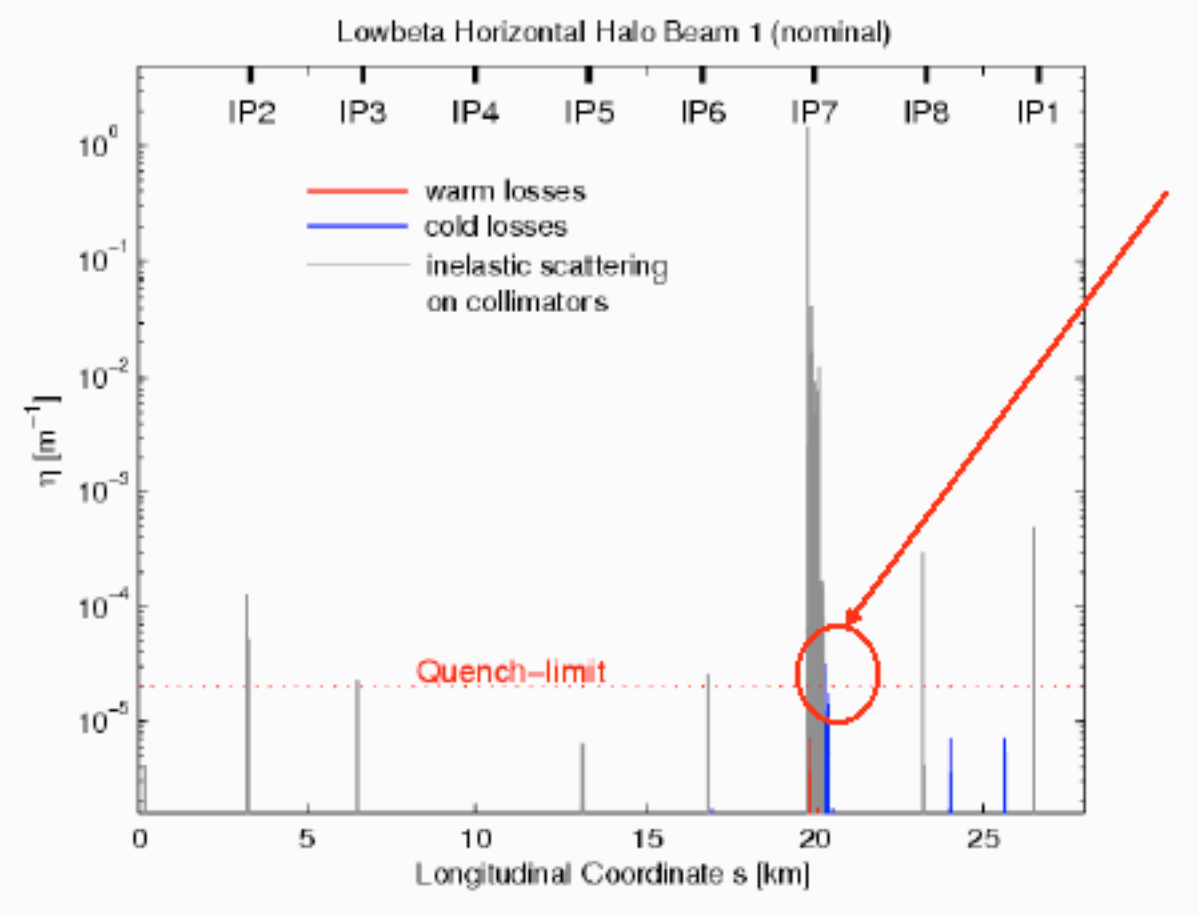
2. **Use TURTLE to find the phase space acceptance of protons from each jaw of TCPH and TCPV as a function of ΔE/E. Assume all secondary collimators and absorbers are "black".**

3. **Use FLUKA to estimate the proton yield from the primary collimators as a function of energy and angle.**

4. **Weight the phase space acceptance with the FLUKA yield to calculate the rate of off-energy protons entering Arc 7. Look for changes to the collimation system to reduce this rate.**

C. Bracco, et. al., CERN/LARP video meeting, 11 Dec., 2006

Beam intensity limitation for phase I



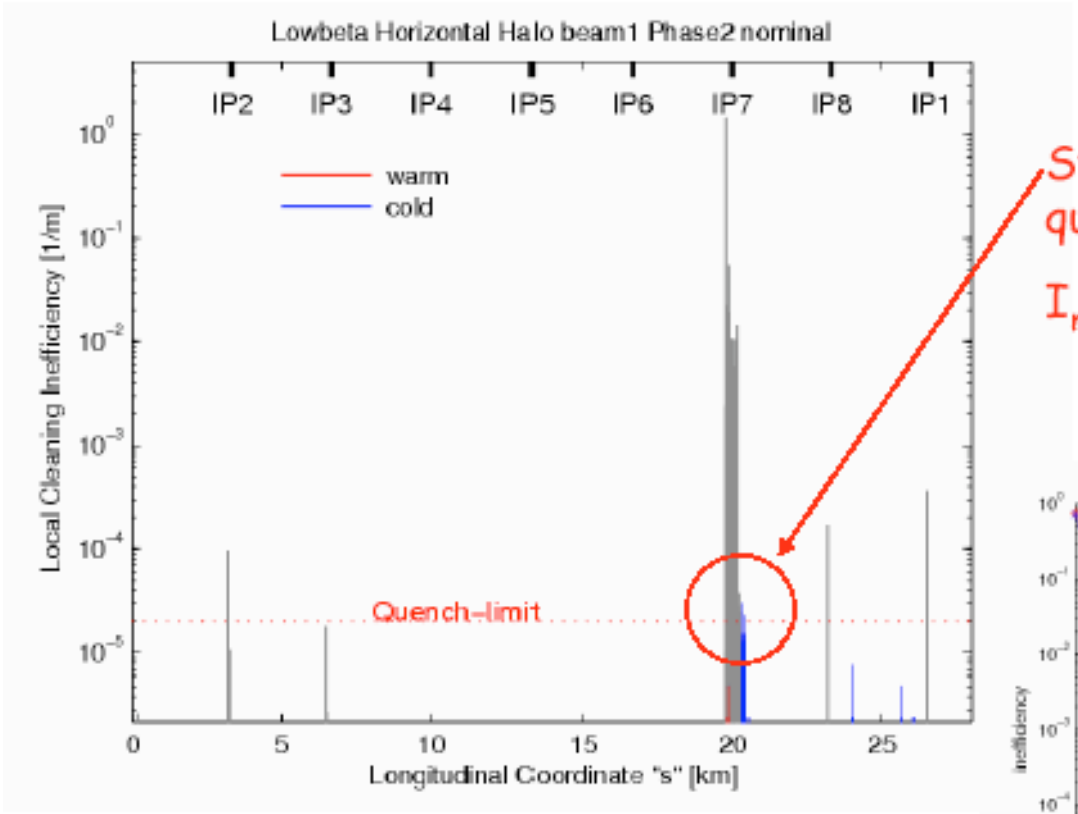
Losses above the quench limit of $2 \cdot 10^{-5}$ [m^{-1}] estimated for a beam life time of 0.2 hours.

$$I_{max} = \frac{2 \cdot 10^{-5}}{\eta_{max}}$$

$I_{max} = 63.09 \pm 14.85\ \%\ I_{nom}$

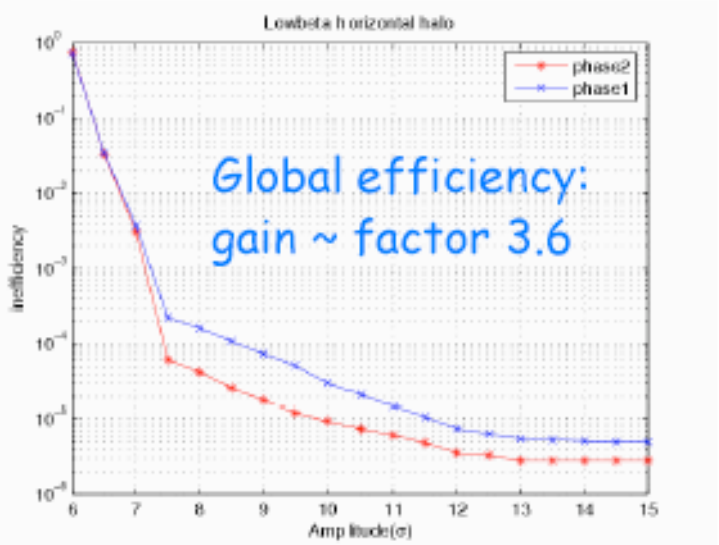
C. Bracco, et. al., CERN/LARP video meeting, 11 Dec., 2006

Beam intensity limitation for phase II



Still losses above the quench limit:

