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Booster collimation system: status and future

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PIP-II Collaboration Meeting

9-10 November 2015

Present activities for collimation system and people involved

*Two stage collimation system for booster designed and installed in 2004.
It was tested but is not used in operations*

Tests for collimators motions :

- Primary collimators moves reliably (tested by Salah Chaurize & myself VK)
- Secondary collimators (Sec-Colls) tests on 23-Jul & 11-Aug (Rick Tesarek, Todd Sullivan, Matt Slabaugh, VK, Salah) have showed some problems for all 3 collimators: vertical motion for all 3 collimators and horizontal motion for 2nd collimator.
- Several meetings & discussions (see Beam-Doc DB); team including Rick, Mike Coburn & Charles Briegel (controls), Matt (mechanics); support from Salah & Todd.
- The last Sept-2015 tests show some improvements after Rick' analysis and suggestions has been realized by Mike & Charles. Thanks !

Simulations support (a'la STRUCT+MARS):

- o General problem formulation and tutions— N.Mokhov & V.Lebedev
- o subroutines for primaries extracted from STRUCT – checked by S.Striganov
- o MARS models for secondary collimators (& Notch-absorber) – created on Heimdall by I.Tropin & I.Rakhno
- o work with MADX – source and gluing scripts – myself

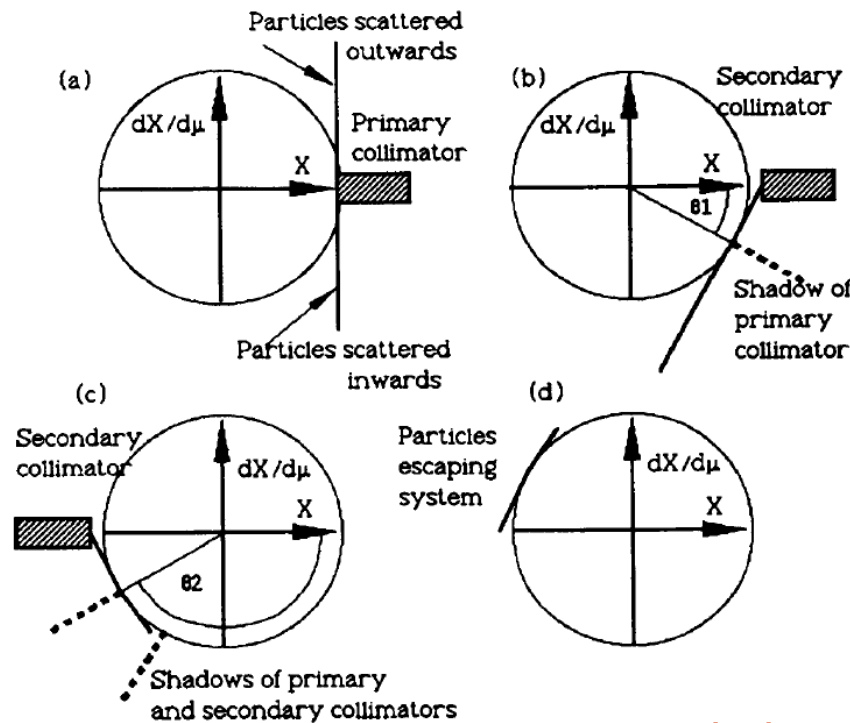
General support, guidance, consulting & encouragements: Bill Pellico, C.Y.Tan, Vladimir Sidorov

Principle scheme of 2-stage collimation system

Usual “1-stage” collimation produces uncontrolled out-scattered protons => “2-stage” scheme

Bryant, in CERN Acc. School (1992), p.174

The primary collimator is followed by two secondary collimators set at optimized phases for intercepting the scattered particles.



- Simulations steps (as with STRUCT):
- ❖ Generate **part. distribution** on edge of Prim-Collimator (halo-particles)
 - ❖ **Scattering** in material of thin P-Coll
 - ❖ **(Non-linear) Tracking** scattered parts
 - ❖ Collect **lost particles** on Sec-Colls and other magnet **apertures**

Fig. 11 Main features of a collimation system

halo particles => large amplitudes =>
Correct treatment non-linear dynamics => ~MADX

Collimator placements in booster

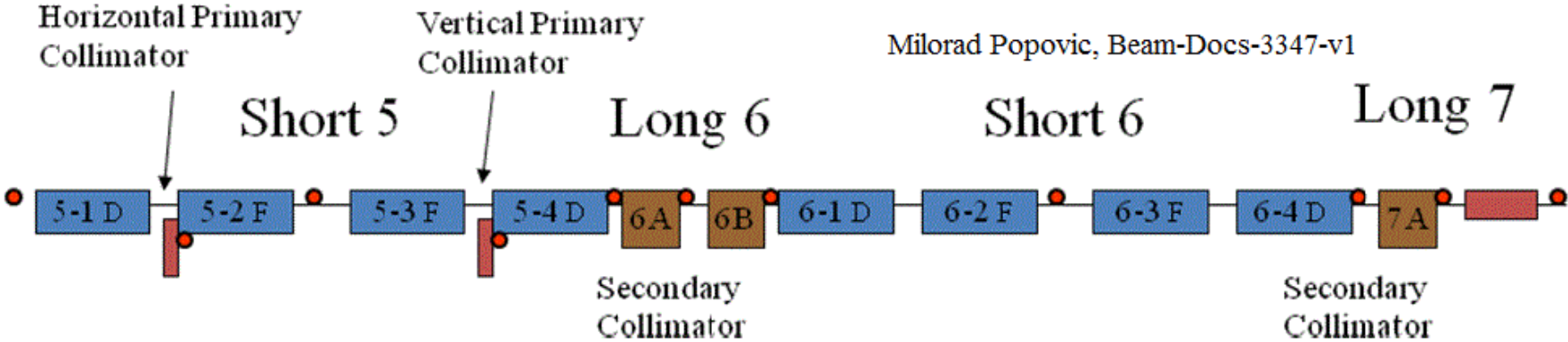
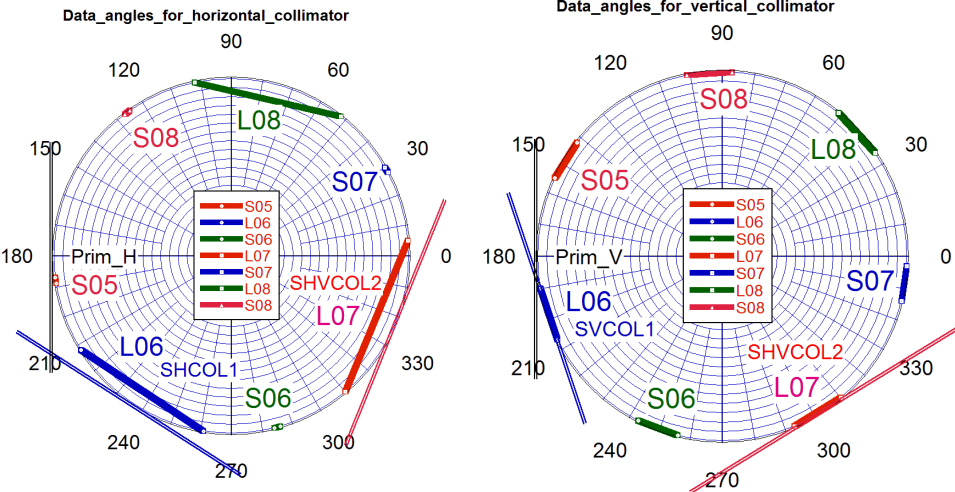


