A proposal for upgrade of Booster collimation system

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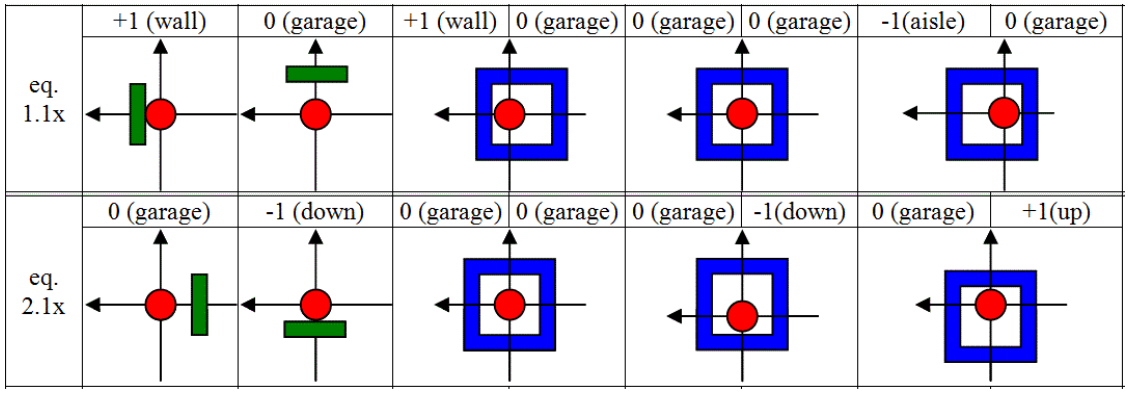
PIP General Meeting, Wed, 22 Feb, 2017

Previous reports & talks

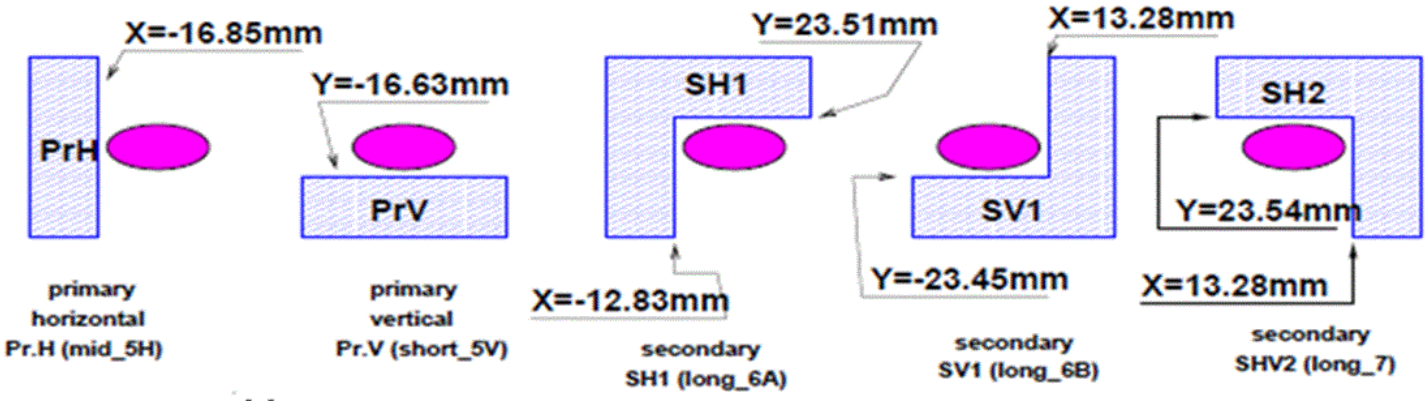
- V.Kapin, “Booster Collimation: 2-stage vs 1-stage”, PIP meeting 24-Aug-2016, Beams-doc-5222-v2
- V.V.Kapin, V.A.Lebedev, N.V.Mokhov, S.I.Striganov, I.S.Tropin, “Numerical Simulations of Collimation Efficiency for Beam Collimation System in the Fermilab Booster”, NAPAC-2016, Chicago, paper WEPOA20. (Pre-release at Web “vrws.de/napac2016”)
- V.Kapin, S.Chaurize, N.Mokhov, W.Pellico, M.Slabaugh, T.Sullivan, R.J.Tesarek, K.Triplett, “Experimental Studies of Beam Collimation System in the Fermilab Booster”, paper WEPOA18, Ibid

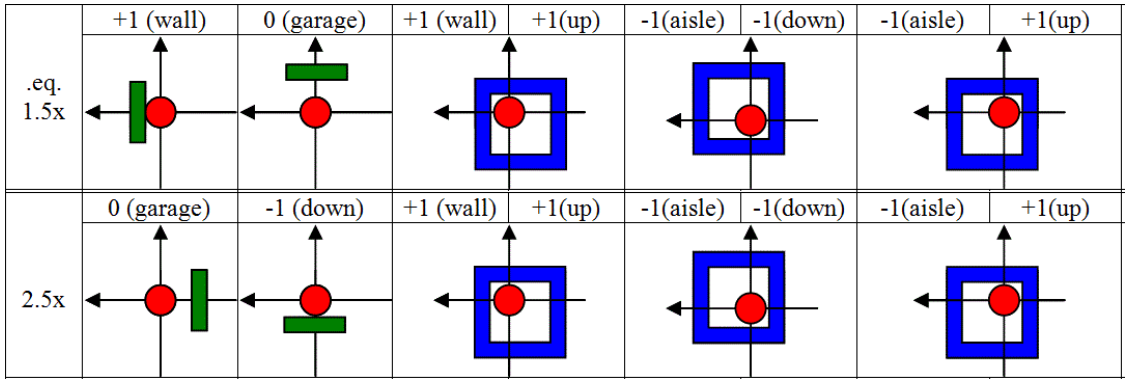
Further maximizing efficiency of 2SC



Previous reported results for pure schemes – collimators touch the beam only in a one given plane (either H or V)

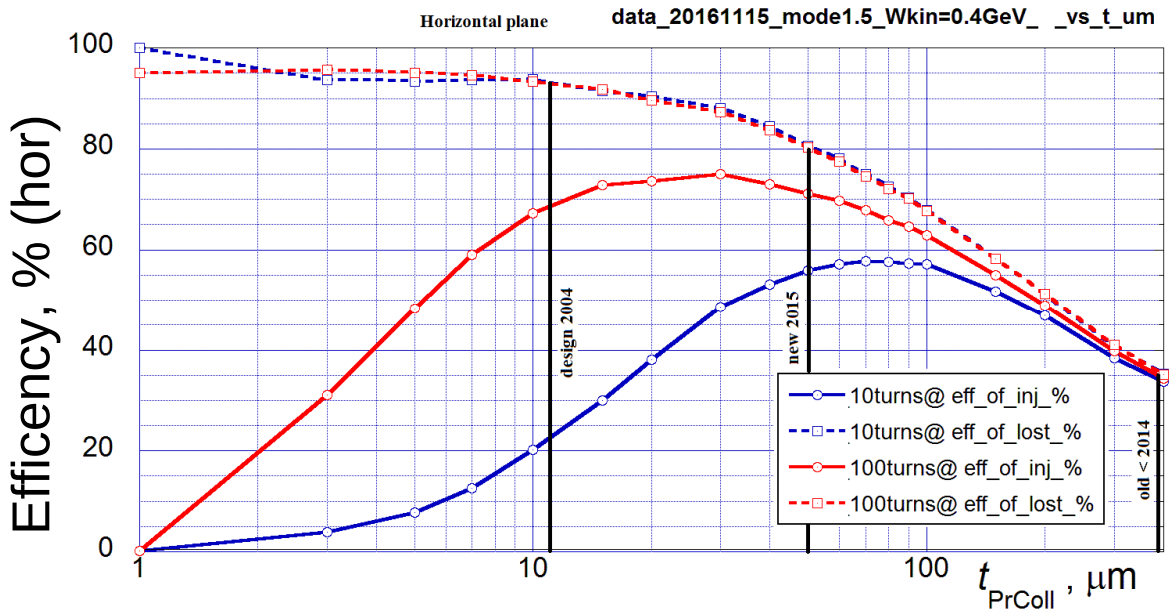
2004 design
By A.D. –
Sec.Colls
touch
In both planes