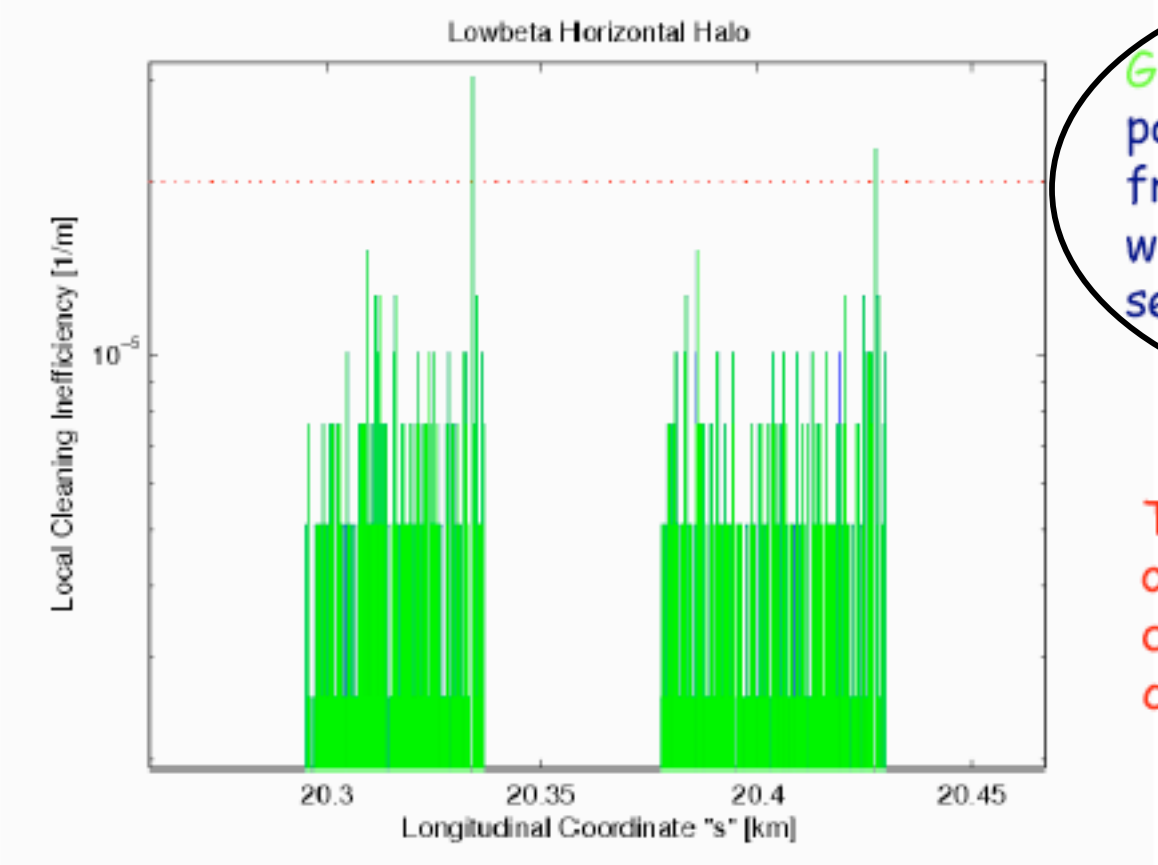
I_{max}= 65.79 ± 18.96 % I_{nom}



Even though the global efficiency with Cu collimators has improved by a factor of 3.6, I_{max} is still only 65% of design current - no change from Phase I.

C. Bracco, et. al., CERN/LARP video meeting, 11 Dec., 2006

Losses in the dispersion suppressor



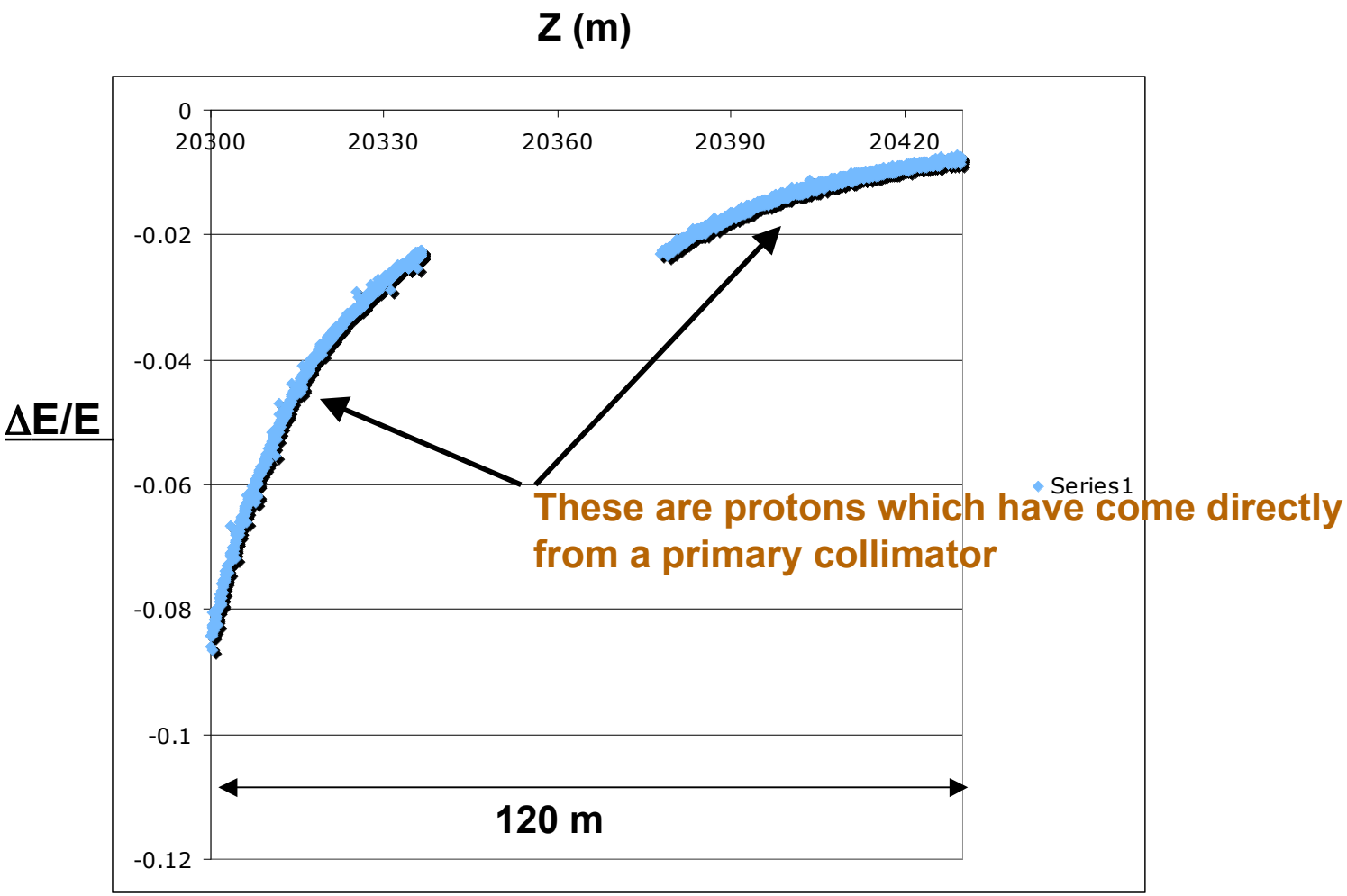
Green lines: losses of particles coming directly from primary collimators without interacting with any secondary collimator.

The local cleaning efficiency of the collimation system depends strongly by primary collimators.