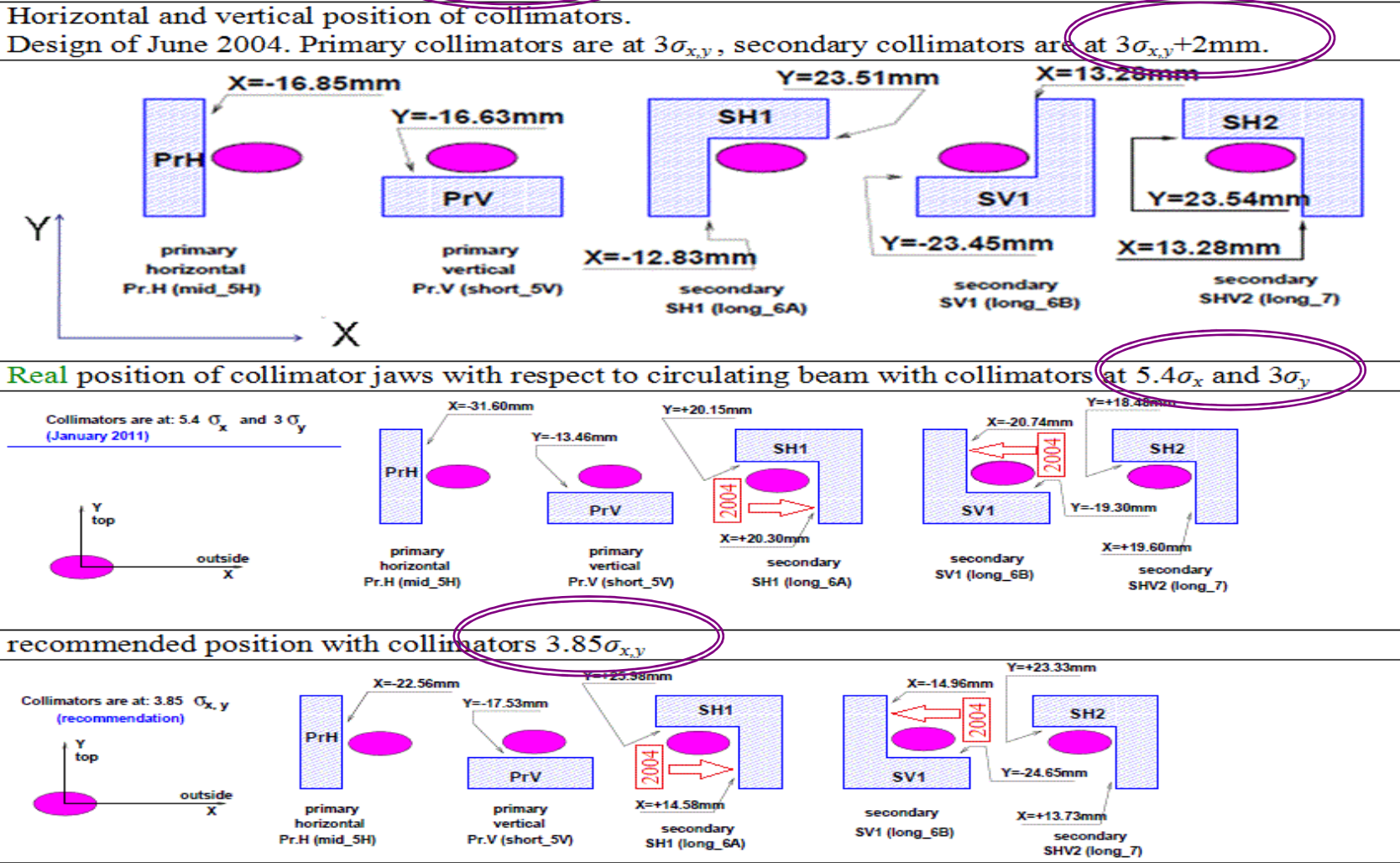
Figure 1. Blue boxes represent the main magnets; collimators are represented by brown boxes.



Restrictions for design:
 Not optimal phase advances;
 Small magnet apertures;
 Bending magnets in coll system;
 Variable beam parameters during accelerator cycle

Collimation system transverse layouts by A.Drozhdin

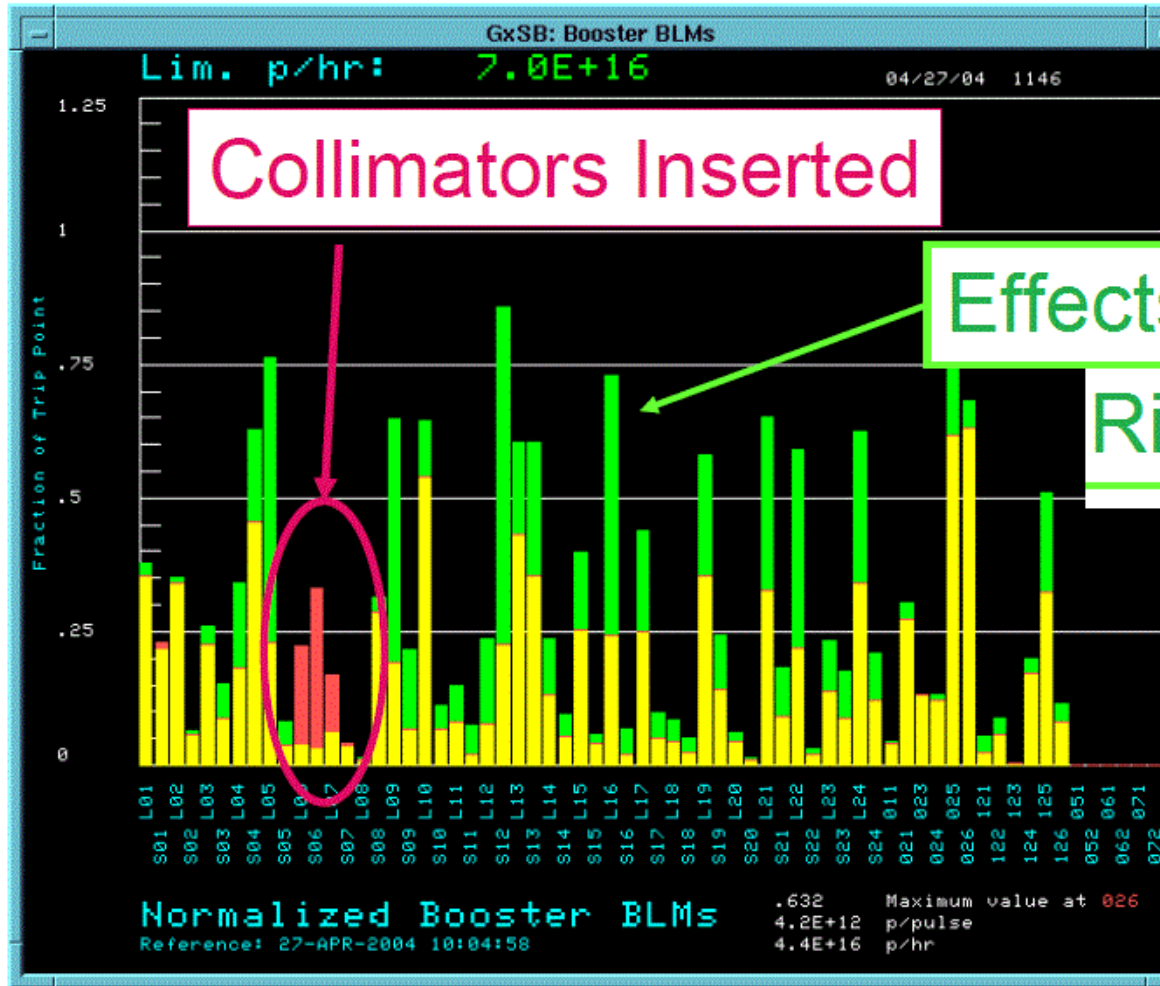
Table. from Ref.1 "pap_coll-2011_new.pdf"