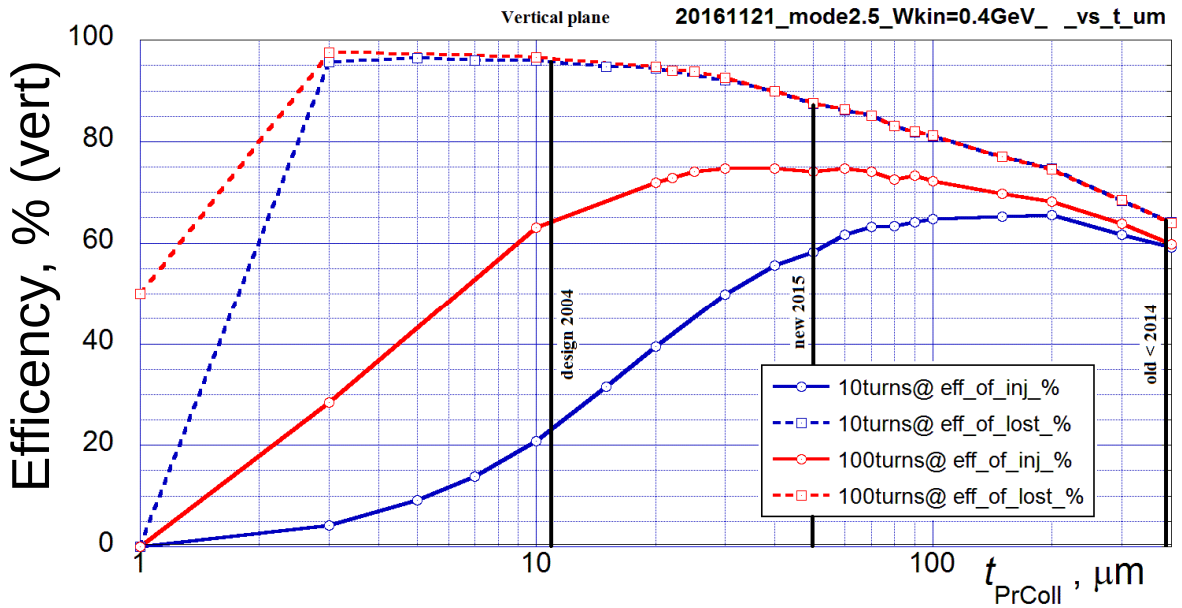




As for 2004 design
Sec.Colls touch
In both planes

Eff. of 2SC (1.5&2.5) vs Cu-foil t,um (Hor & Vert)





Efficiency:

a) "Eff.of lost" = N_lost_colls/N_lost, N_lost <= 1E4

b) "Eff.of inj" = N_lost_colls/N_halo; N_halo = 1E4

Conclusions:

1) Old before 2014 worse;
2) Design 2004 – best after >>10turns (~100);
3) Installed new foil – better after ~10 turns

For ideal simulation conditions:

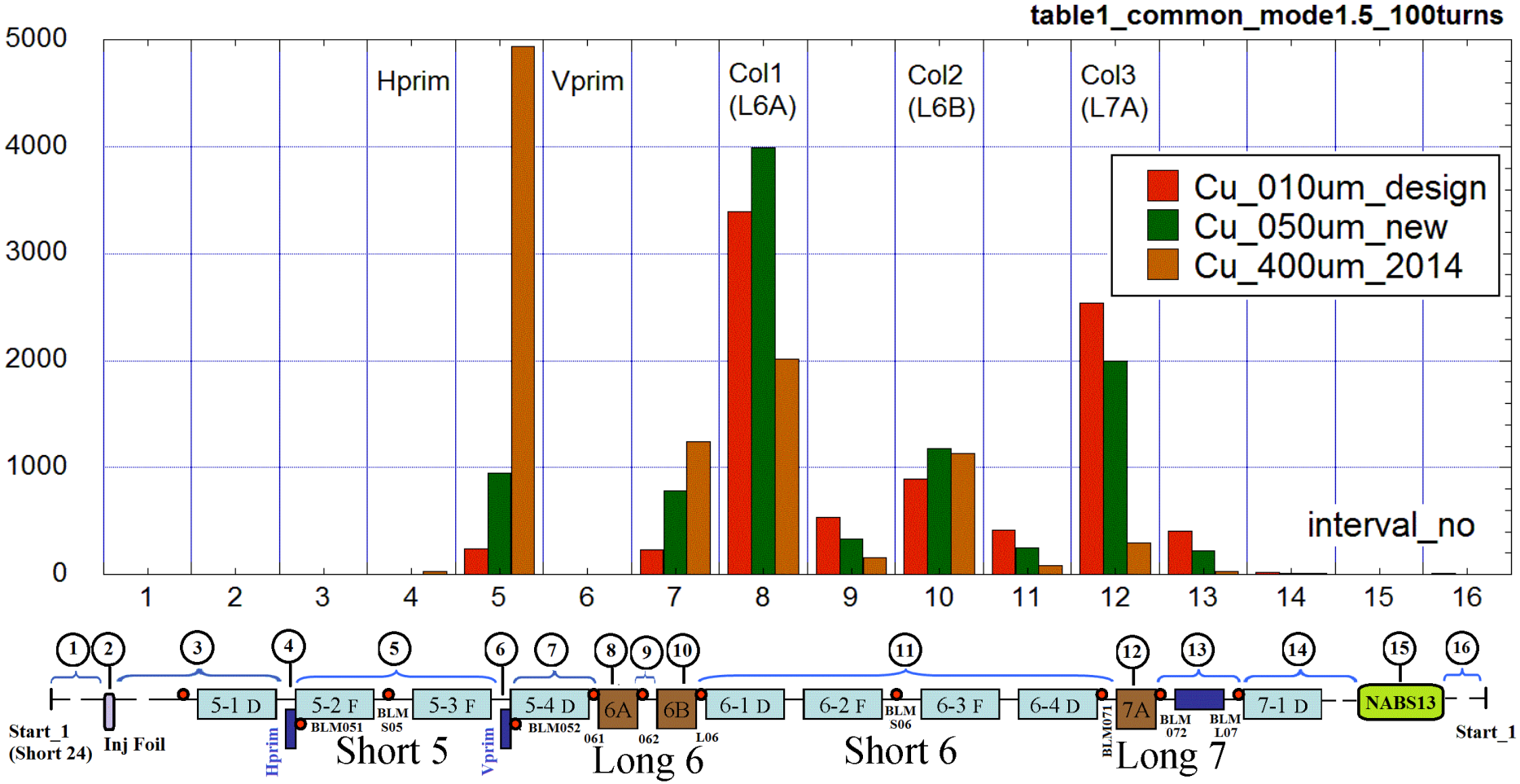
Max eff -> 75%(100turns) & 60%(10 turns)

(In a reality must be less!)

2SC in hor-plane – loss distrib for 3 diff. foils

400um (~2014) Cu foil - ~60% losses in magnets on intervals 5&7;

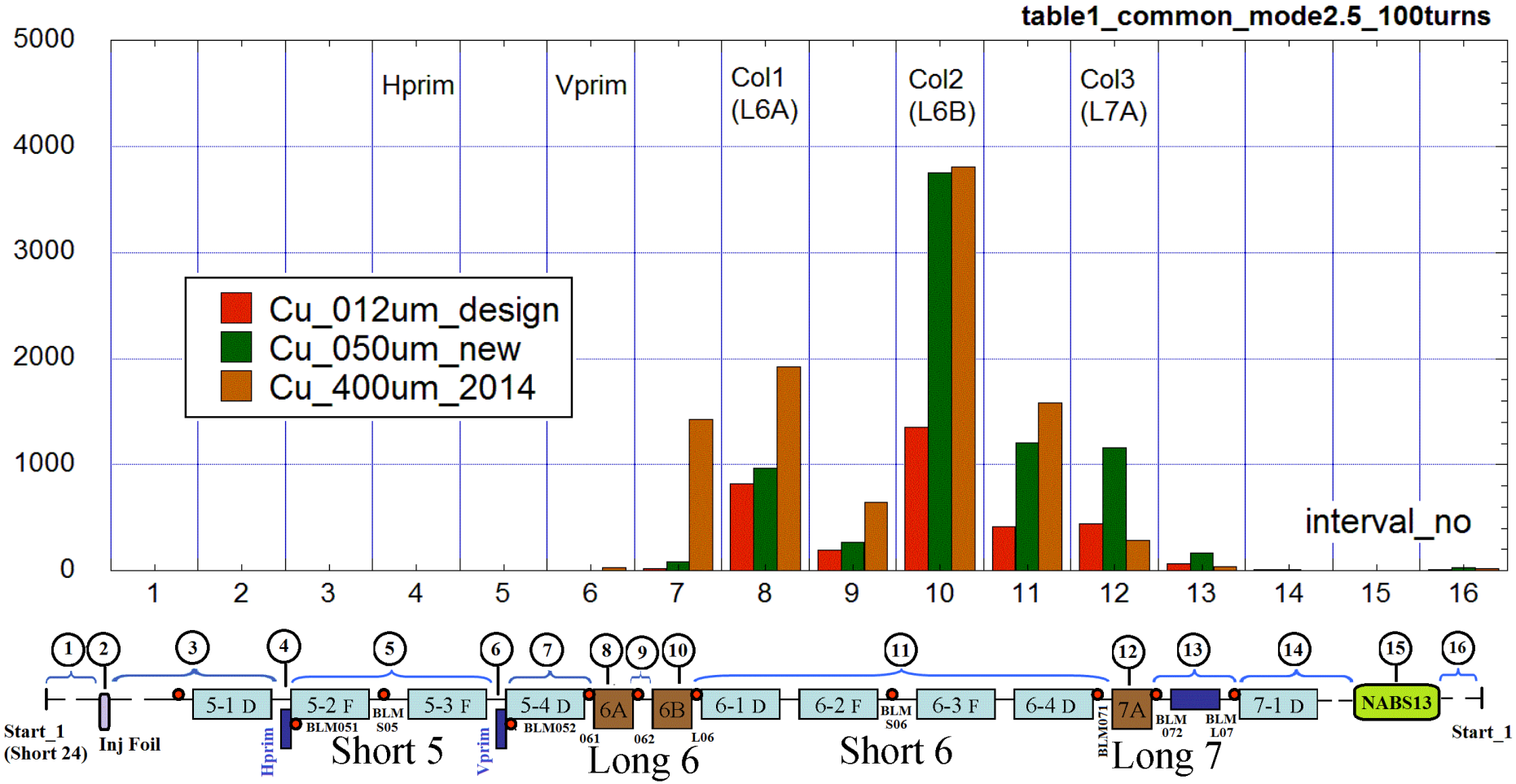
10um (2004 design) Cu foil – minimal losses in magnets on intervals 5&7



