# New Booster Collimation Unit Update

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PSP/Taskforce Meeting
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# History & relevant reports & talks

**Acknowlegements**: C.Bhat, S.Chaurize, D.Johnson, V.Lebedev, N.Mokhov, W.Pellico, T. Sullivan, S.Striganov, C.Y.Tan, R.Tesarek, A.Triplett, I.Tropin

## 2015-17: Existing Collimators study (1SC & 2SC) & new Collimation Unit proposal

1) V.Kapin et al, "Study of Two-Stage Collimation System in Fermilab Booster", June 12, 2017, Beams-Docs-5519-v1 (The final **write up** for study of existing 2SC in Boo)
2) V.Kapin, "A proposal for **upgrade** of Booster collimation system", 22-Feb-2017, BD-5340-v1

## 2017-18: Conceptual Design of new Collimation Unit (400MeV, PIP-I+)

1) V.Kapin, "Booster Collimation Upgrade Plans for PIP-I+", talk on 15-Nov-2017, BD-5930;
"References List and other info", BD-6661 (8-Aug-2018)
2) V.Sidorov, "New BOOSTER Collimation System **Conceptual design**", talk on 15-Nov-2017, BD-5927
3) I.Tropin & N.Mokhov, 3 talks on MARS studies of New Booster Collimator:
BD-6919-v1(12-Dec-2018), BD-6589-V2(14-Aug-2018), BD-6589 (22-May-2018).

## 2020: Preliminary Design of new Collimation Unit (400MeV, 800MeV PIP-II)

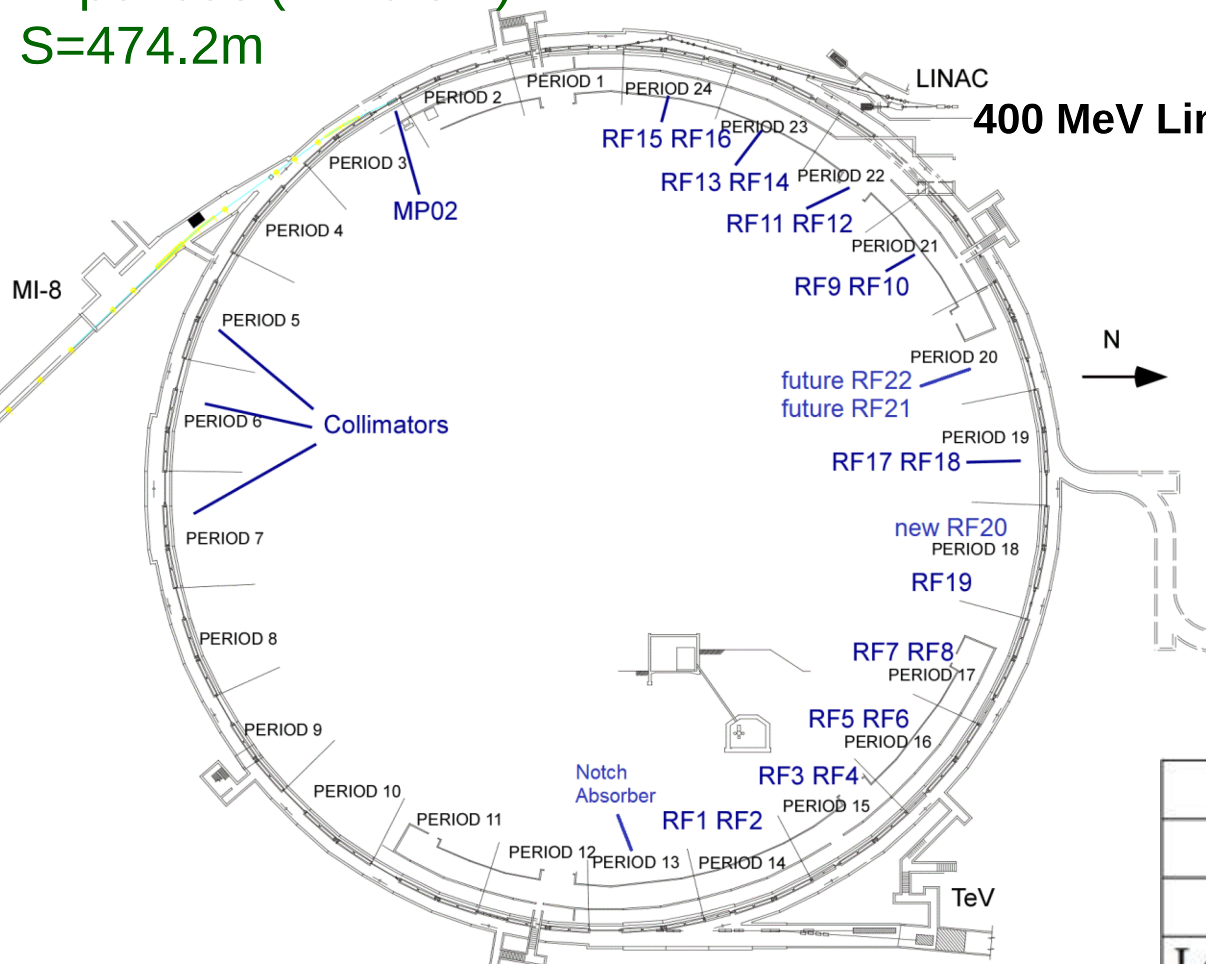
1) V.Kapin, V.Sidorov, "New Booster Collimation Unit - Preliminary design",21-Jan-2020, BD-7953
2) I.Tropin & N.Mokhov, "MARS studies of New Booster Collimator": BD-8359, 5-May-2020.