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Tests for effects of collimator on Ring Losses

2005 Pellico & Sullivan
Booster Collimation
DOE-Review



Two-stage collimation is not used in operations (variable beam size and position due to e.g. "momentum cogging")

March 29 - 31, 2005

DOE Review of Tevatron Operations at FNAL

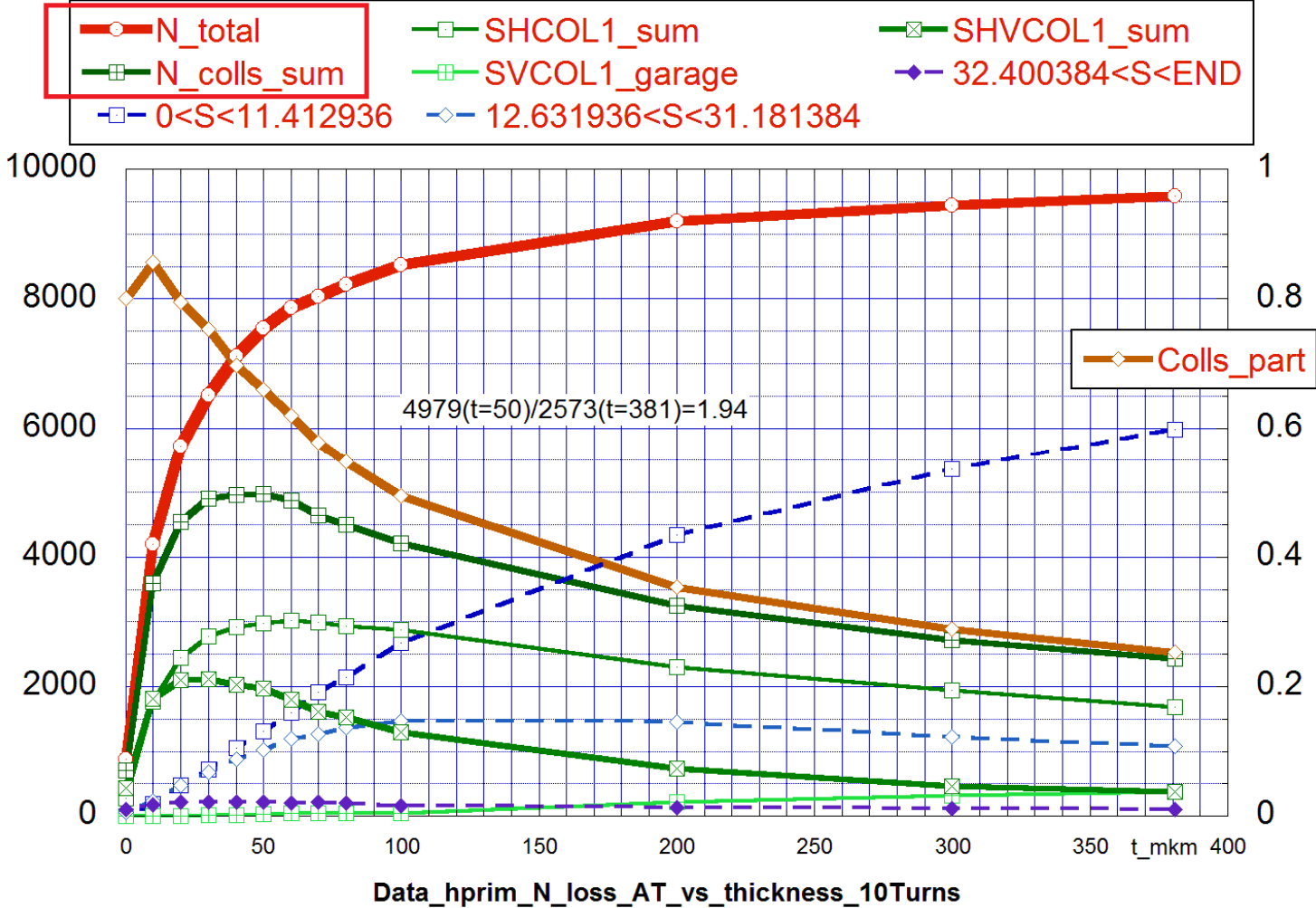
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Task started in 2014: optimal thickness of primary coll.