2SC in ver-plane – loss distrib for 3 diff. foils

400um (~2014) Cu foil - ~30% losses in magnets on intervals 7&11;

10um (2004 design) Cu foil – minimal losses in magnets on intervals 7&11



Features 2SC-design for Booster

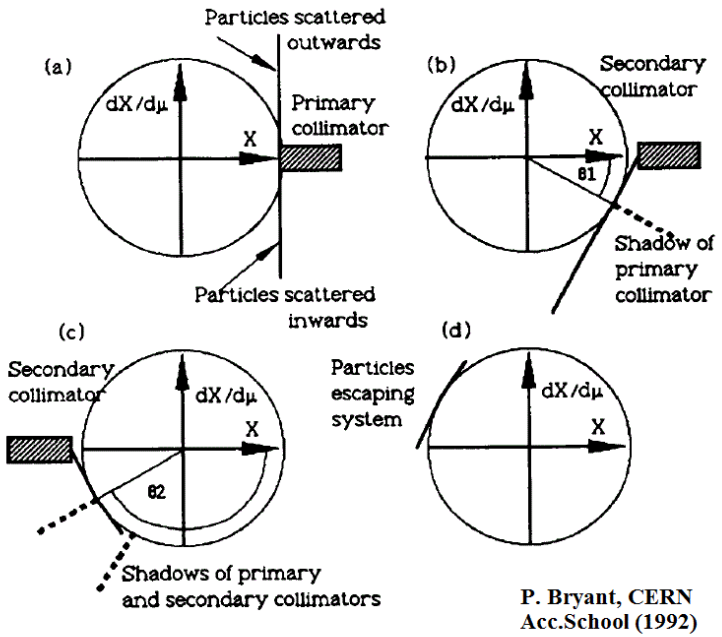
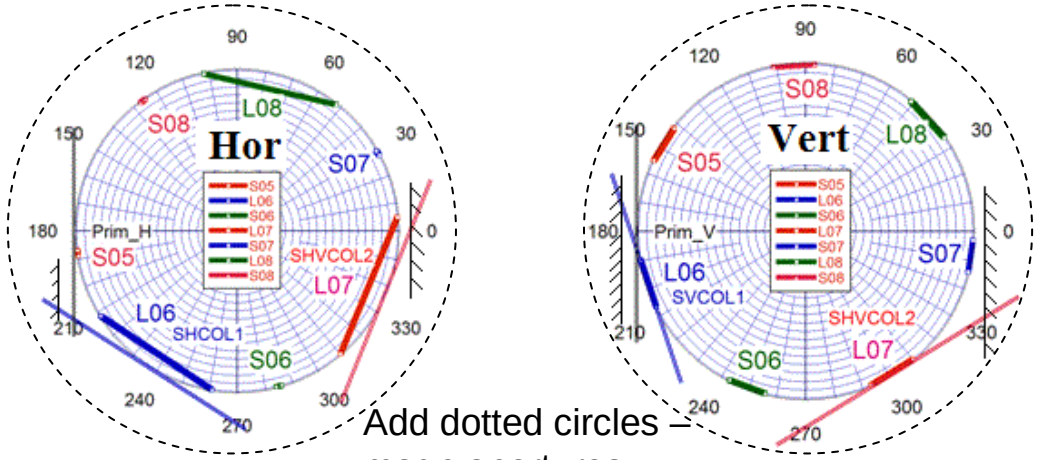


Fig. 11 Main features of a collimation system

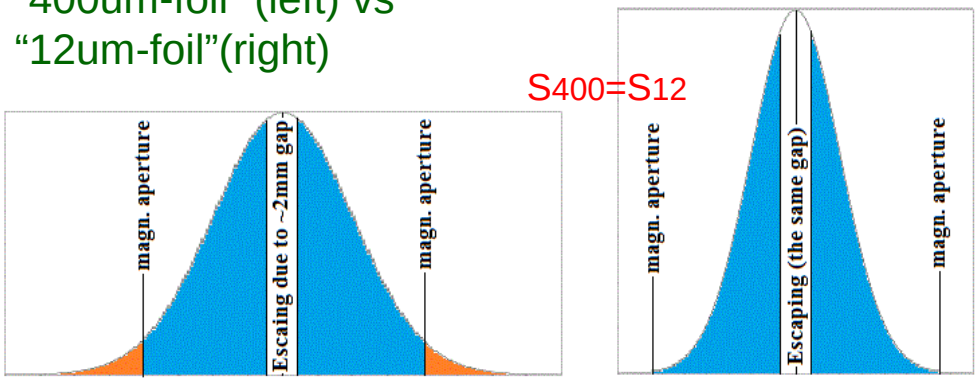
Booster: not quite optimal phase advances + Restrictions from small magnet apertures



Add dotted circles – magn apertures

X'-distributions at PrimColl: "400um-foil" (left) vs "12um-foil"(right)

S400=S12



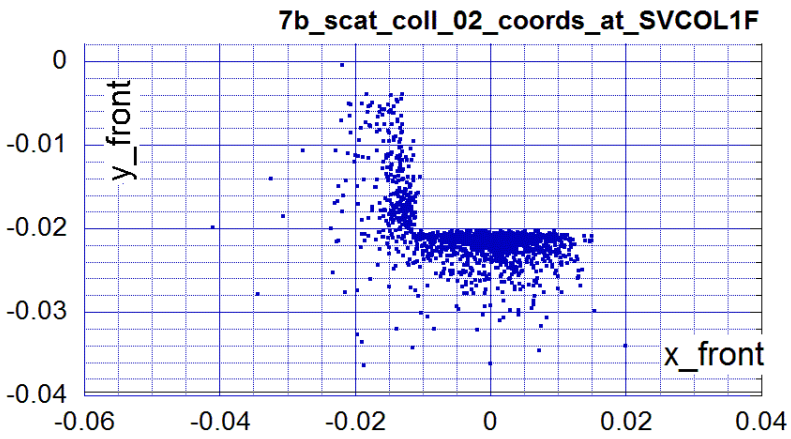
Aperture restrictions => narrow X'-distribution (smaller scat. angles);

Keeping the design ~2mm gap => More escaping particles,

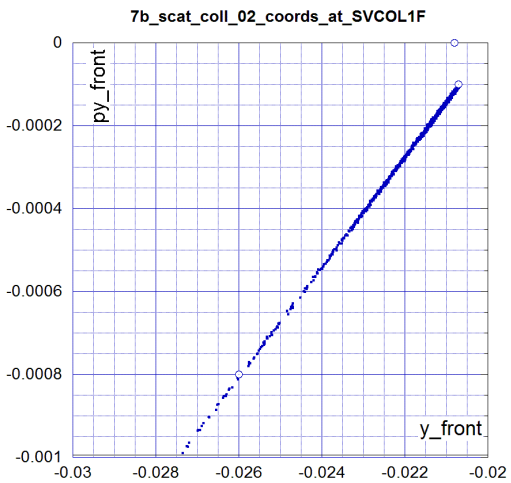
Which can be collimated only after many turns (under some conditions)

Example: Vert. 2SC – Phase spaces at front Col2(L6B)

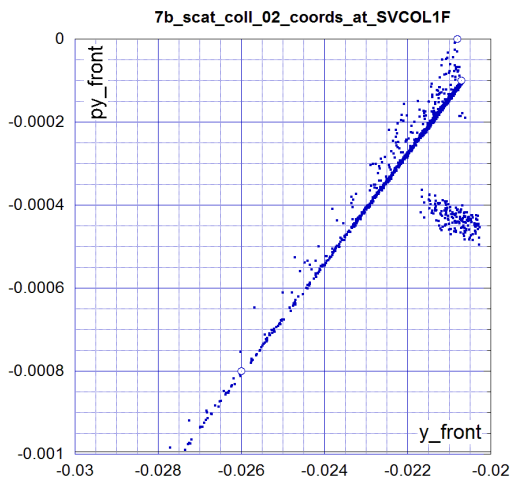
Design Cu foil 12um: y vs x



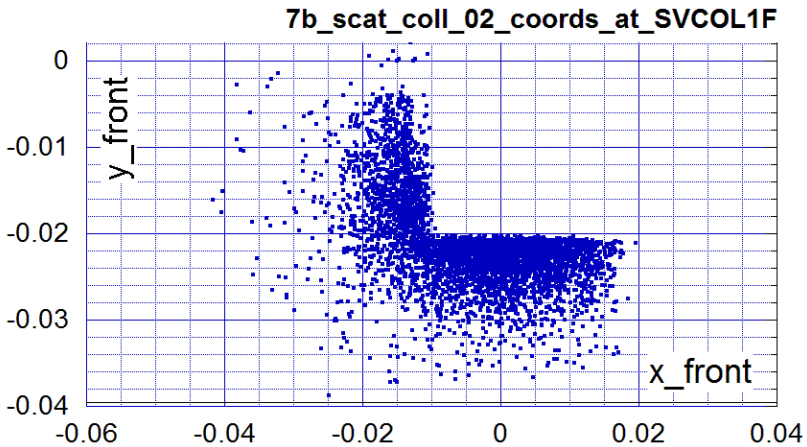
y' vs y (1st pass)