L. Keller
May '08

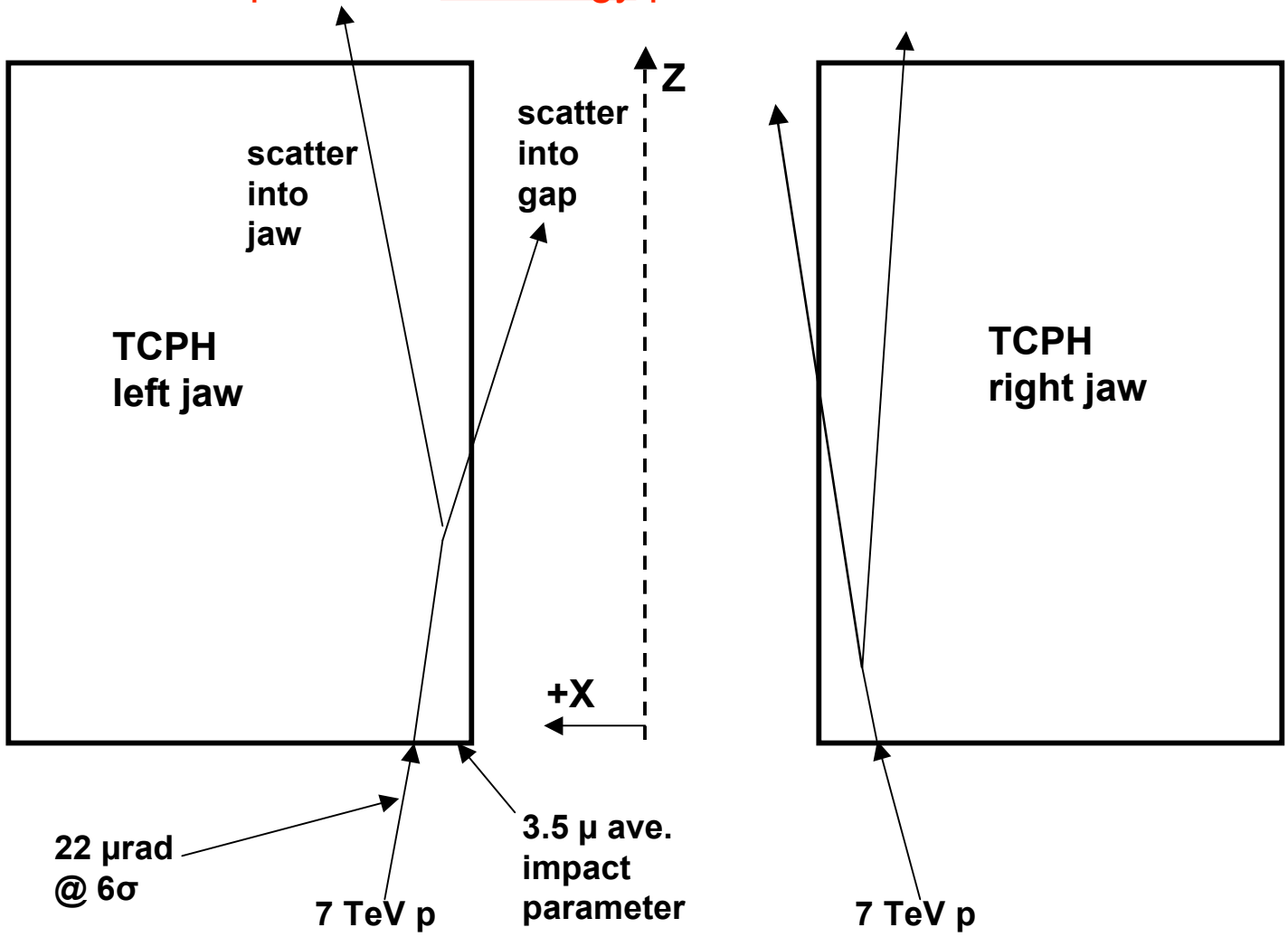
Loss Position vs. ΔE/E in the First 120 m of Arc 7

Data supplied by C. Bracco and Th. Weiler



Simple FLUKA Model to Estimate High Energy Scattered Proton Yield

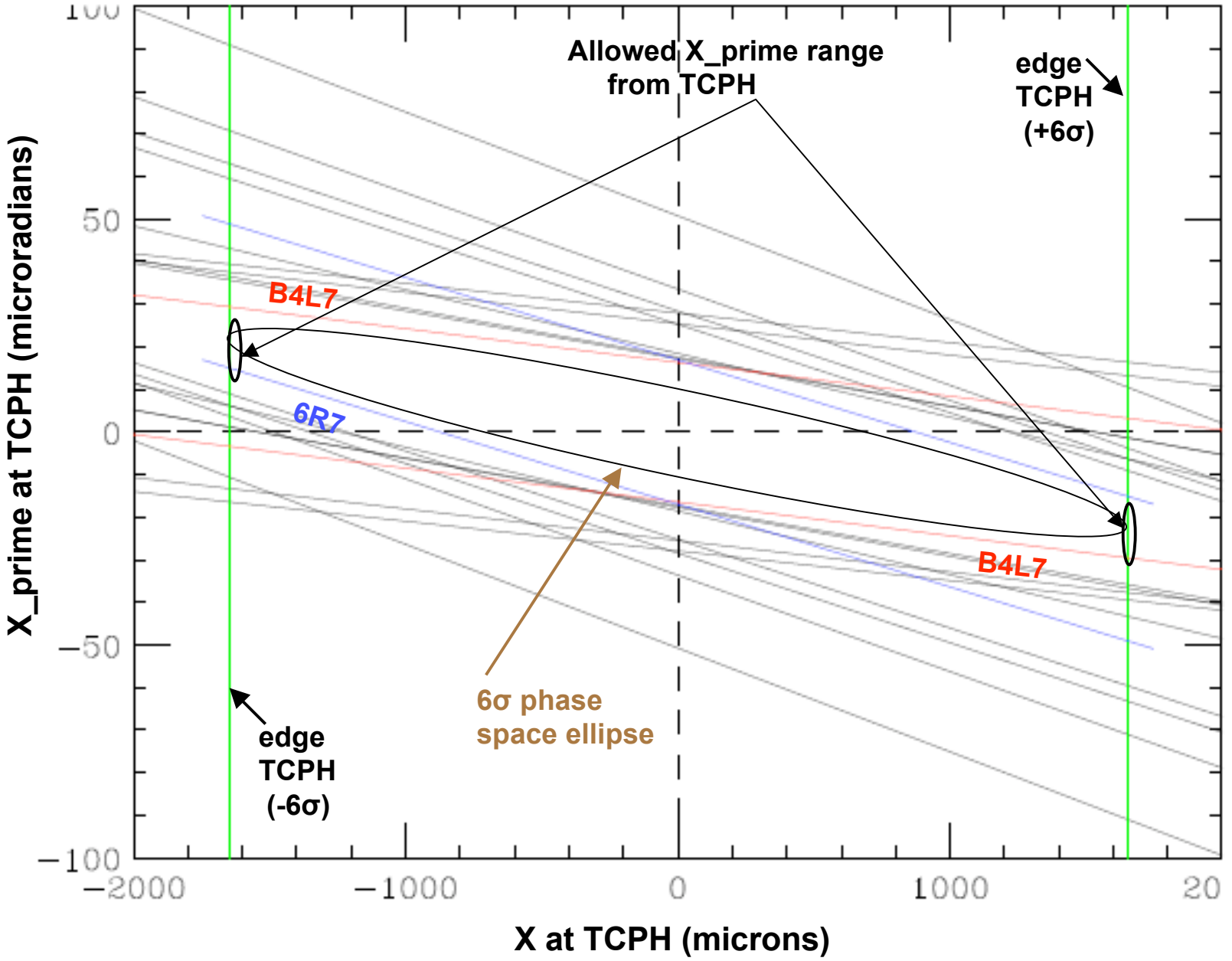
Beam line acceptance of off-energy protons is different for each TCPH jaw



1. Discard all produced particles except protons above 6.3 TeV (-10% of beam energy)
2. Record the scattered proton energy and angle with respect to the beam axis.
3. Also make runs with the jaws tilted 22 μrad, so the beam enters parallel to jaw face.

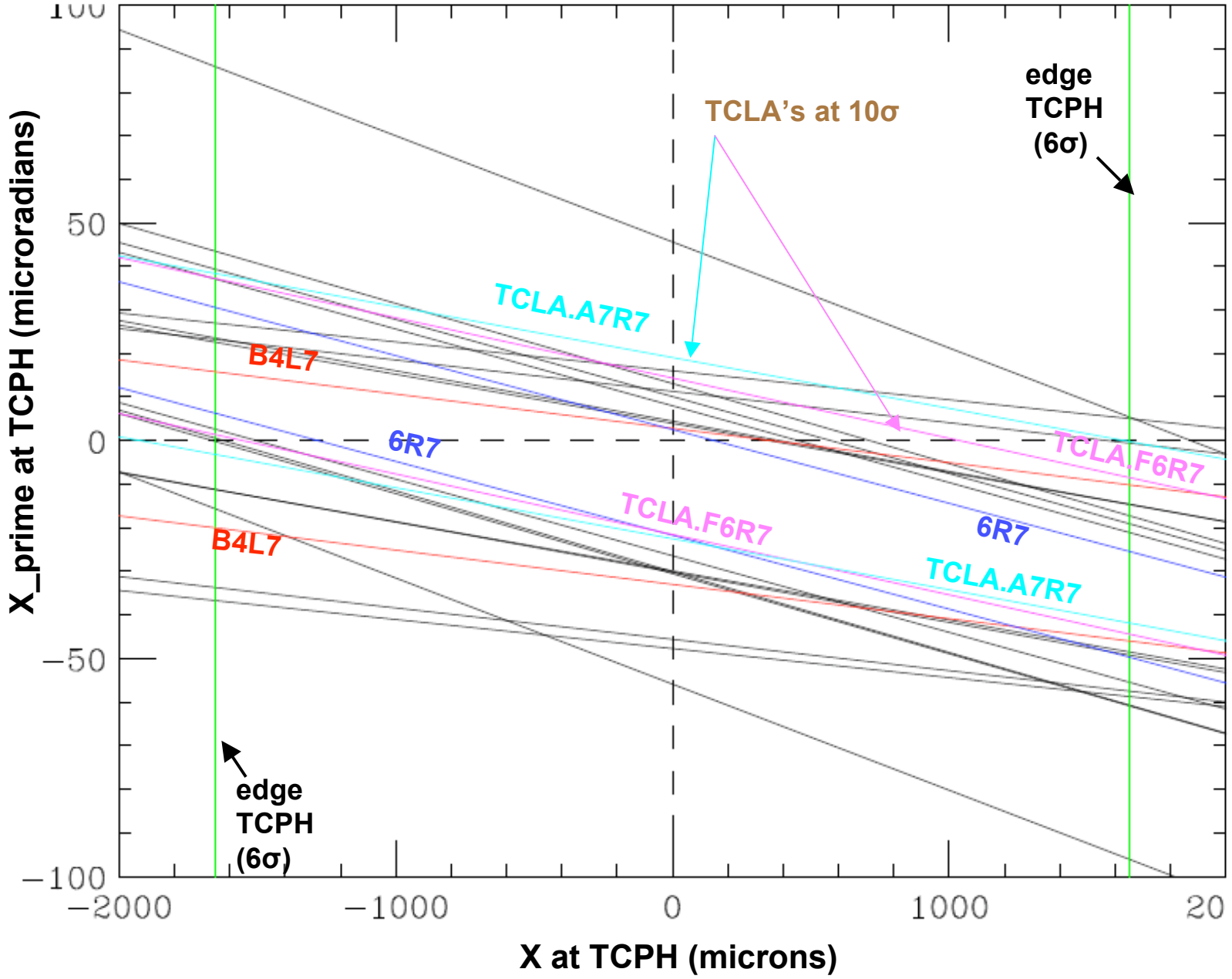
Secondary Collimator Apertures Projected onto TCPH, 7.0 TeV