- **MADX code** has been modified to include **proton interactions with thin primary collimators** (Prim-Colls), while out-scattering from secondary collimators is neglected
- **Dependence of collimation efficiency on thickness** of **Cu** Prim-Colls at injection energy (**400MeV**) within thickness range {0; 381um} has been simulated. It is quite smooth.
- Collimation efficiency grows up **with the number of turns** (simulated up to 100) under simulation approach that all accelerator parameters are constant (*is it a case of booster ?*)
- **Optimal thickness** of Prim-Colls for Cu is **~50um (or thinner)** to reduce losses of scattered protons in magnet apertures and pipes between primary and secondary collimators.
- ~50 mkm is much less of **existing 381 um (0.015") Cu foil** for both hor. and vert. primaries
- Original STRUCT's calculations at 400 MeV corresponds to **equivalent Cu foils of ~12um**

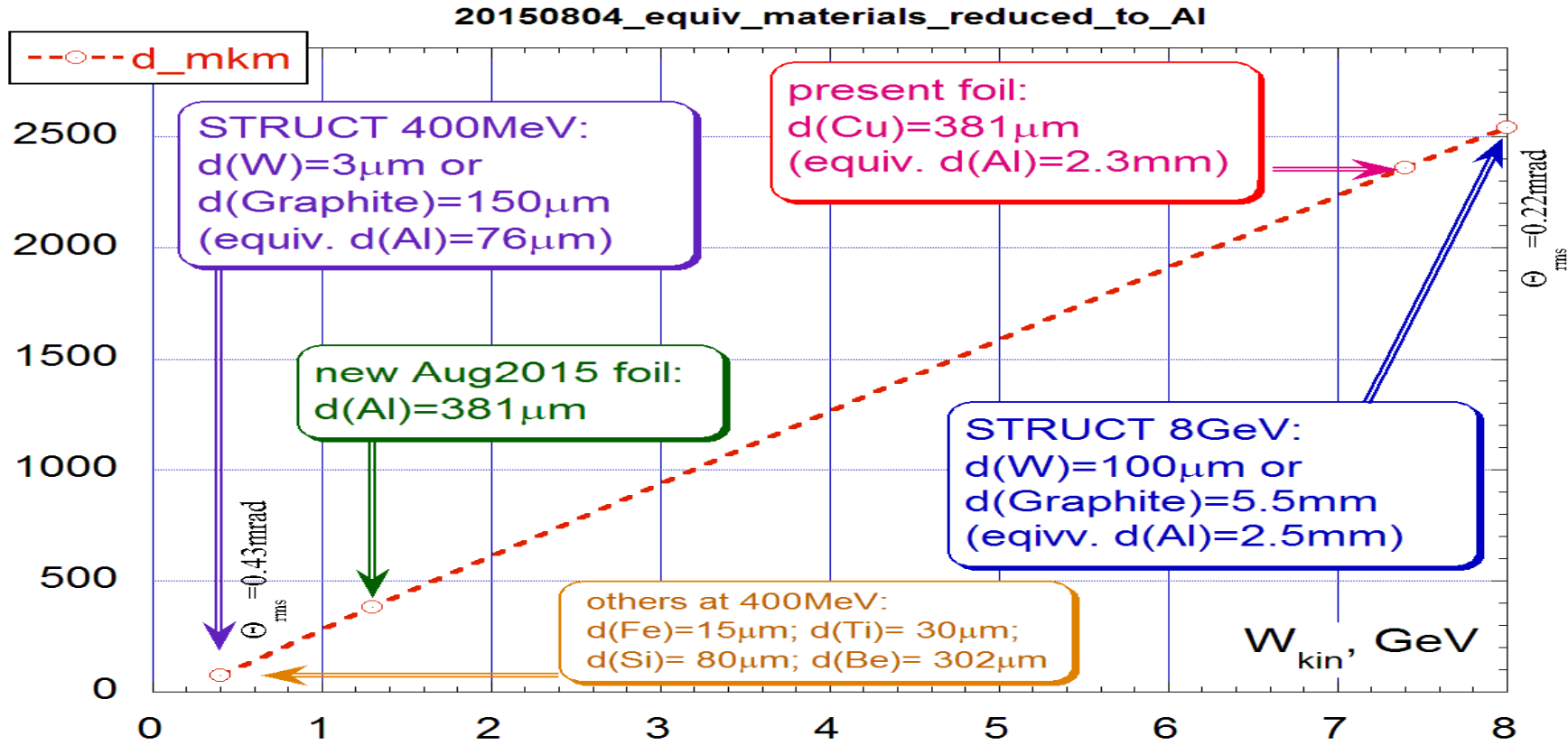
MADX (w/o out-scattering): horizontal collimation for 2004-design

After 10 turns



Maximum N_{colls_sum} at 50um (within 30-60um)

Primary thickness for ~2004 “STRUCT” design & Equiv. materials



RMS scattering angle

$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta c p} z \sqrt{x/X_0} \left[1 + 0.038 \ln(x/X_0) \right] \quad x[\text{g/cm}^2] = \rho[\text{g/cm}^3] \cdot d[\text{cm}]$$

New aluminium Prim-Colls

2005: Cu primary heat sink with signal cable (+ceramic ins.)



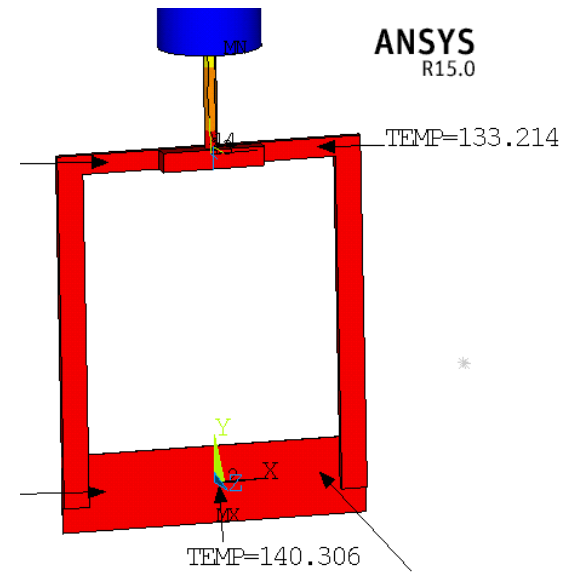
Aug. 2015: 381 um Al primary with the same sizes as Cu



Oct.2015 New simplified primary assembly (just Al plate without any ceramic insulators):

R.J. Tesarek, B. Hartsell, V. Kapin, N.V. Mokhov, M.Slabaugh, "Calculations of Power Deposited in the Booster Primary Collimators", Beams-Doc-5983, November 4, 2015.

From abstract: ... a candidate primary collimator design of a uniform aluminum foil with a uniform thickness of 381 um. ... the steady state temperature of the collimator under nominal beam conditions to be at or below 140 C (absorb <4.6W).