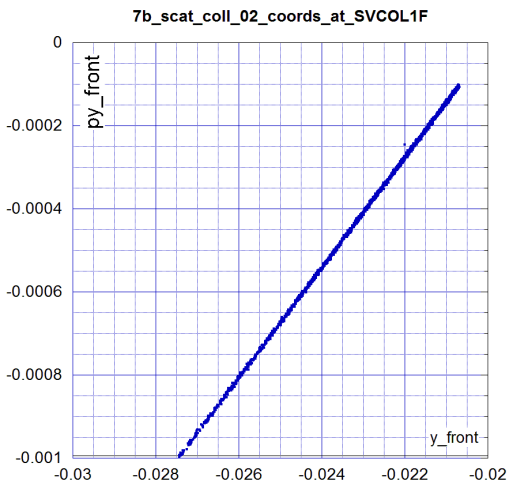
y' vs y (10turns)



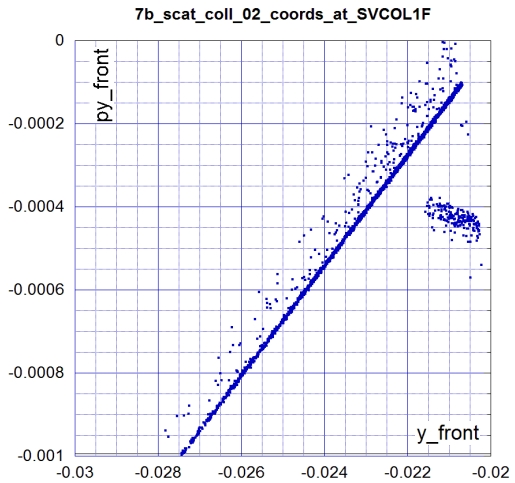
New Al (as Cu 50um): y vs x



y' vs y (1st pass)

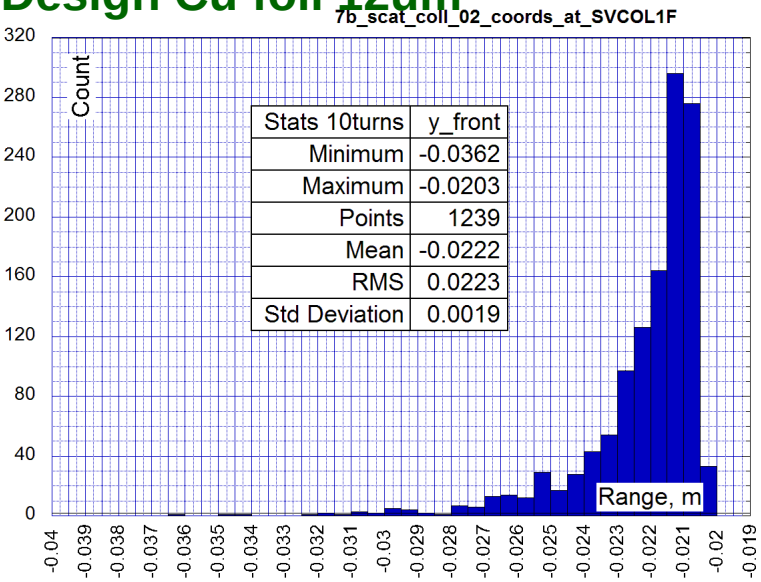


y' vs y (10turns)

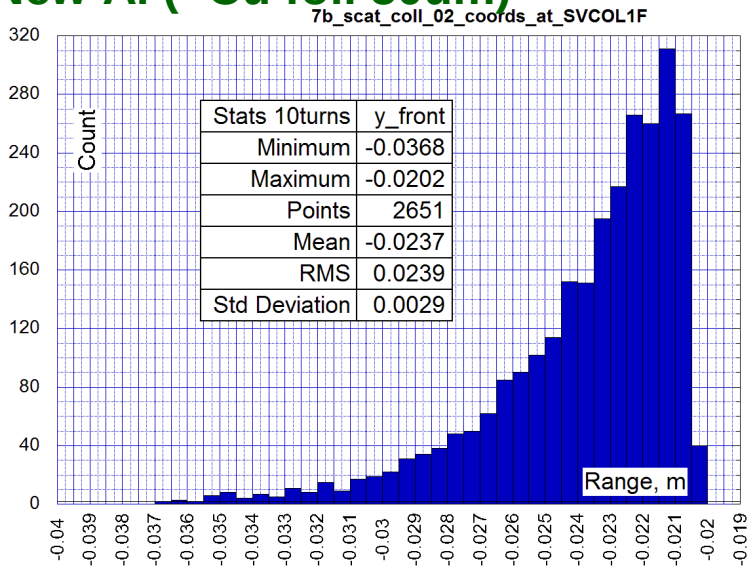


Example: Vert. 2SC – distribution at front Col2(L6B)

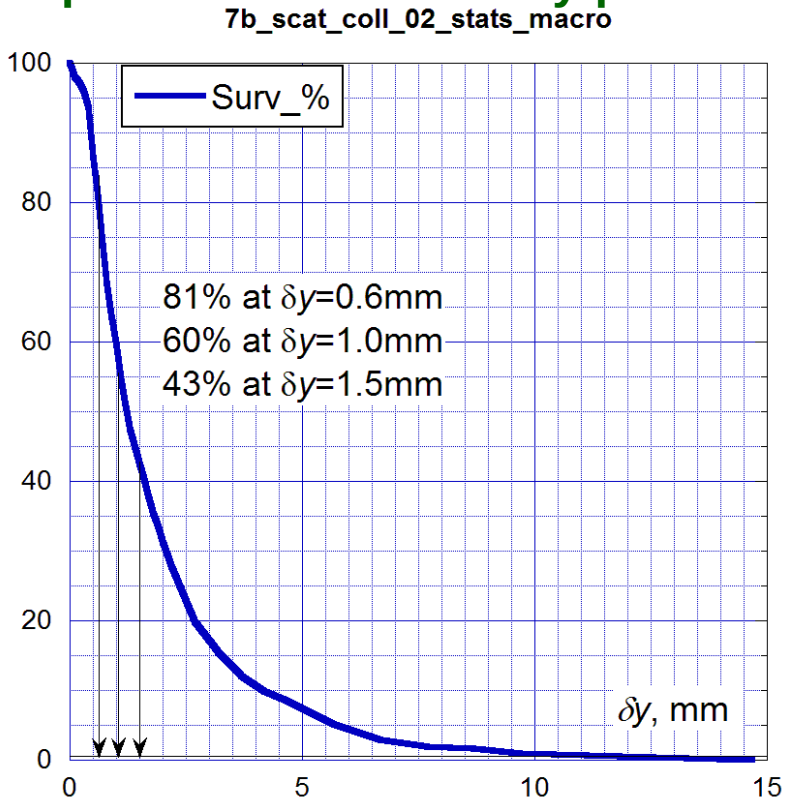
Design Cu foil 12um



New Al (~Cu foil 50um)



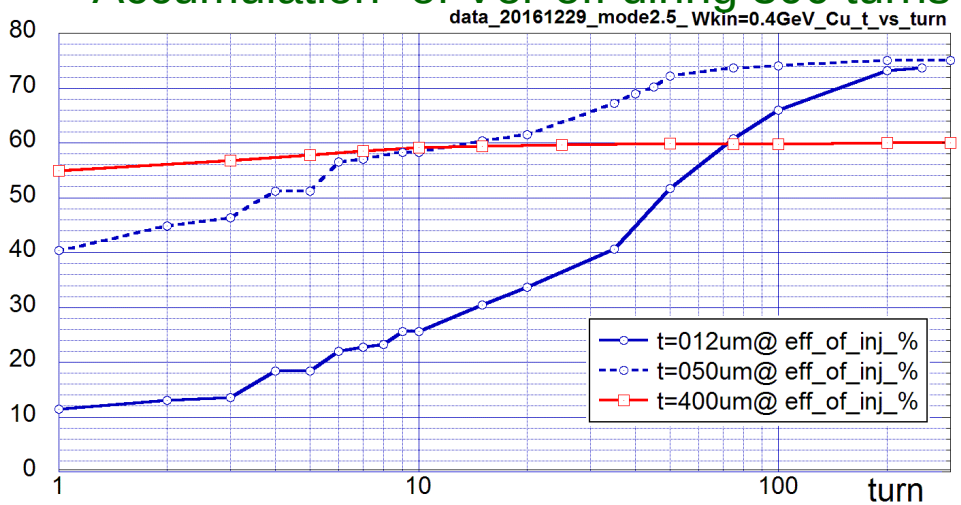
Design Cu foil 12um: Dependence on error in y-position



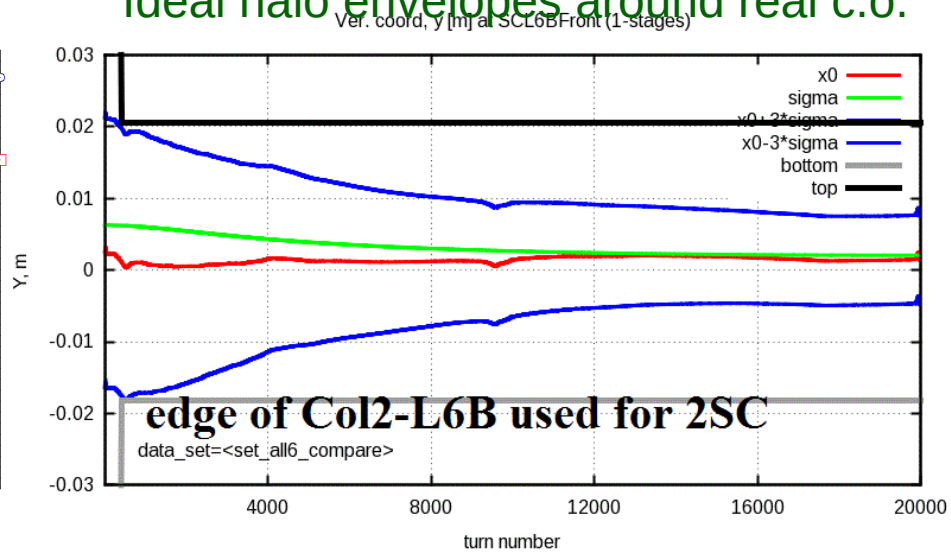
New Al (~Cu 50um) – larger width (std.dev~3mm vs 2mm of 12um). Tolerance for position of p+ halo relatively collimator ~ <1mm

On feasibility of ideal simulation conditions

"Accumulation" of Ver-eff diring 300 turns



Ideal halo envelopes around real c.o.