(for y0_prime = 0)



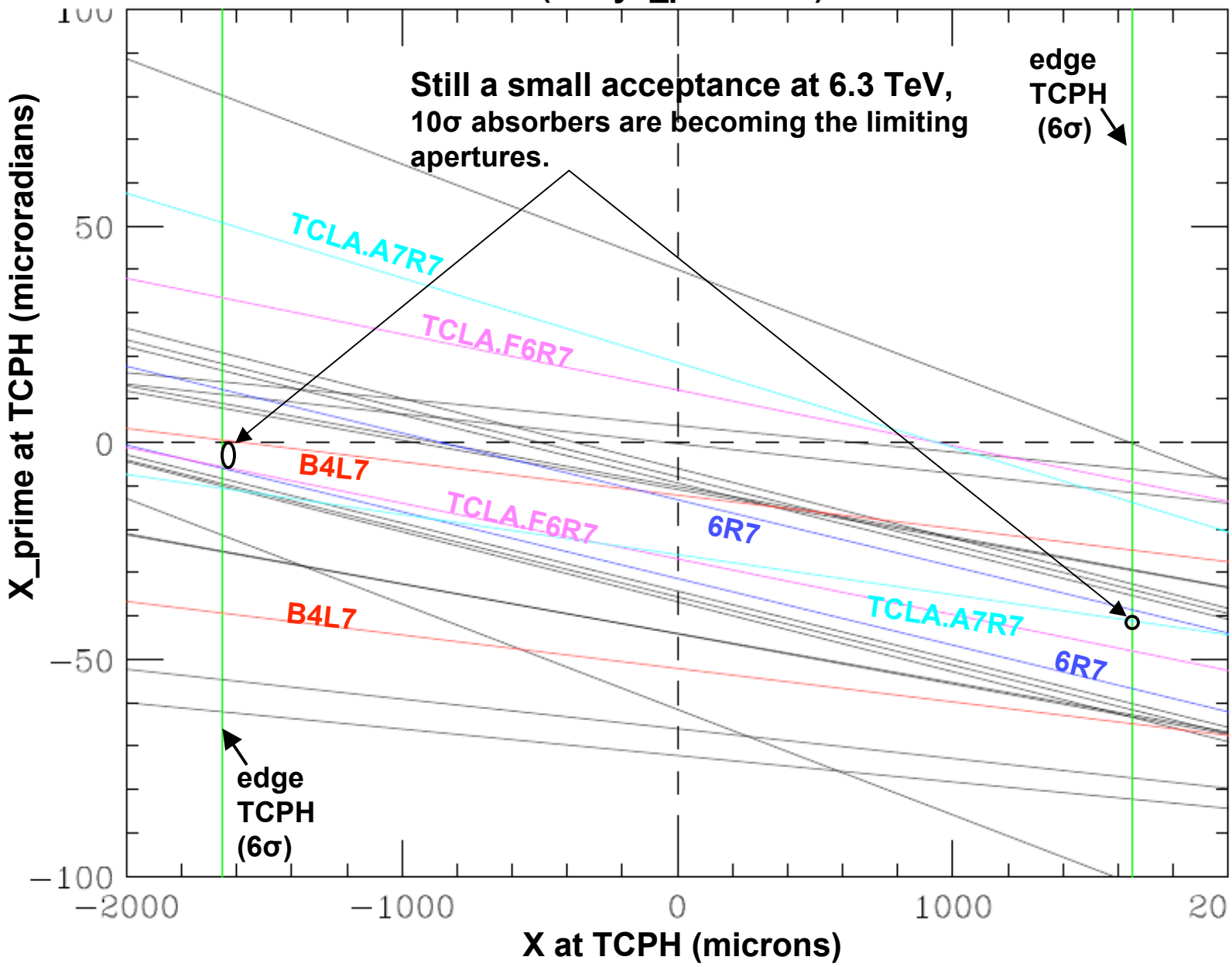
Secondary Apertures at TCPH for 6.65 TeV (-5% ΔE/E)

(for y0_prime = 0)



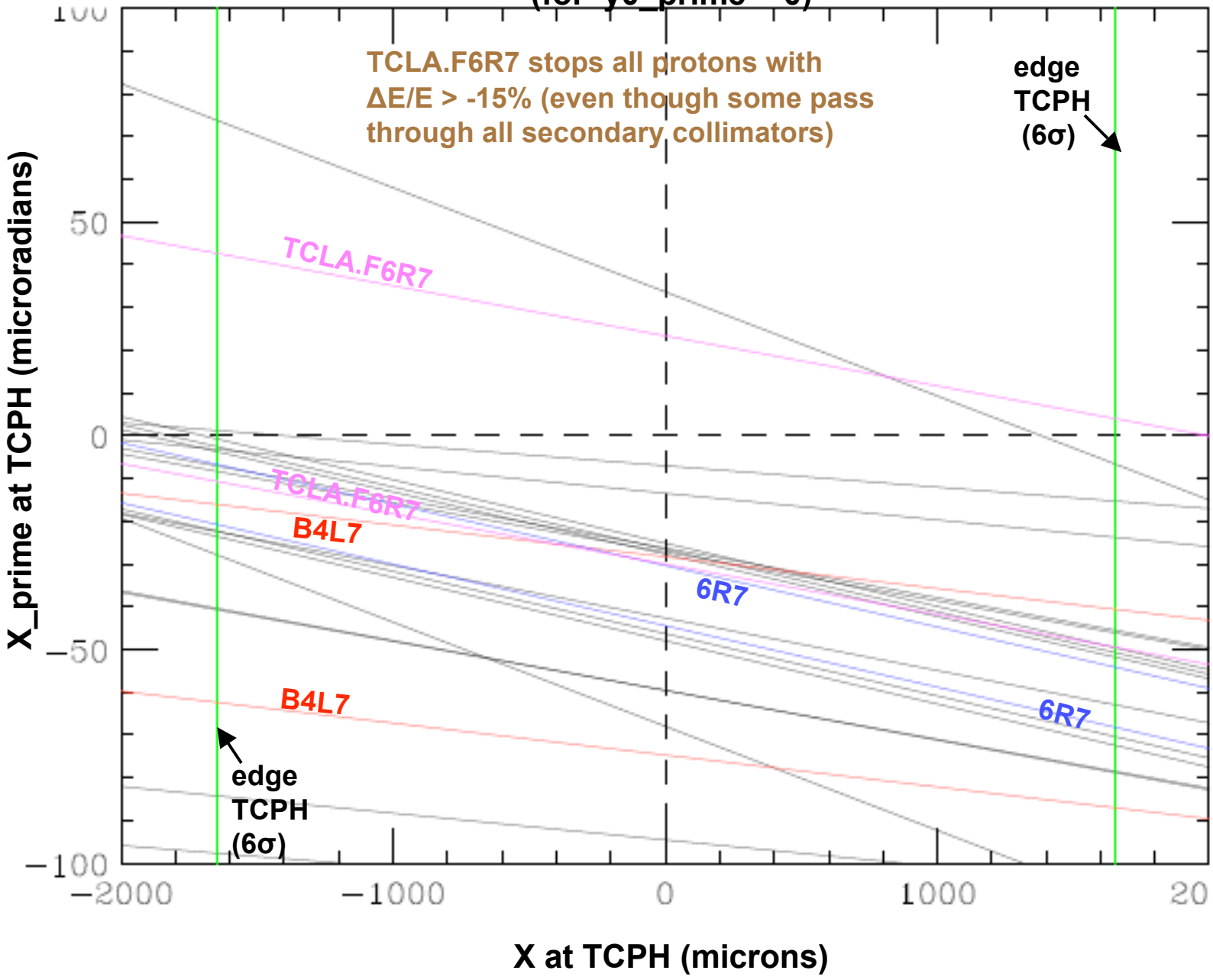
Secondary Apertures at TCPH for 6.3 TeV (-10% ΔE/E)

(for y0_prime = 0)