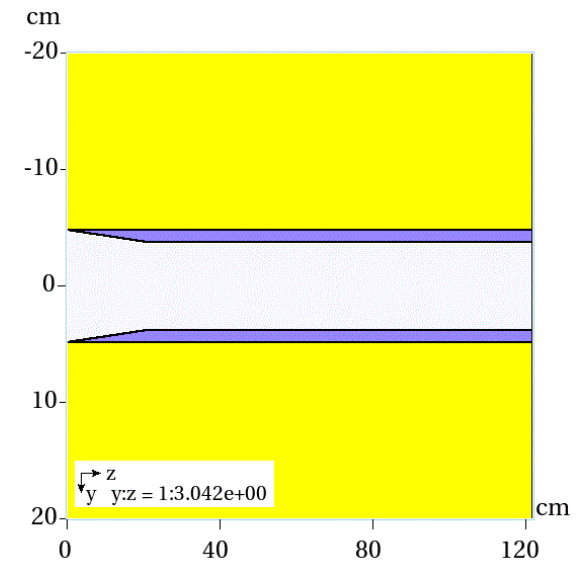
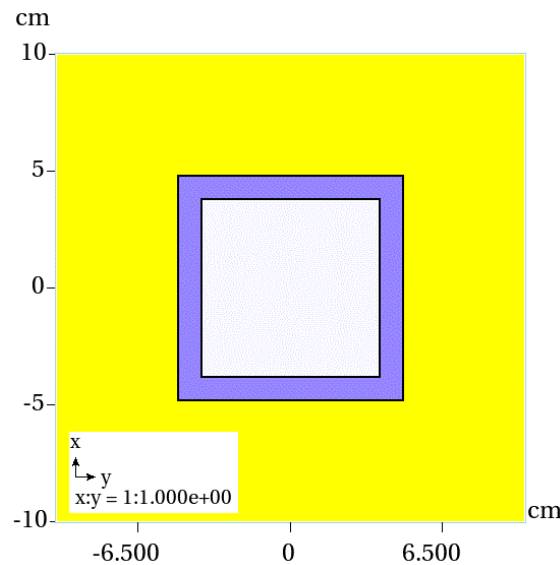
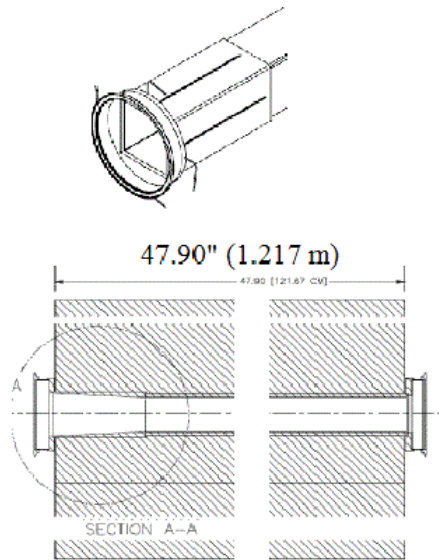
New simulations: upgraded model

- A new simulation approach including **out-scattering in Sec-Colls** is under development for a correct **comparison of two-stage and one-stage collimation** in the booster.
- The proton interactions with Sec-Colls are simulated by MARS (Mokhov's group) and will be used by MADX tracker as black-boxes.
- The first runs performed on the last week (below)
- Plans: simulations for different beam sigma and halo sizes
- Calculations for different collimator layout (2004-design; 2011 Drozhdin “real” configuration; and find optimal one)
- Optional: Optimizations for existing single-stage scheme

New simulations: Mars model for booster secondary collimators

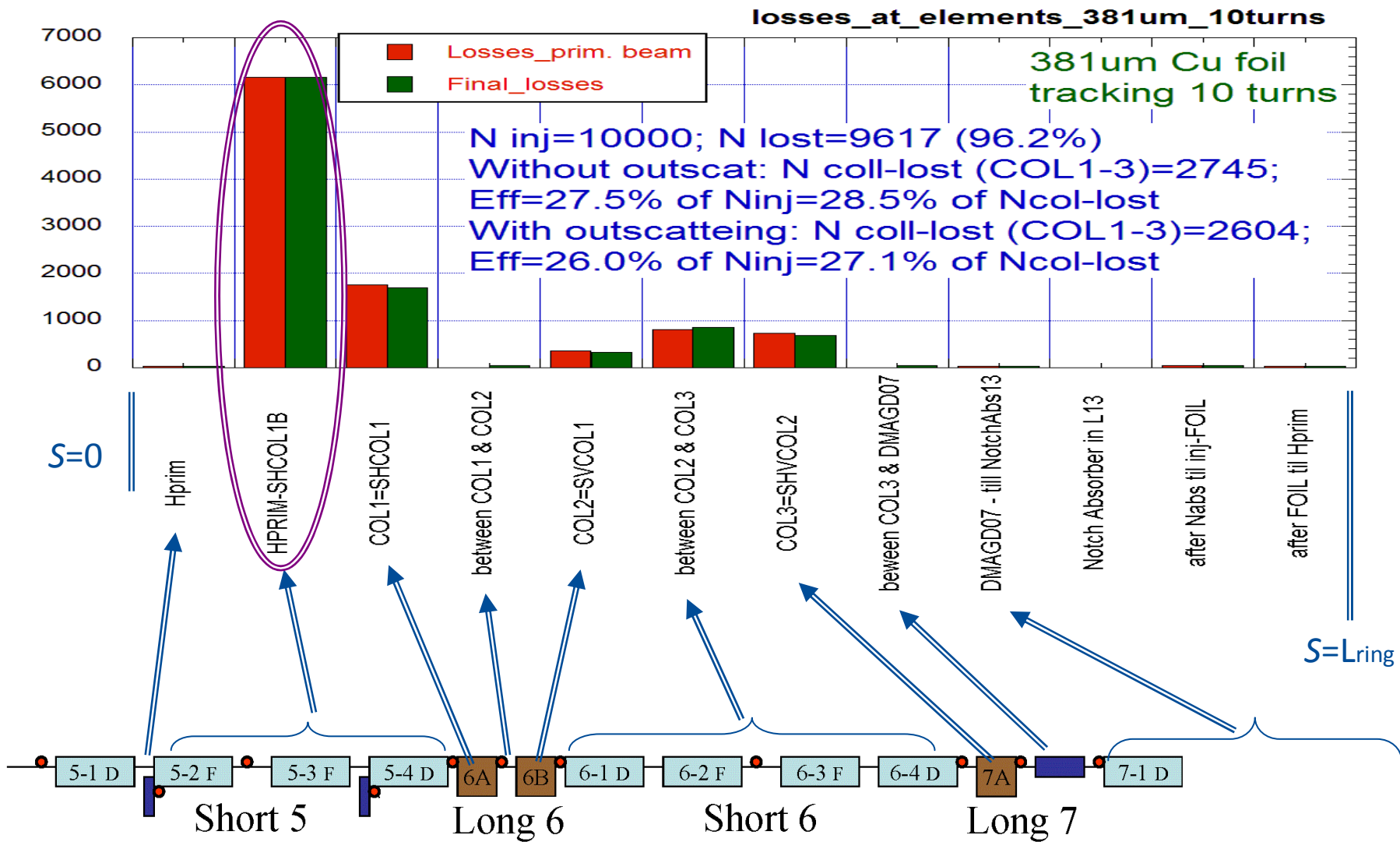
Model created by I. Tropin & I. Rakhno.