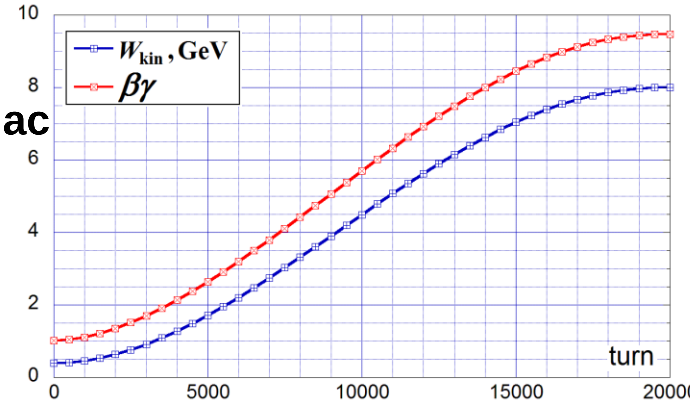
*2020, May, 29 – PDR (Preliminary Design Review) :*

*"preliminary assessment was positive"*

# Booster Layout

24periods (L=19.8m)
S=474.2m

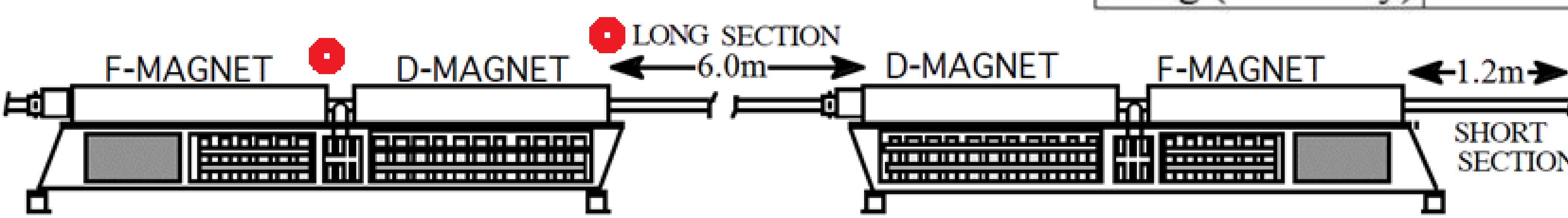



400MeV -> 8GeV
33ms (20,000 turns)

*Relatively small apertures*

| element | $a_{min}$ / $b_{min}$, in $\sigma_{rms}$ |
|---|---|
| F magnet | 6.6 / 4.5 |
| D magnet | 6.5 / 4.5 |
| Long (RF-cavity) | 7.3 / 4.5 |