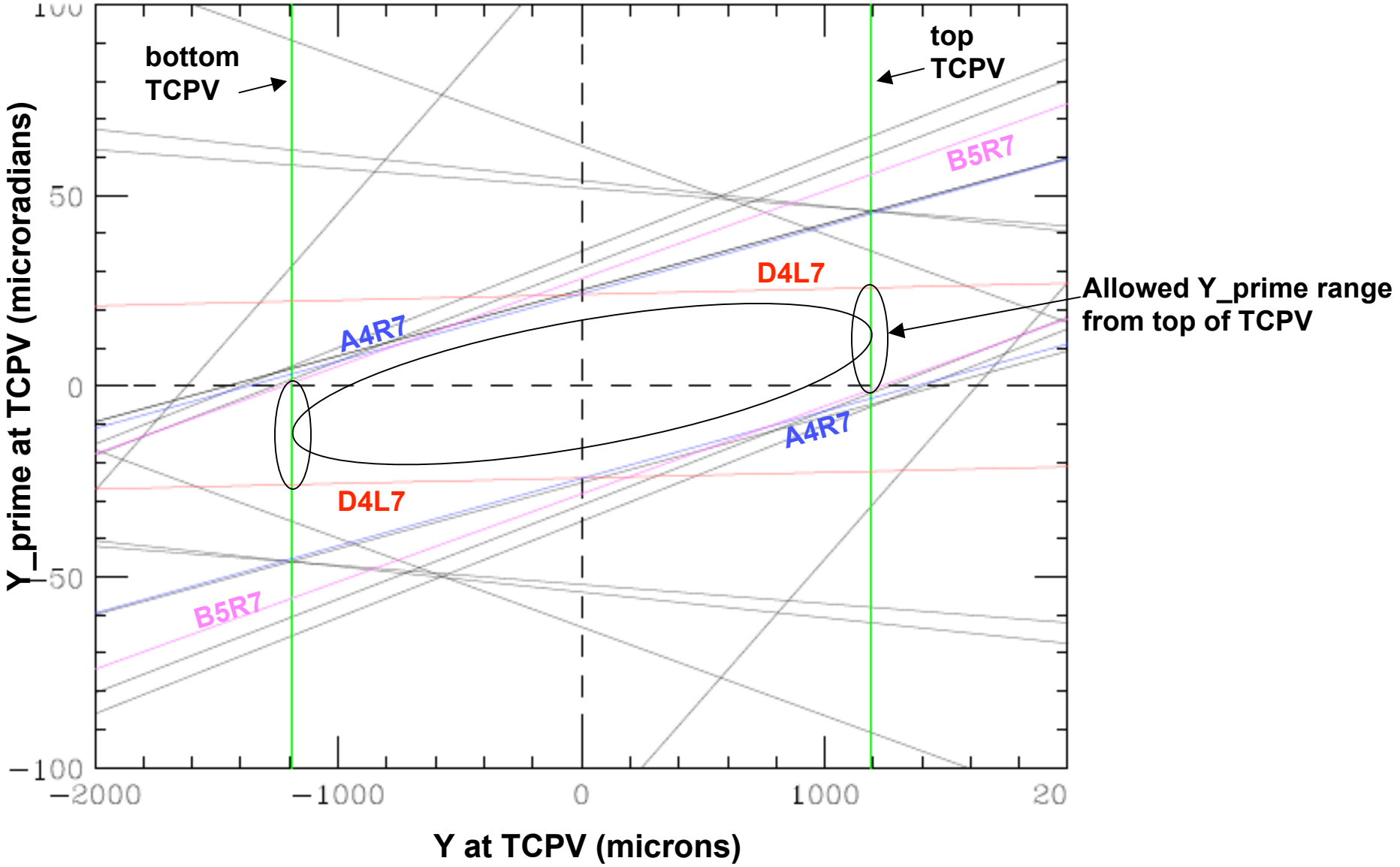
Secondary Apertures at TCPH for 5.95 TeV (-15% ΔE/E)

(for y0_prime = 0)



Secondary Collimator Apertures Projected onto TCPV, 7.0 TeV

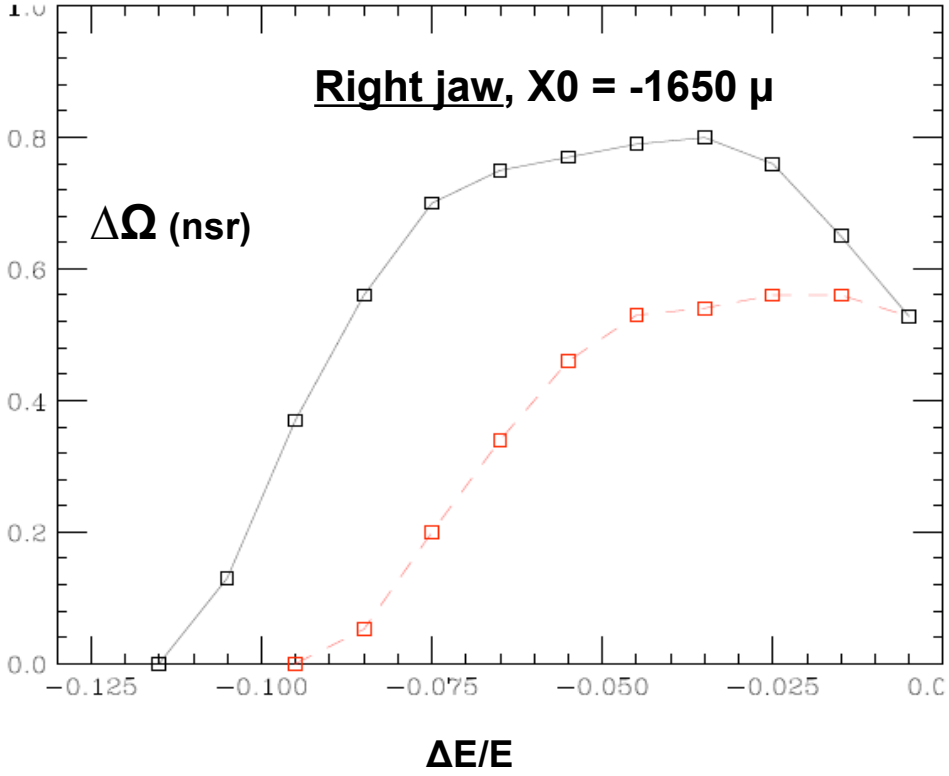
(for x0_prime = 0)

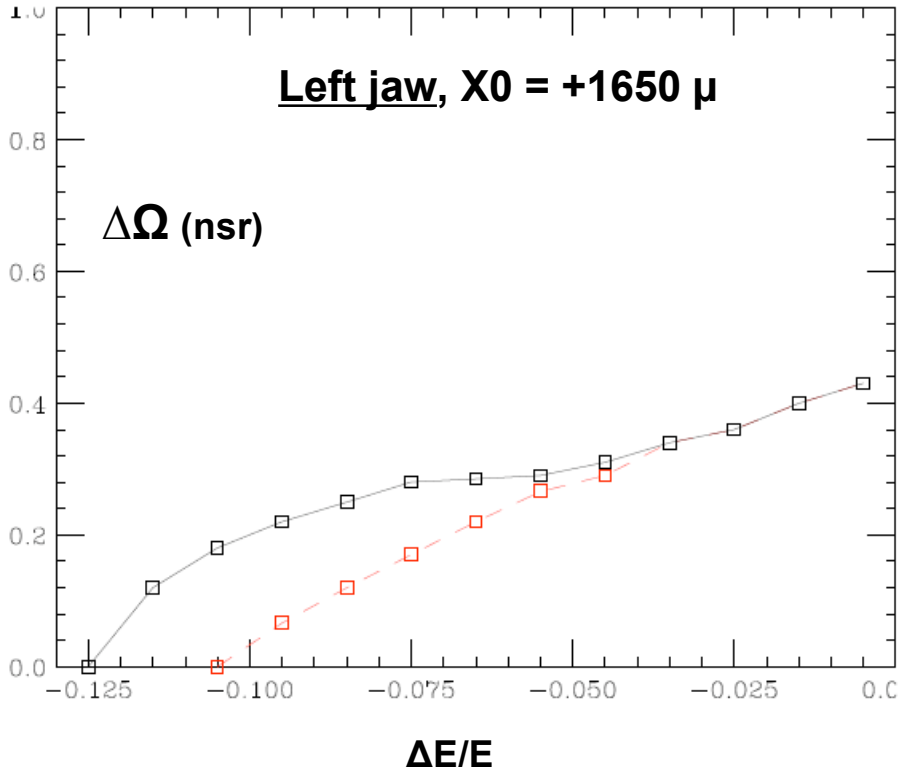


IR-7 Beam Line Acceptance from Edges of TCPH vs. ΔE/E (using TURTLE)