Interface with "STRUCT" coordinate system (x,x',y,y',p)

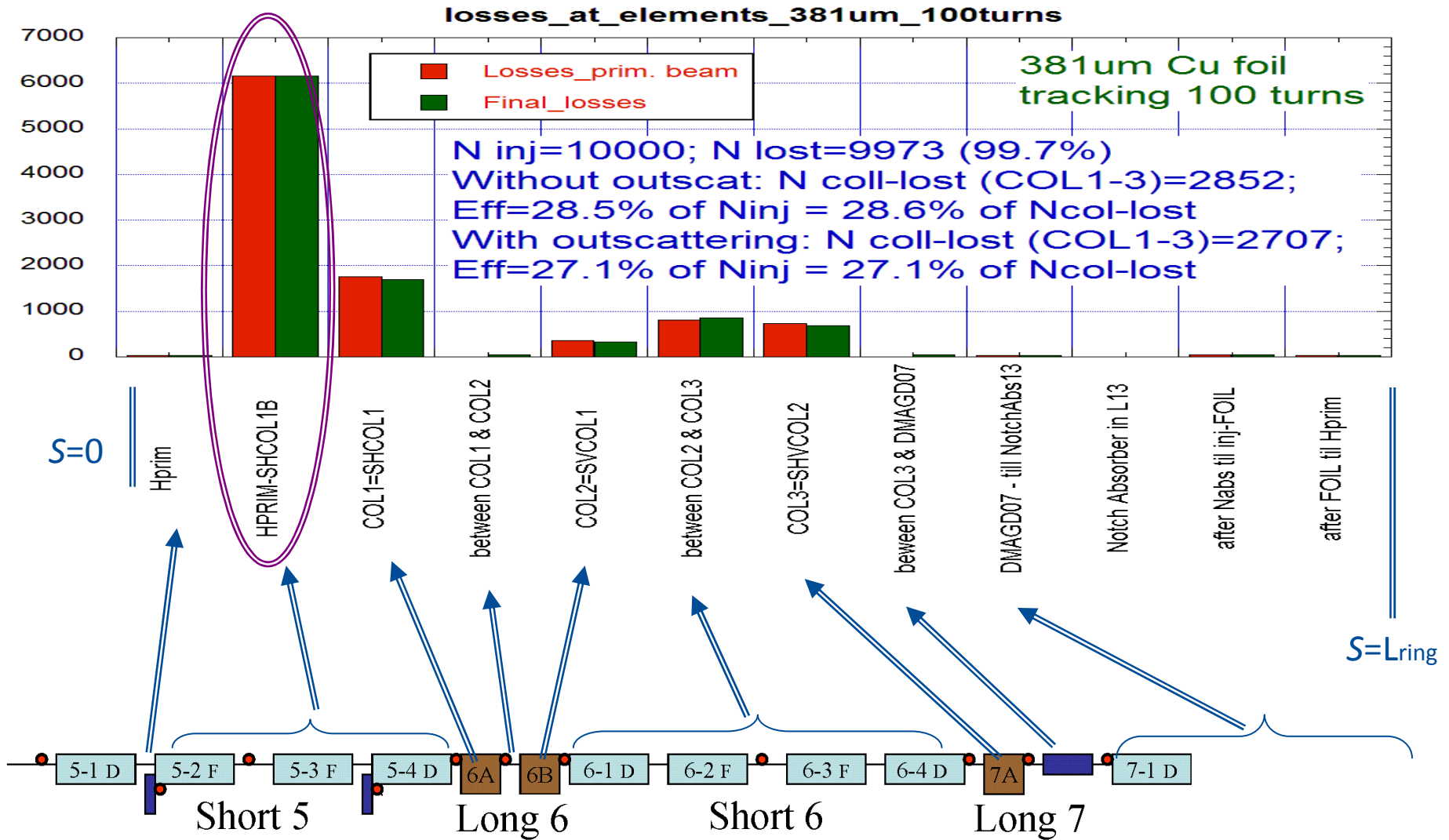


Model is centered on ref. orbit. Transverse shifts simulated
Via shift of input and output particle coordinates for MADX

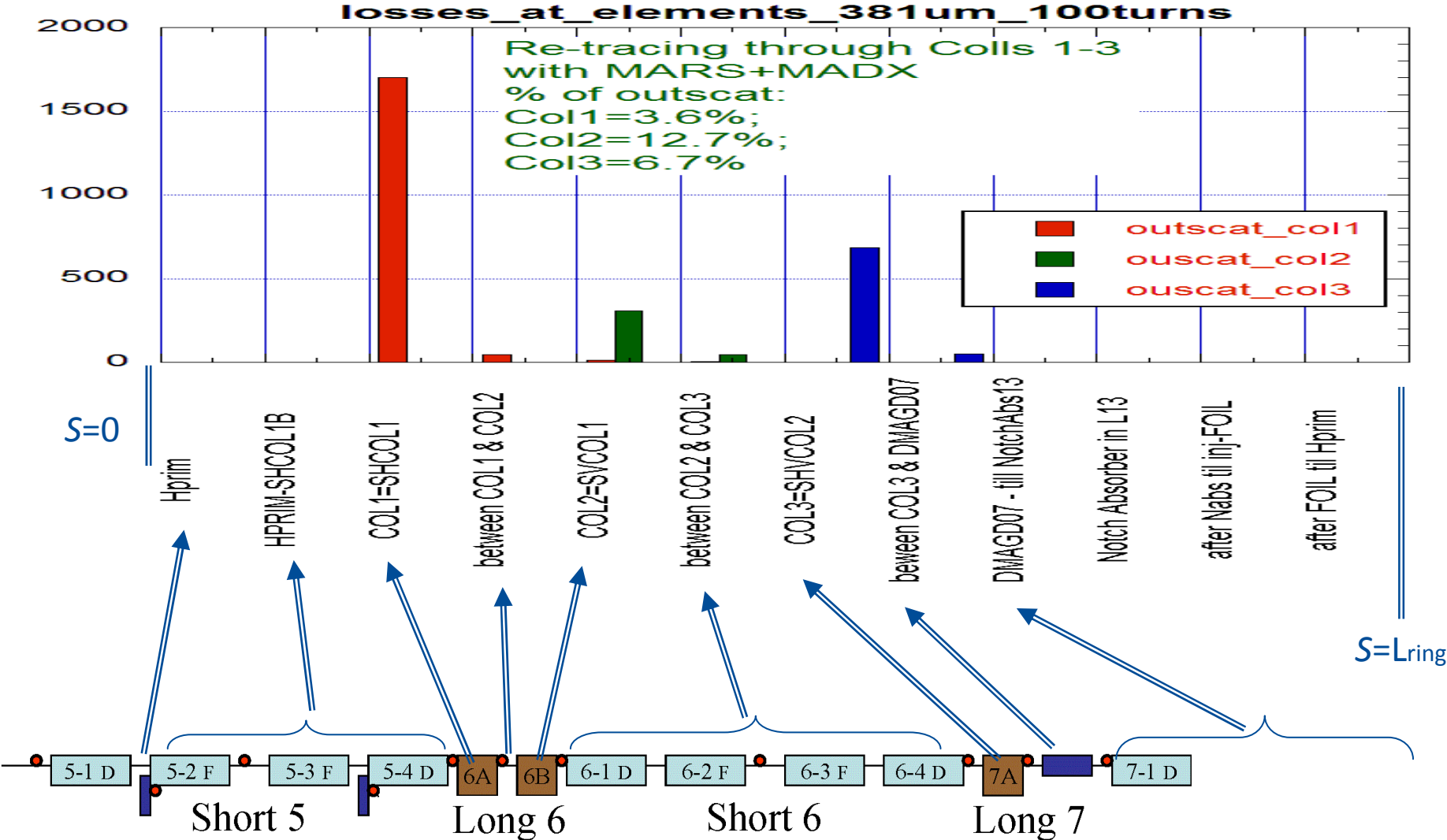
Loss distributions with present 381um Cu foil (10turns)