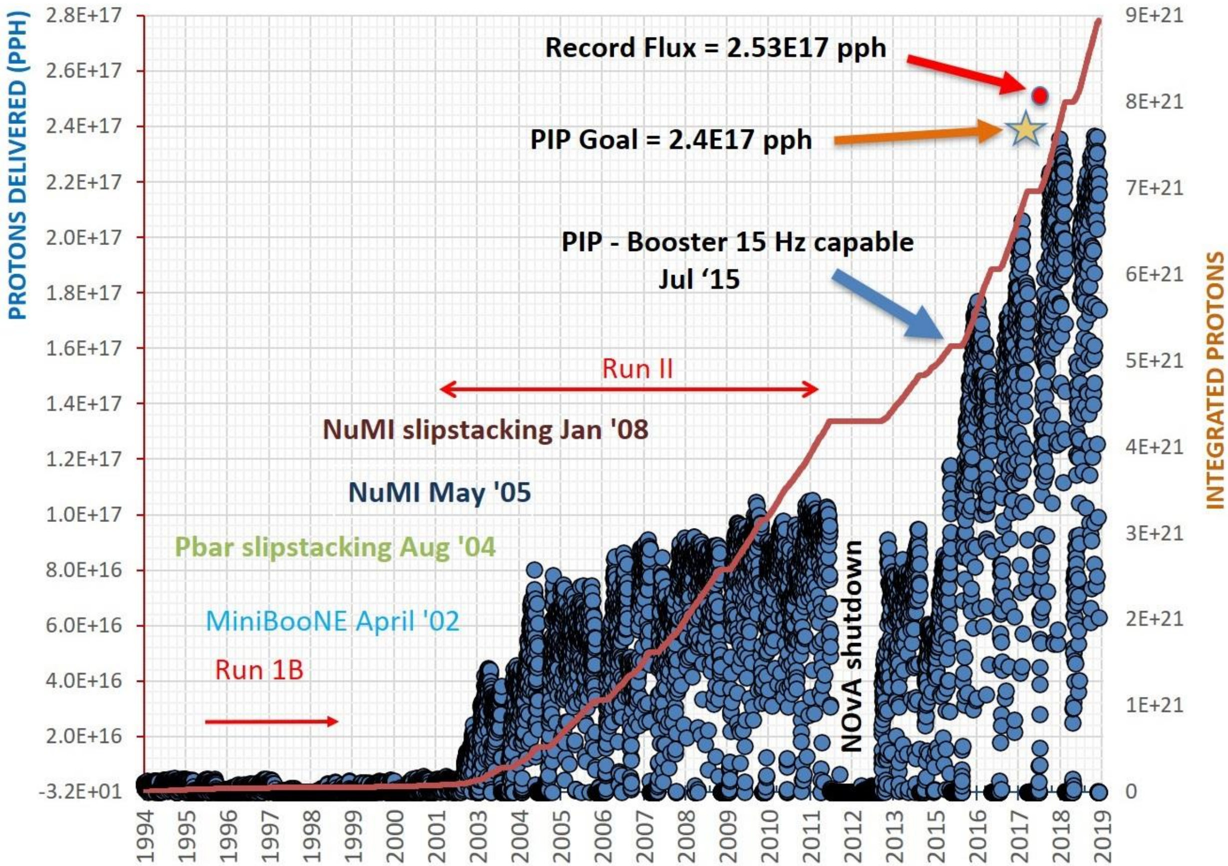


# Evolution of Booster Intensity (end 2019)

PIP campaign is $2.4 \cdot 10^{17}$ protons/hr (maintaining 2012 activation levels)

Intermediate "virtual" PIP-I+ (AIP) with a goal $2.7 \cdot 10^{17}$pph proposed in ~2017

PIP-II with the new SC linac (~2025) requires up to $4.8 \cdot 10^{17}$ pph in Booster.




*Plot from W.Pellico, Beam-Docs-7601 (2019)*

~2004 commissioning of **present** collimation system => ~ $2.0 \cdot 10^{16}$ pph

Increase in Booster intensity :