absorbers F6R7 and A7R7 at 10 σ

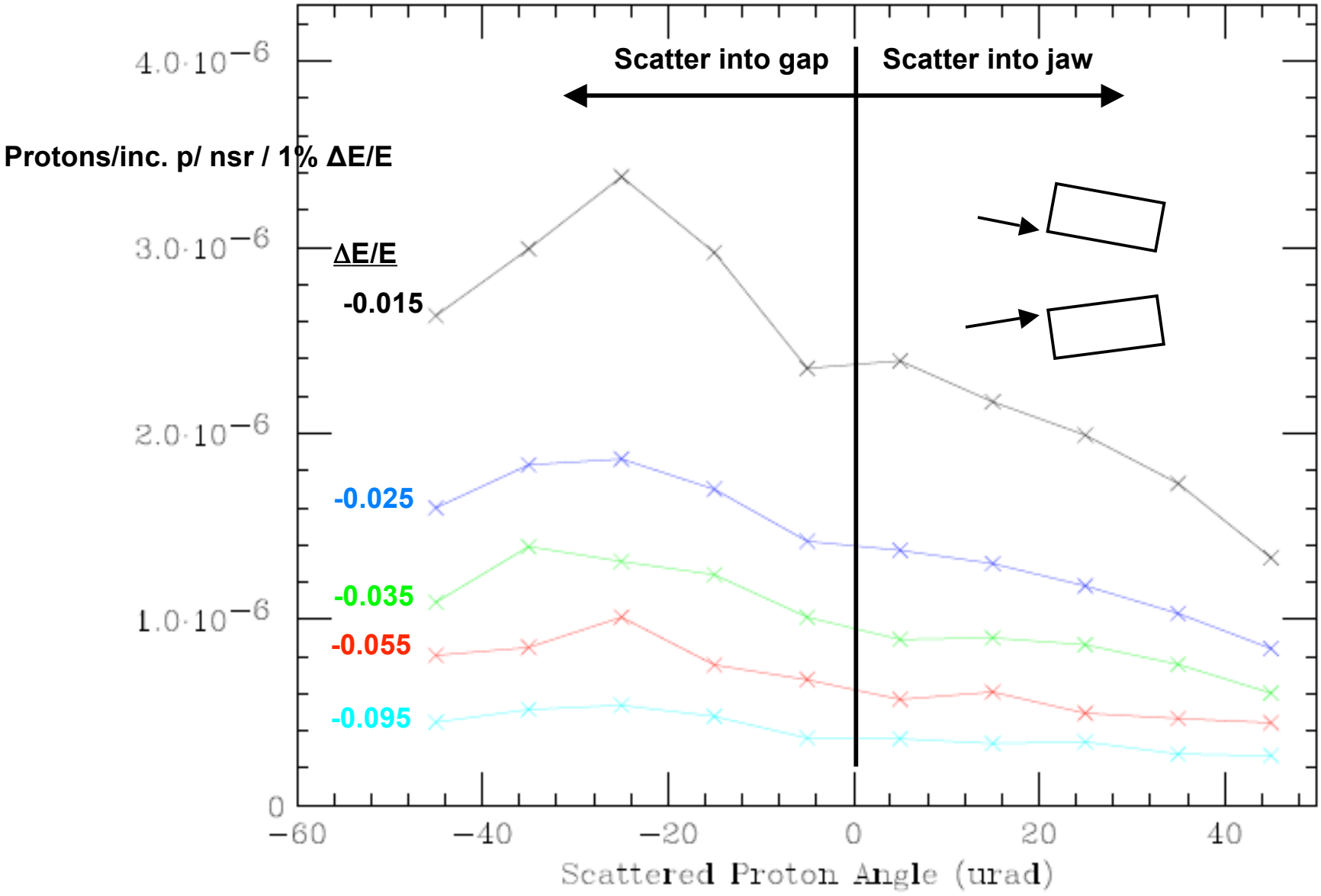
absorbers F6R7 and A7R7 at 7 σ





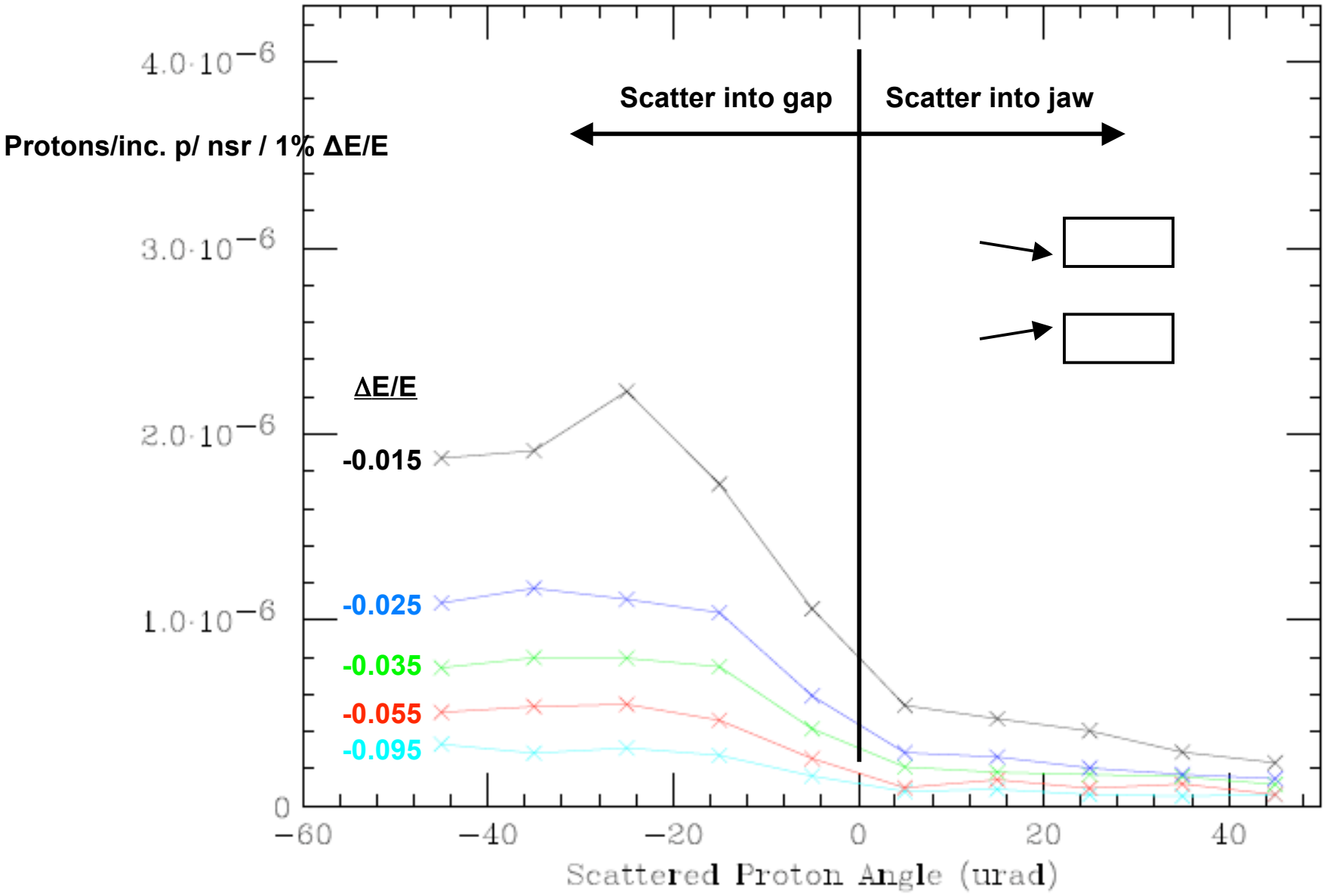
Proton Yield from TCPH vs. Angle and Energy (using FLUKA)

Jaws Tilted – halo parallel to jaw face



Proton Yield from TCPH vs. Angle and Energy (FLUKA)

Jaws Parallel – single pass



Rate of Off-energy Protons Entering Arc 7 from TCPH, 0.2 hour lifetime

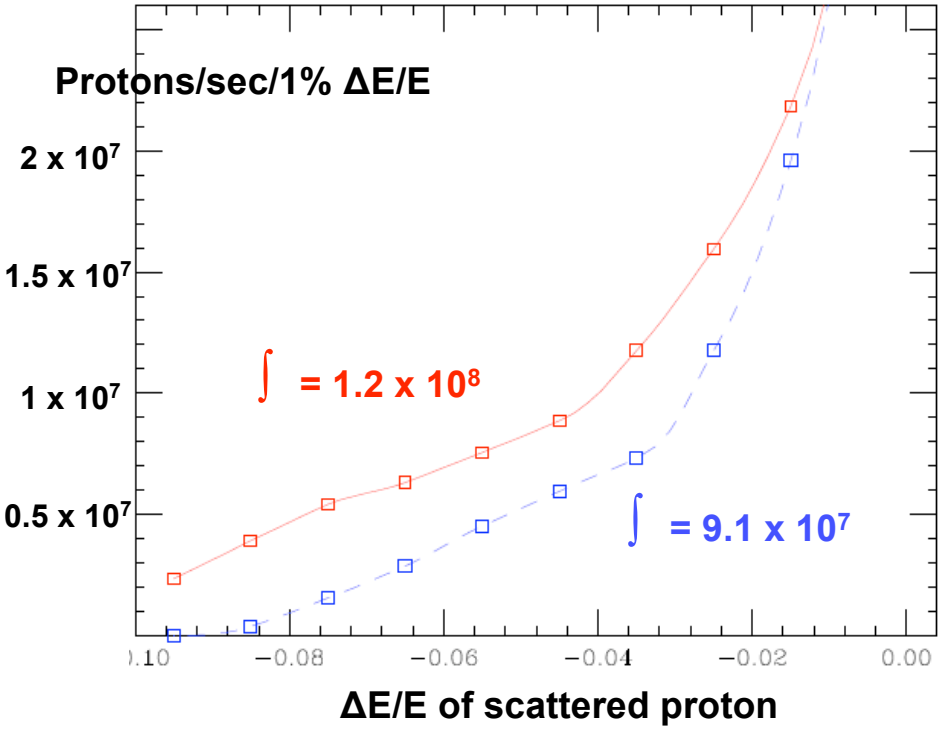
(all of these will be lost somewhere in the first 120 m of arc 7)

absorbers F6R7 and A7R7 at 10 σ,
sum both jaws (ΔE/E < -0.005) = 1.9 x 10^8 p/sec