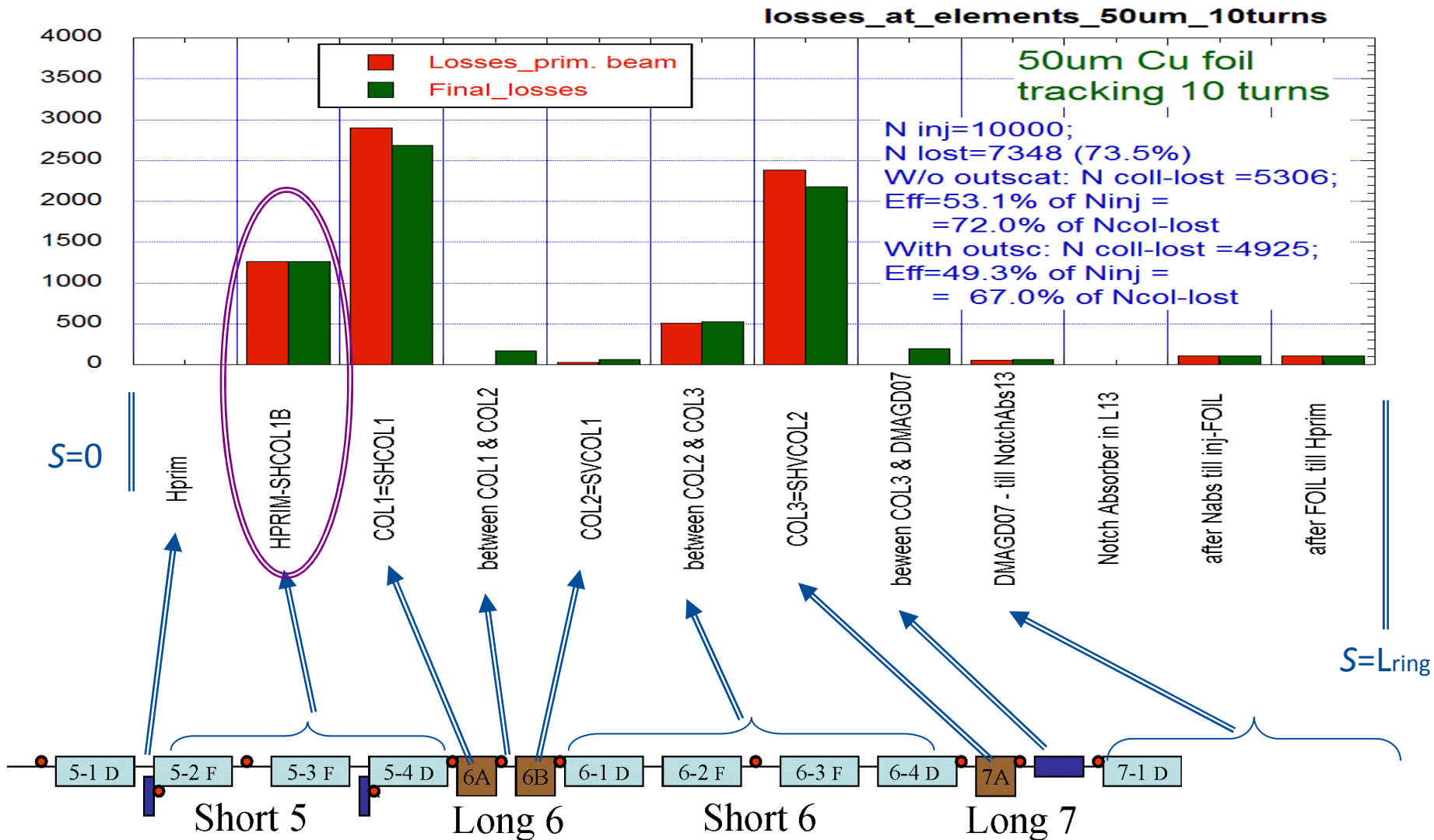
Loss distributions with present 381um Cu foil (100turns)