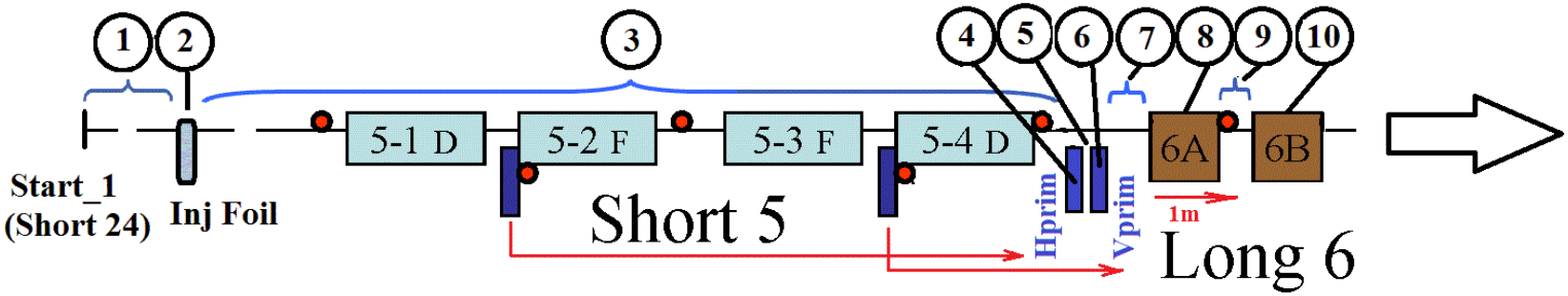


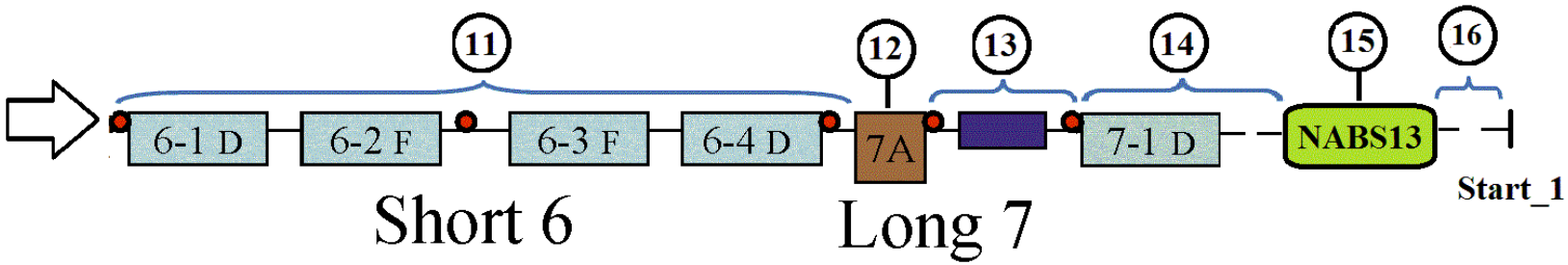
The position of halo particles at collimators must be preserved during ~100turns

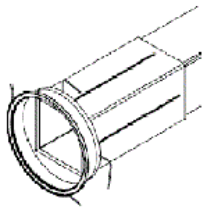
The position of halo particles = sum of central orbit (c.o.) and beam envelope:
1) C.O. is not flat curve during Booster cycle – measured by BPMs (~0.x mm ?)
2) Beam envelope may vary (emittance growth & acc.damping) unpredictably – measured by IPMs (rms-size – qualitatively only ?)
Thus, positions of halo particles are unknown and could not be controlled at all !

Experim. data for Vert. 2SC showed its failure by a factor 2 vs 1SC with 3 sec.colls

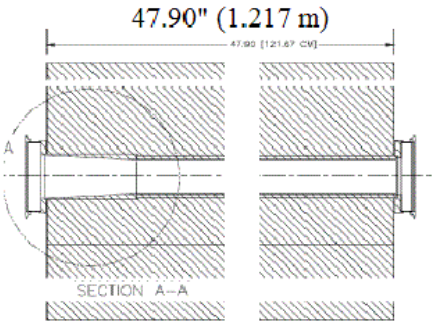
Num. experiment: 2-stage collimation with “thick” foil in L06

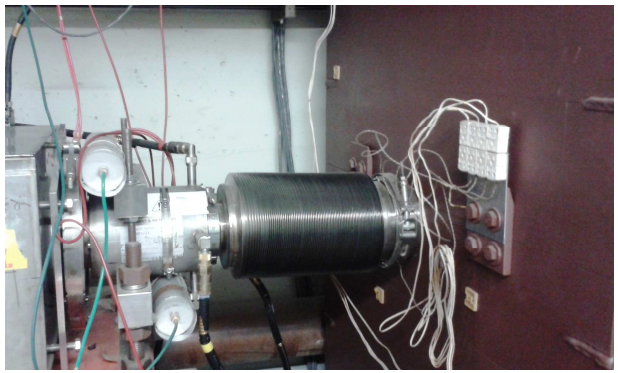






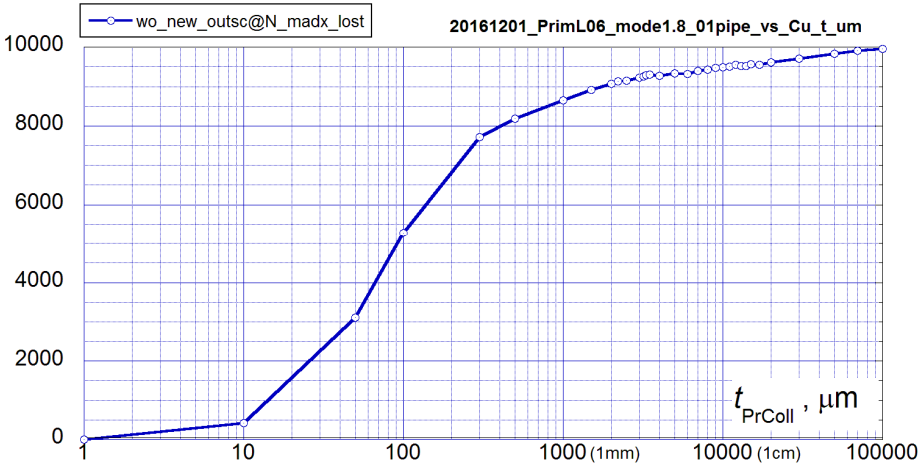
Pipes between collimators are usual 6inch pipes (or masks) => Radiation protection only inside of sec. collimators