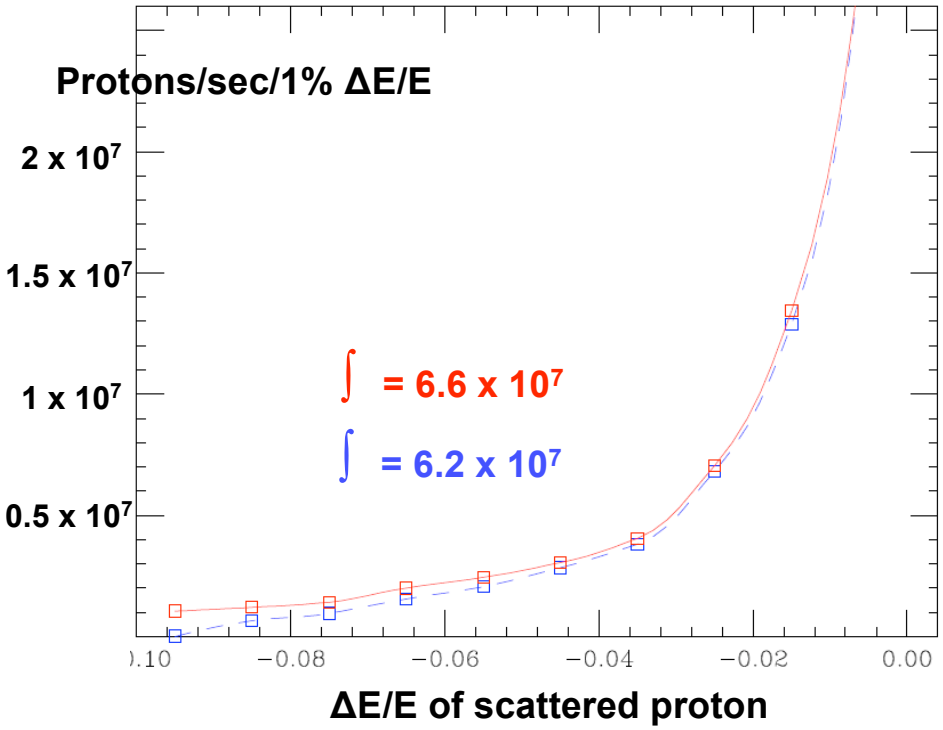
absorbers F6R7 and A7R7 at 7σ,
sum both jaws (ΔE/E < -0.005) = 1.5 x 10^8 p/sec

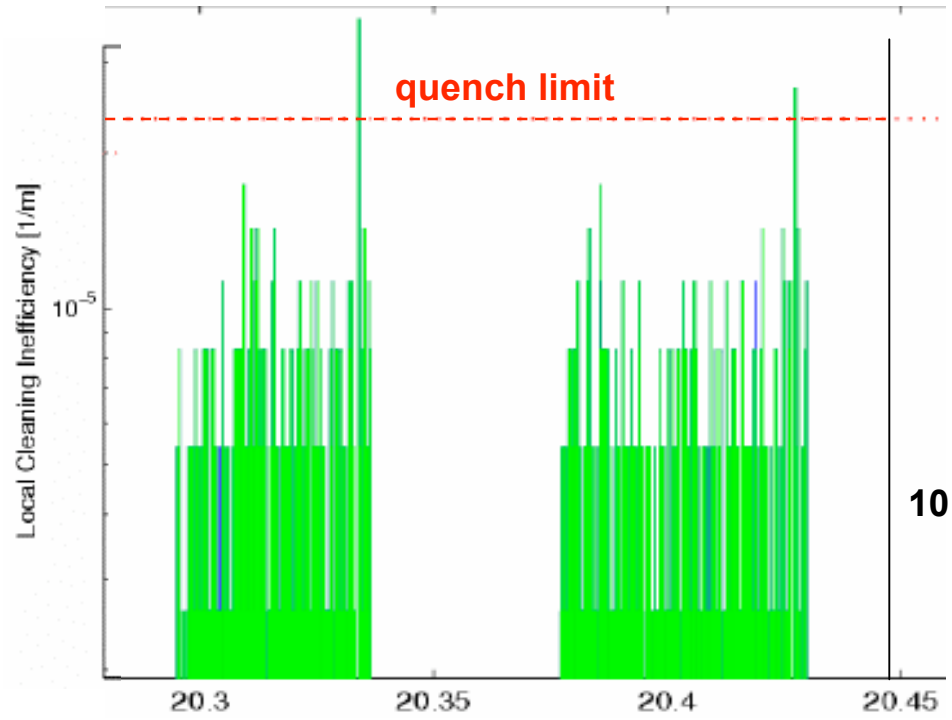
Nominal quench limit is 7 x 10^6 p/m/sec