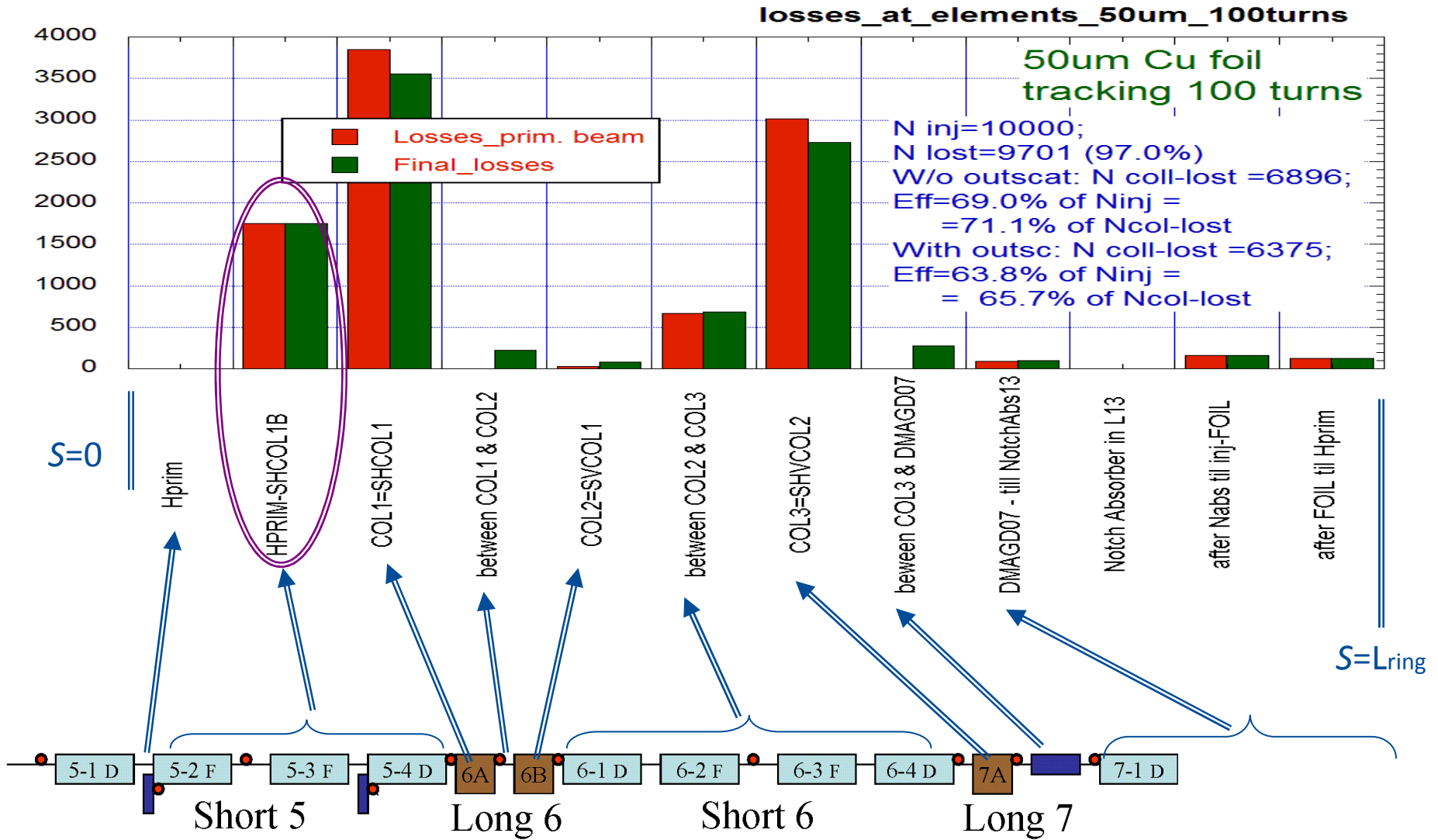
Loss distributions with outscattering (381um Cu foil)



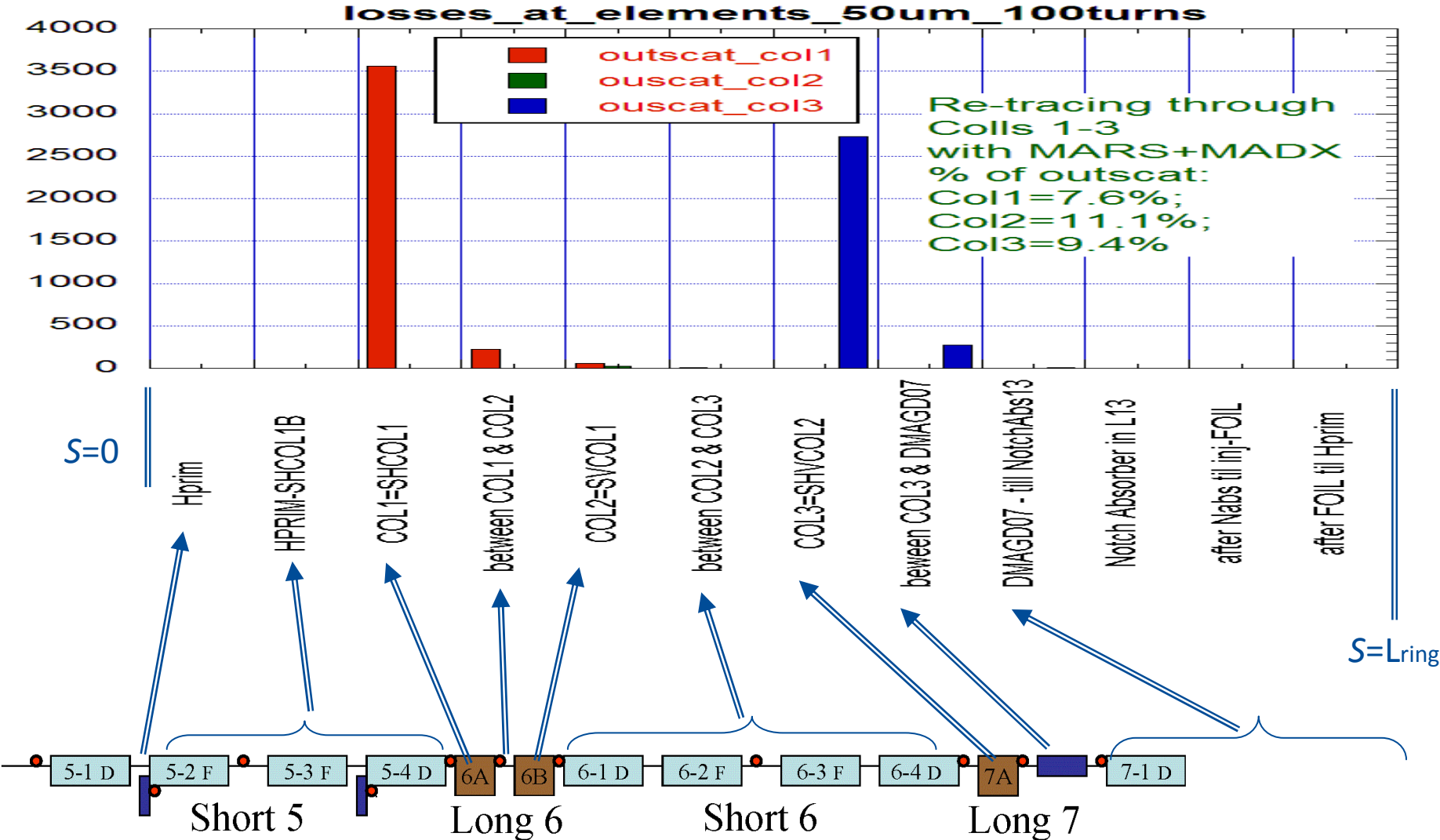
Loss distributions with new 381um Al “50um Cu” foil (10turns)



Loss distributions with new Al “50um Cu” foil (100turns)



Loss distributions with outscattering (new Al 381um foil)



Plans for near future

- Matt made drawings for new Al foil and its “fork ” holder: submitted for fabrication (this week) & alignment measurements
Installation of both(?) primaries in vacuum (a future >8hrs shutdown)
- “Easy” replacement of prim. plate (Al: 0.015” ->0.005” -> ? mm-Be)
- Beam tests could be started afterwards (~Dec. 2015)
- Simulations plans (see above) include comparison with 1-stage colls
- Due to many concerns (collimation in synchrotron, not storage/collider ring) : review of collimation systems on similar proton synchrotrons (J-PARC, SNS, ISIS, ?) to work out possible alternative solutions, if present booster two-stage collimations is failing.
- Considering alternative collimations schemes (e.g. a’la “septum” suggested by V.Lebedev)