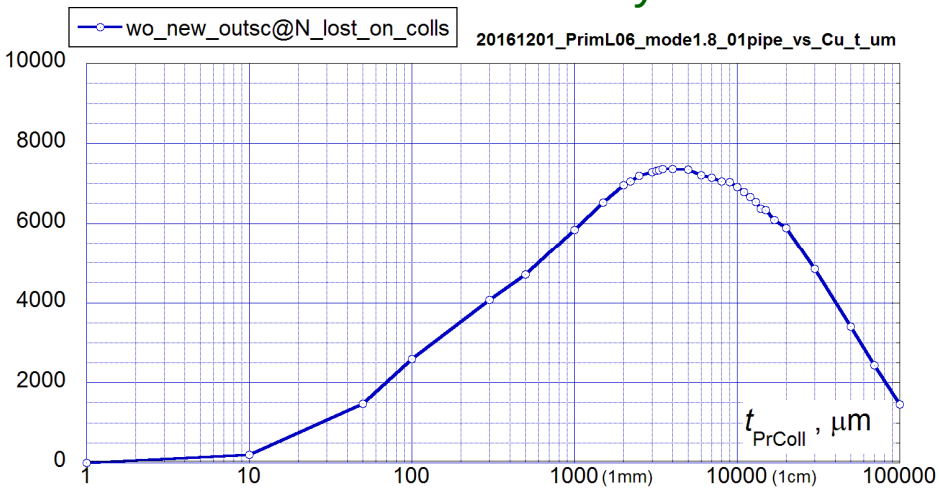


Efficiency of 2SC thick foil (horiz) - 1turn

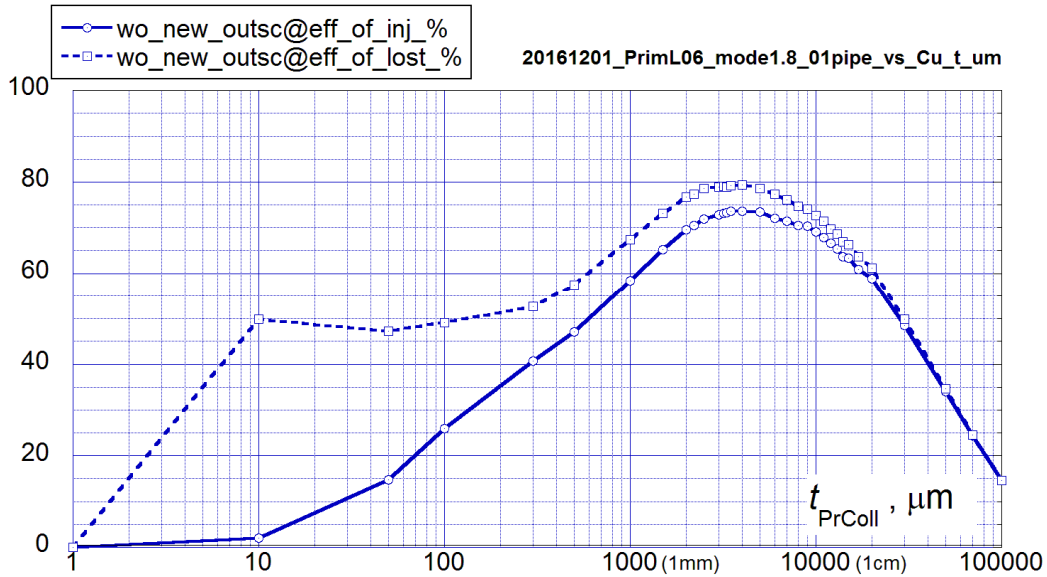
Total losses around the ring vs t_Cu



Sum losses on 3 secondary collimators



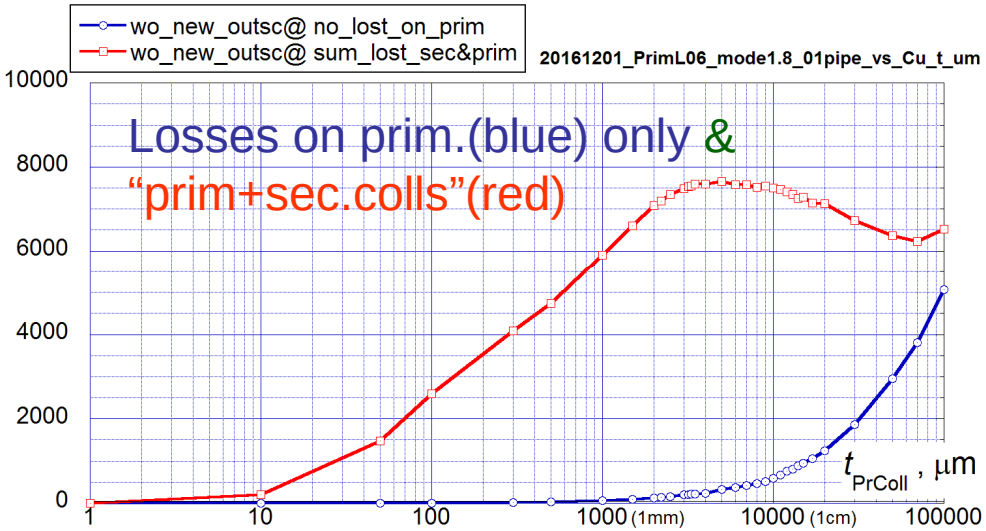
Eff_of_lost (dotted) and eff_of_inj(solid)

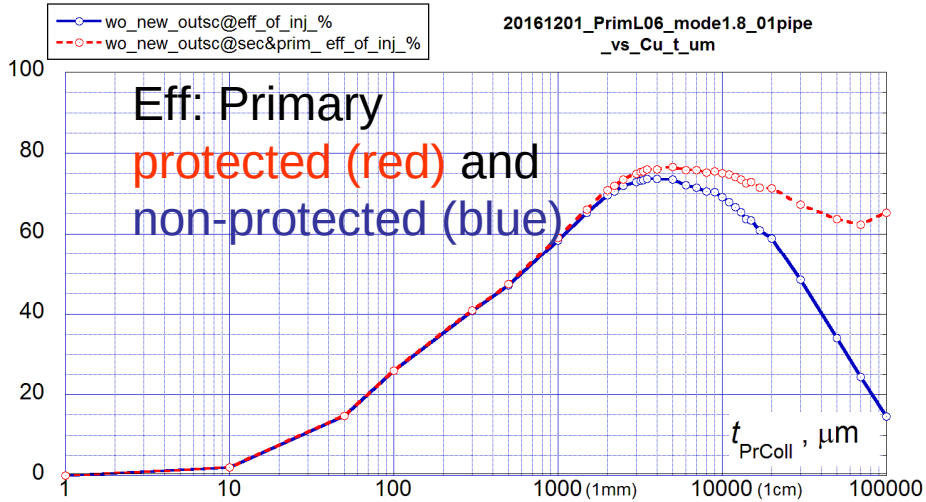


Max Eff_of_inj ->75%
in one pass
(during the 1st turn)
=>
Max eff. of existing 2SC
(also ~75%, but ~100turns)

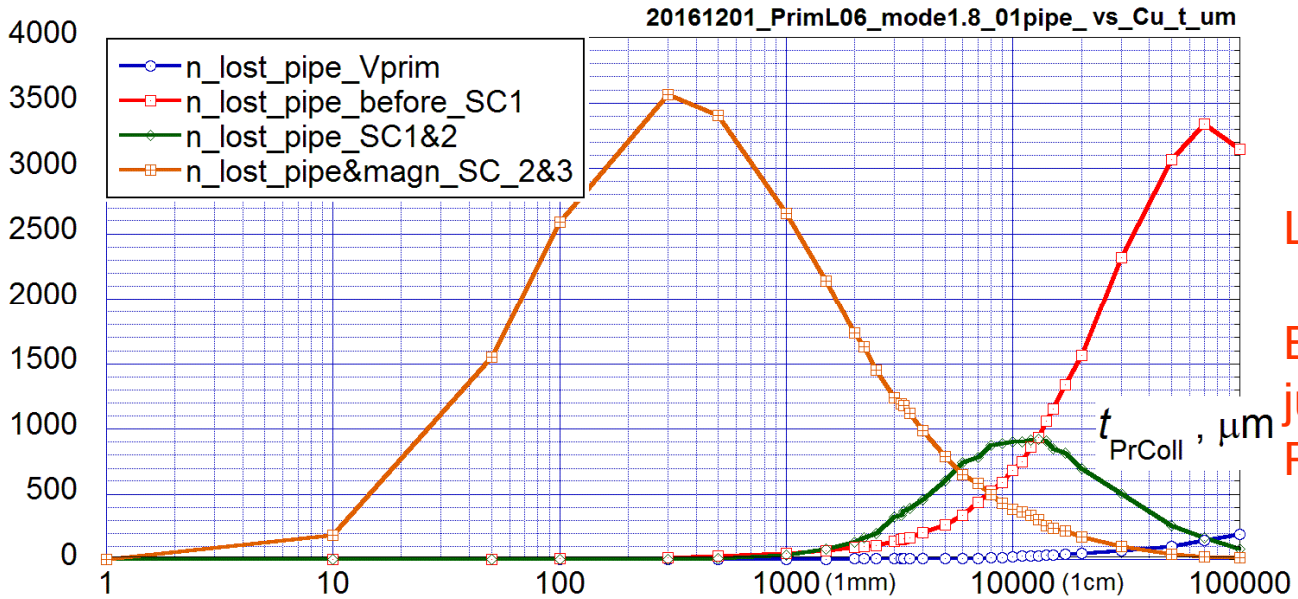
The same efficiency w/o
complex multi-turn optics

Considerable losses on a thick primary collimator & pipes





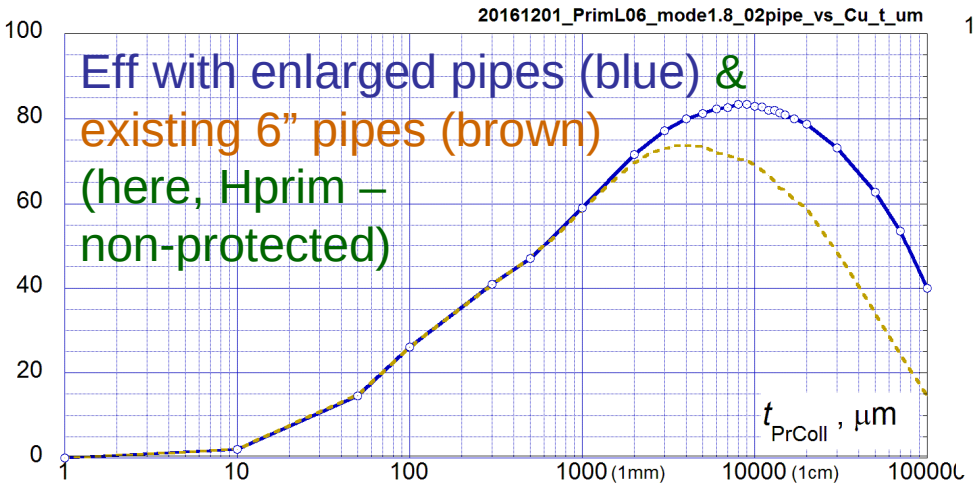
Losses on usual pipes between secondary collimators and on Vprim