Right jaw

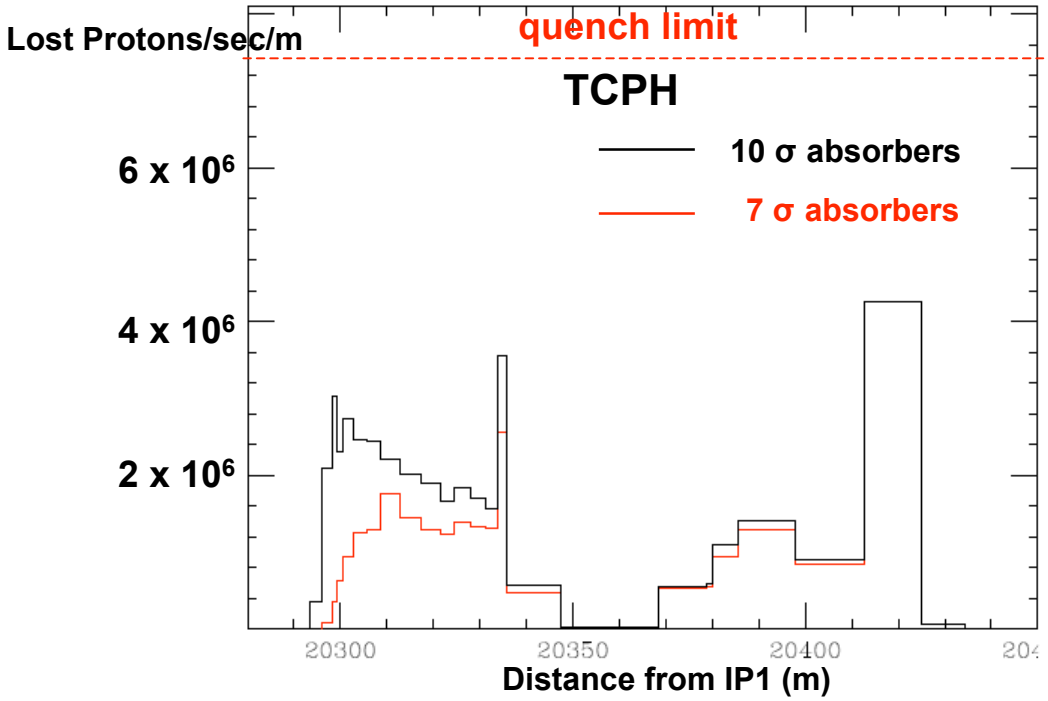


Left jaw





10 cm resolution



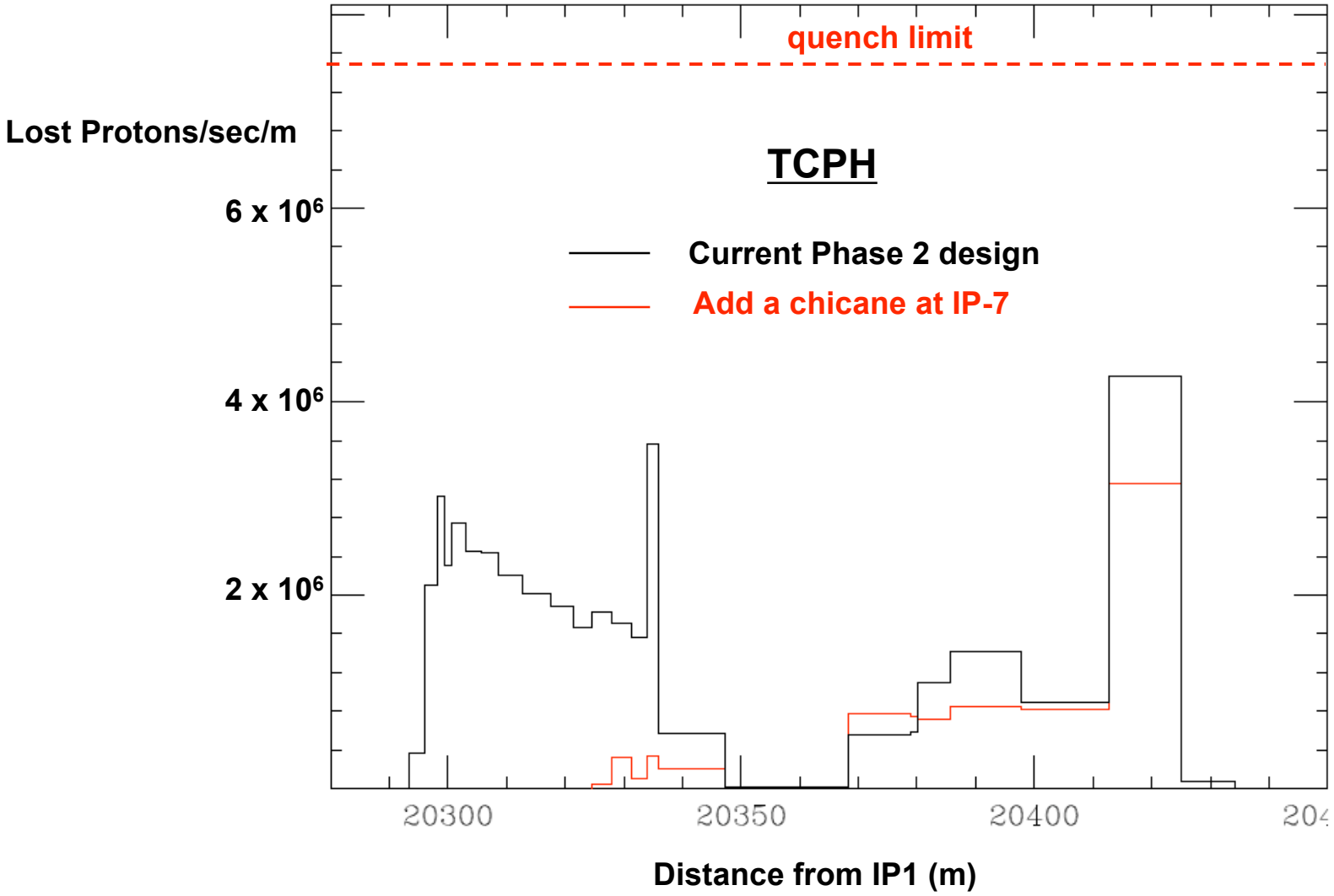
~1 m resolution

Comparison of this Study with Bracco, et.al.

qualitative agreement

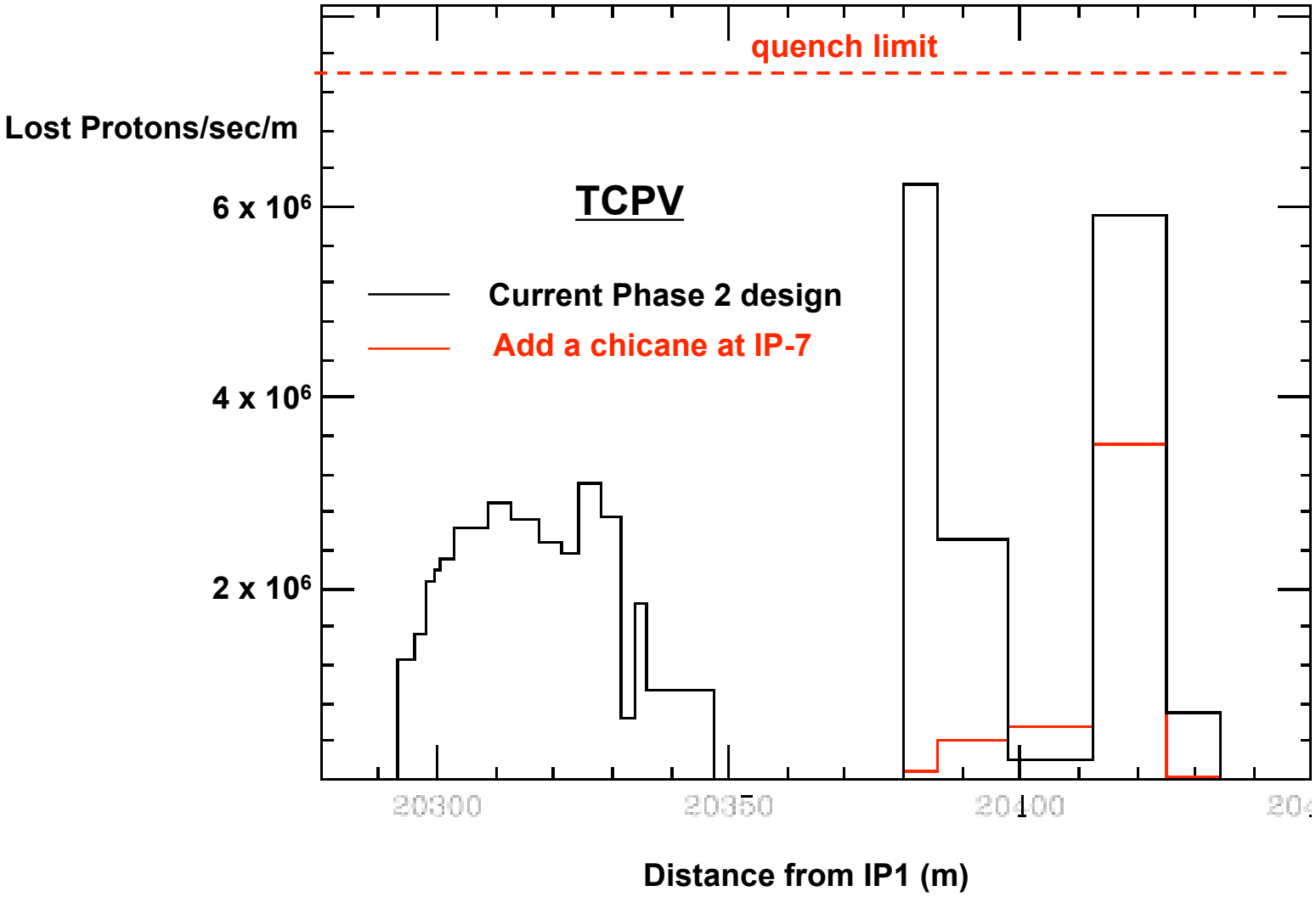
Loss Distribution in Arc 7 before and after Addition of a Chicane at IP-7, TCPH

(the chicane is 112 m long, located between MQWA.A4L7 and MQWA.A4R7)



Loss Distribution in Arc 7 before and after Addition of a Chicane at IP-7, TCPV

(the chicane is 112 m long, located between MQWA.A4L7 and MQWA.A4R7)



Power Lost on "Cryogenic" Collimators, Beam 1

(See Th. Weiler talk, Phase 2 Meeting, 22 May, 2008)

0.2 h lifetime, cryo. collimators at 15 σ

Proton Source	TCRYO.AR7.B1	TCRYO.BR7.B1
TCPH left jaw	62 w	12 w
TCPH right jaw	128	7
TCPV top jaw	91	13
TCPV bottom jaw	85	16

Summary

For the Class of Off-energy Protons which Reach Arc 7 and Do Not Hit Secondary Collimators:

1. **Using a simple FLUKA model of a primary collimator jaw, the high energy proton yield as a function of $\Delta E/E$ and $\Delta\Omega$ is simulated.**

2. **Using a TURTLE/TRANSPORT model of the IR-7 Phase 2 collimation system, $\Delta\Omega$ as a function of $\Delta E/E$ from the primary collimators is calculated.**

3. **Combining these results with a TURTLE model of the first 120 m of Arc 7 gives the rate of lost protons/meter, i.e. the local inefficiency in Arc 7.**

This technique allows the user to quickly estimate the effect of different versions of the IR-7 collimation system on the local inefficiency in Arc 7.

Summary (cont.)

Results for Different IR-7 Versions:

1. Reducing two horizontal-gap absorbers, F6R7 and A7R7, from 10σ to 7σ cut the total losses in Arc 7 by about 20%.

2. Adding a strong chicane surrounding IP-7 reduces the bandwidth of the collimation system and can substantially reduce the rate of lost protons. This would be more effective if the IR-7 optics could be changed to give better energy resolution at the center of the chicane.

3. Lengthening the primary carbon collimators to 100 cm had little effect on the loss rate.

4. Adding five new collimators in IR-7 Phase 4 locations had a negligible effect on the losses in Arc 7.