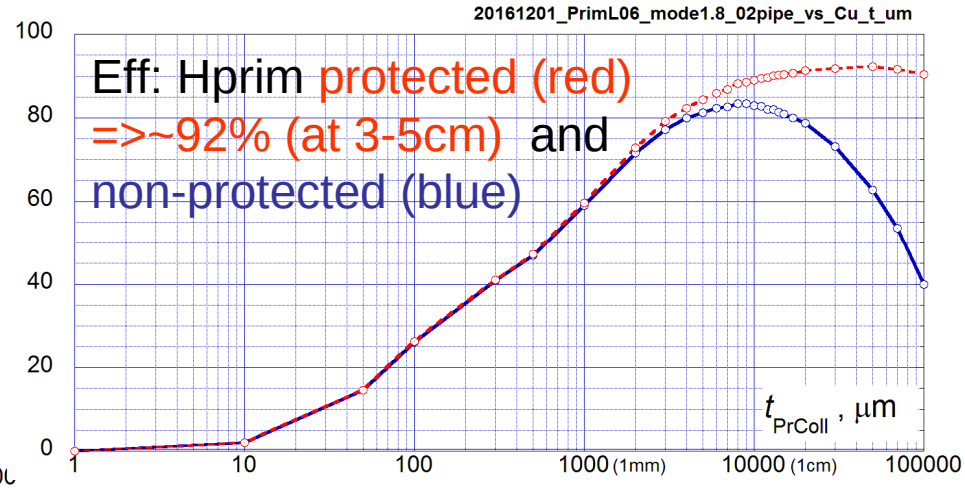


Let's protect these pipes !

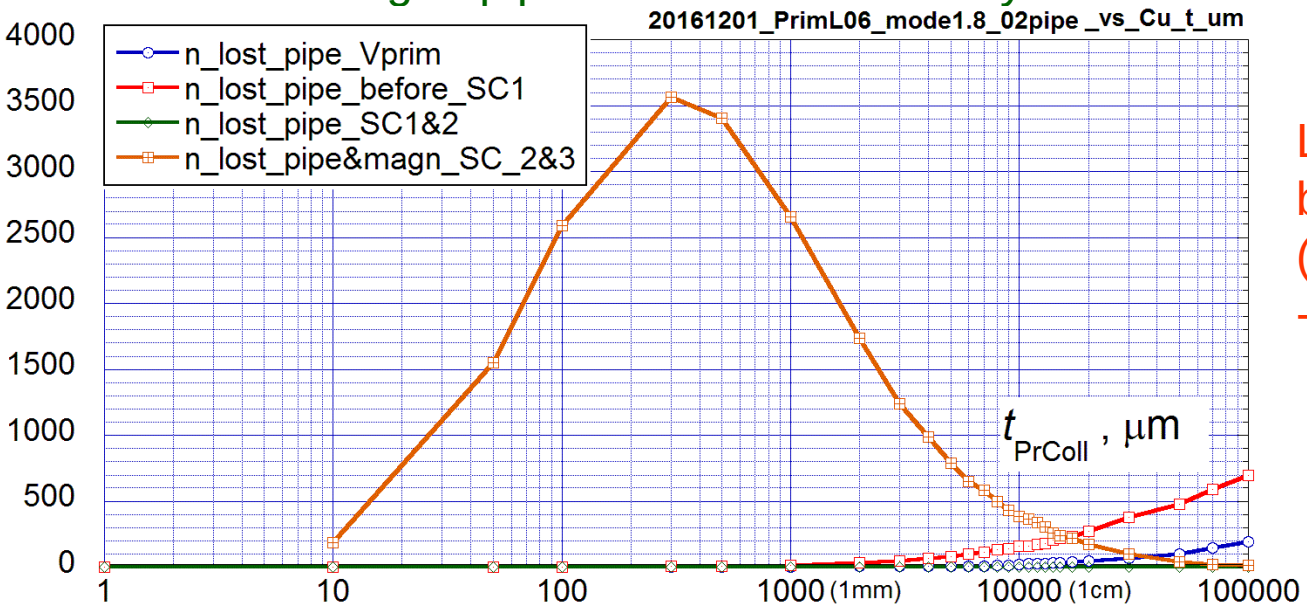
Equivalent for simulations: just increase 6" pipes to R=25cm

2SC with thick foils & large beam pipes between collimators





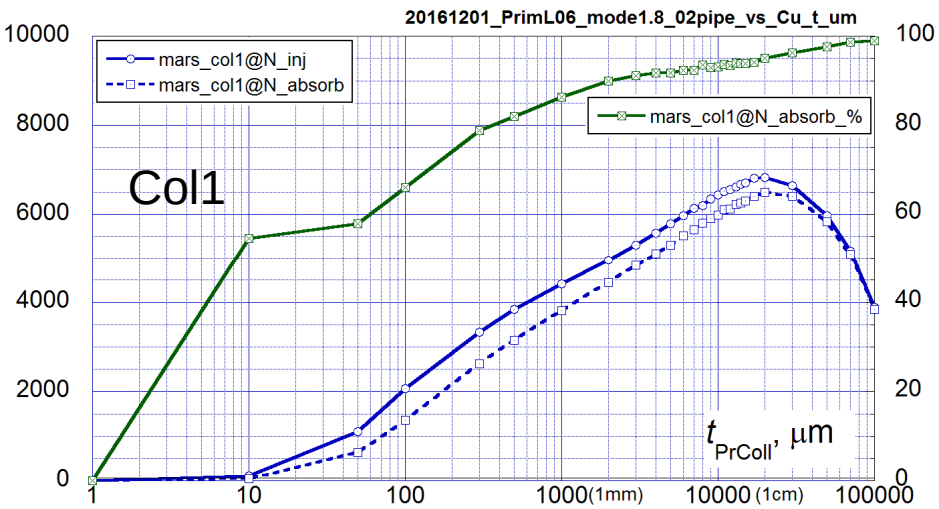
Losses on enlarged pipes between secondary collimators and on Vprim

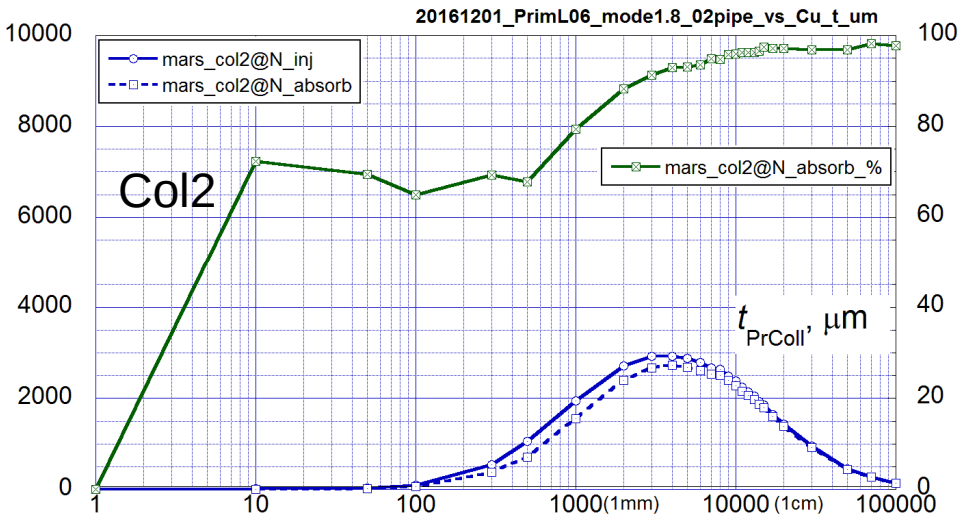


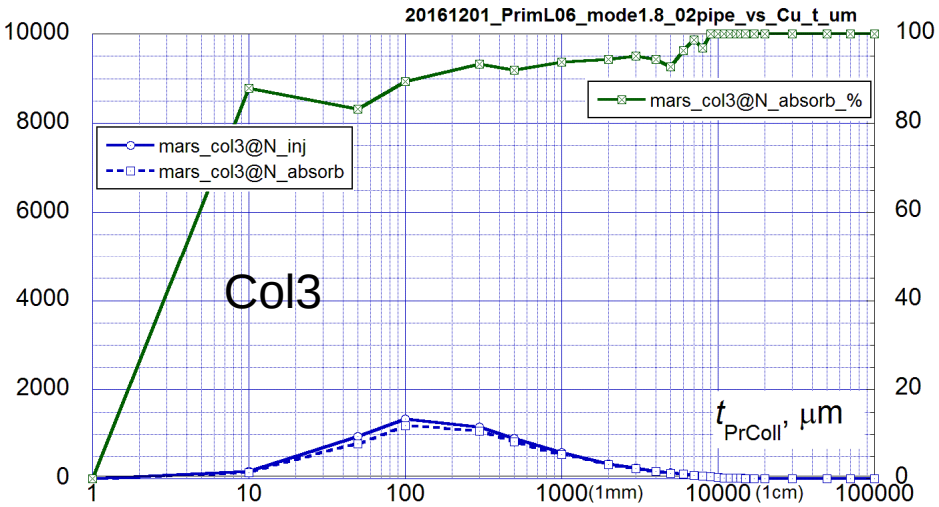
Losses on interval
between Col2 &Col3
(it includes magnets)
->0 for foil with t > 3cm !!!

Losses on secondary collimators

Double y-plots: a) left scale for N injected (solid-blue) & N_absorbed (dotted-blue);
b) right-scale for absorption eff. (green)



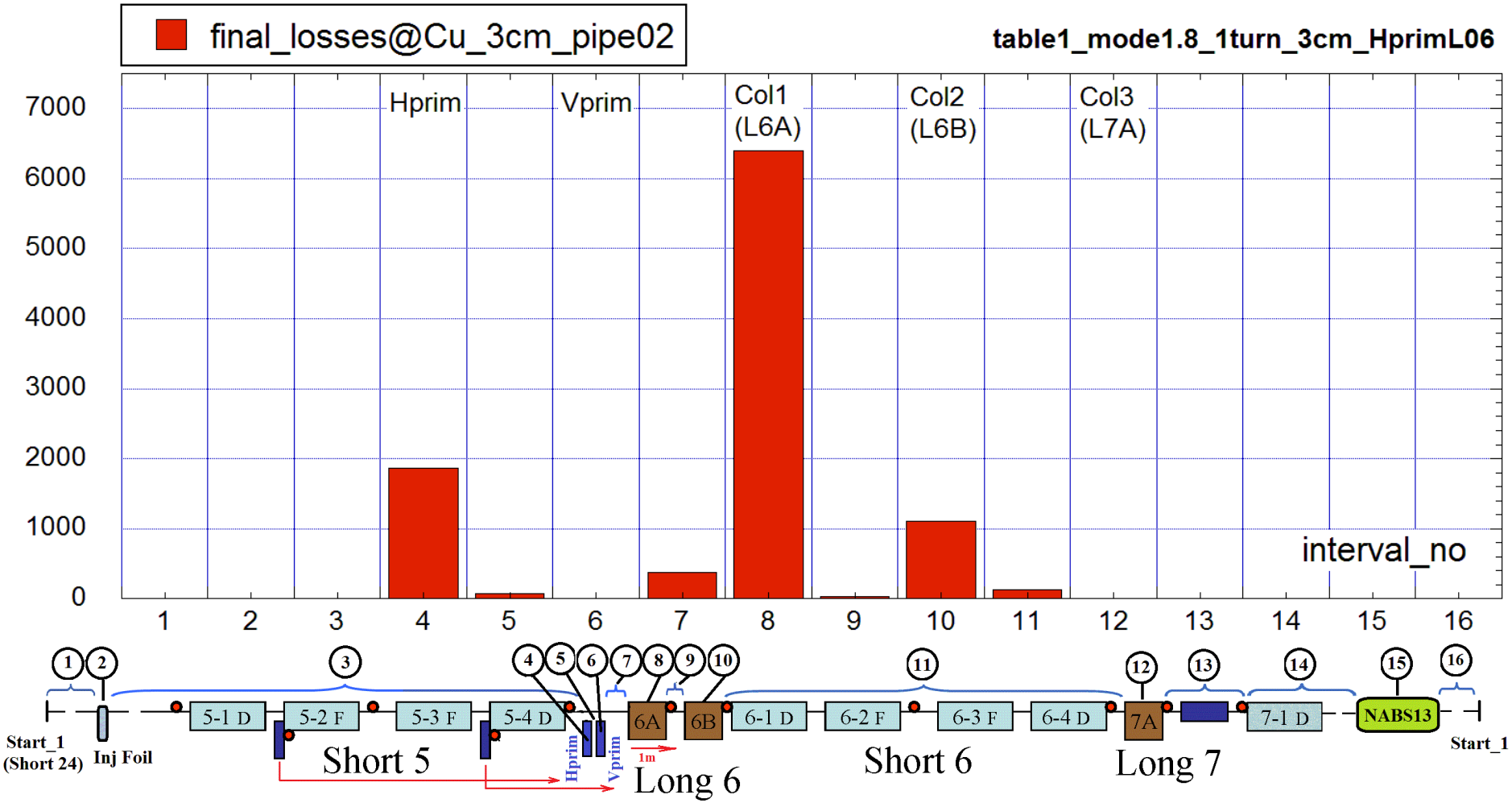




Absorption efficiency (green) on all sec. collimators > 95% for t>2cm

Losses on Col3 are negligible for foils with t>1cm
=> Col3 can be excluded !!!

Loss distribution for 2SC with 3cm Cu-foil and enlarged (protected) pipes between collimators



Intervals 8 & 10 are sec.colls; 4-7,9 are new protected pipes;
11 – need for magn protection(?)

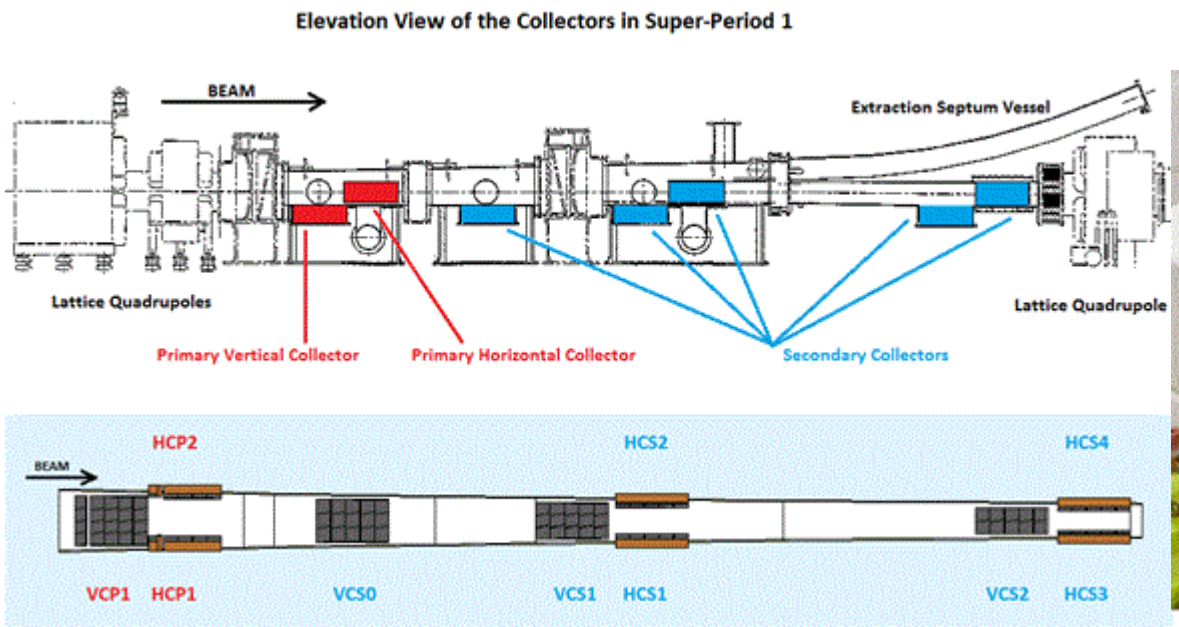
Conclusion

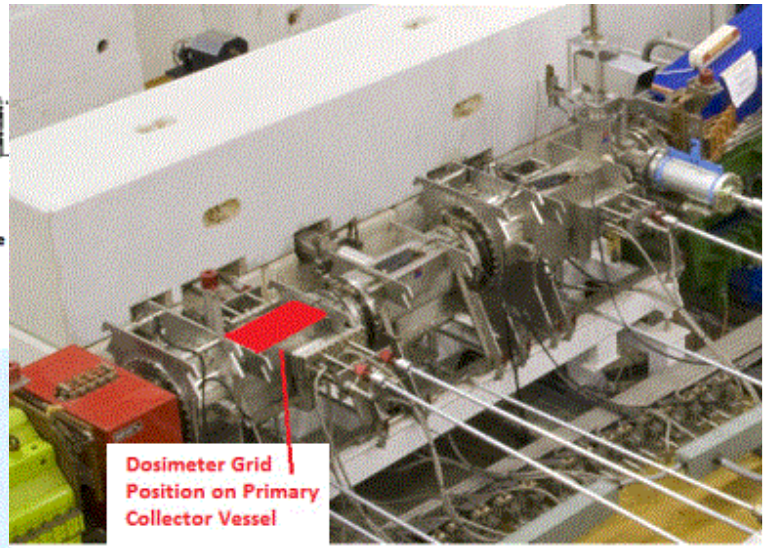
- Existing 2SC is difficult for implementation in Booster: it requires to control a halo position during ~100 turns
- New “thick-foil” 2SC is optically easier, it could reach the same efficiency (~75%) as existing 2SC in a single pass
- Efficiency of new 2SC can reach up to 92%, if beam pipes between sec. colls (& around prim) will be enlarged (and well protected)
- With a new 2SC beam losses “ineff~(1-eff)” could be reduced by a factor ~2-3 (from ineff=25% to ineff=8%)
- New system consisting of 2 prim & 2 sec. collims can be located within any empty long section, e.g. L08, L10.
- New 2SC may be duplicated while preserving existing 1SC (probably, a better protection of RF cavities, if halo particles with fast-growth rates are able to avoid a single 2SC)
- Realistic design will require simulations with MARS code

~Somewhat similar 2SC at RAL RCS ISIS (SNS)

70MeV -> 800MeV, C=163m, 3xE13 ppp, 160kW->240kW

Collimation systems are located in one well shielded 5m drift section
It evolves from 198x till now (~35years; successful ?)





1) PAC-1981 p. 2125, “Features of … SNS synchr”: **scrapers** 70-100MeV (Cu+graphite), 800MeV (stainless)
2) EPAC-2004, p1464 “Studies of Beam Loss Control … ISIS”
3) IPAC-2014, p893 “Activation model of ISIS Collectors”, 10collectors (3prim+7sec. collims) in straight one