PIP (2017) ~x12

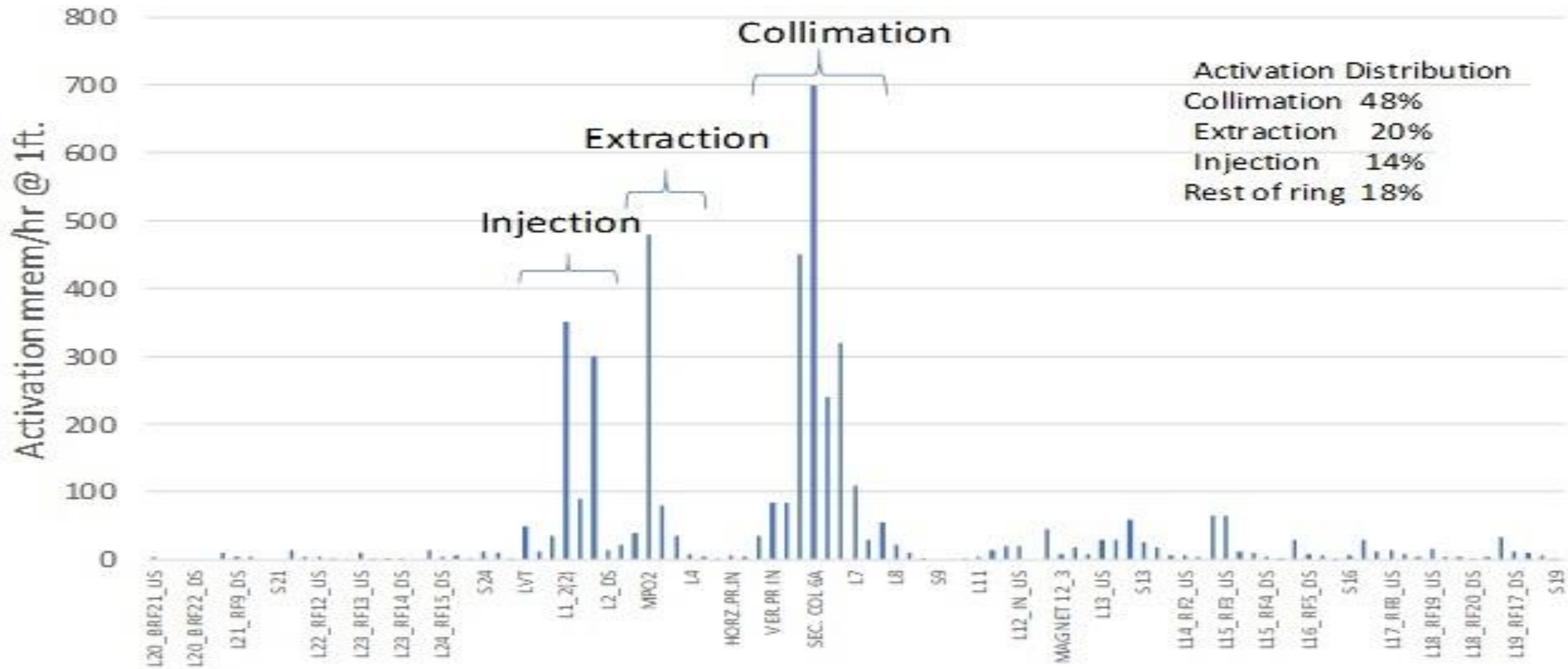
PIP1+ -> ~x14

PIP-II -> ~x24

**Demand:**
**More effective control of beam losses via improved beam efficiency & collimation**

# Booster Residual Activation at 1ft (May 11, 2019)

Average Booster throughput 2.35E17 protons/hr




High radiation levels in the following regions (see Boo layout slide):

1) Injection - period 01 – 14% of total (up to 350 mrem/hour );
2) Extraction – around period 3 - 20% of total (up to 500 mrem/hour);
3) Collimation – periods 5-7 => ~ 48% of total (up to 700 mrem/hour)
4) Rest of the ring => ~ 18% (incl. Notching – periods 12 & 13 up to 150 mrem/hour)

Relatively small radiation in "RF" periods 14-24 (< 200 mrem/hour), however RF stations require a frequent maintenance works -> exposure of rad. workers

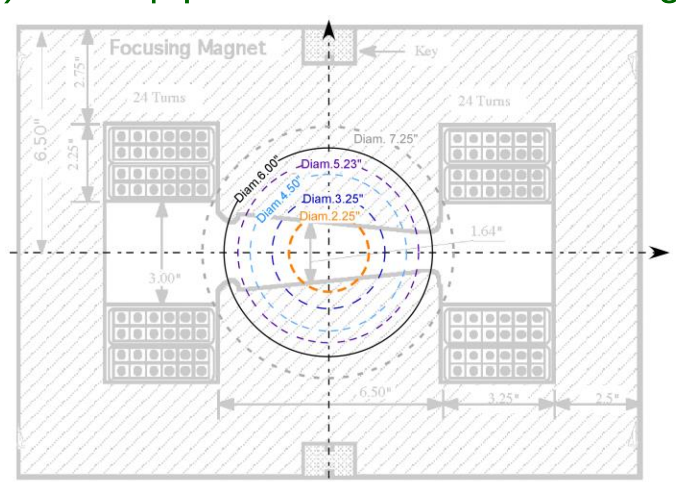
# Booster Apertures

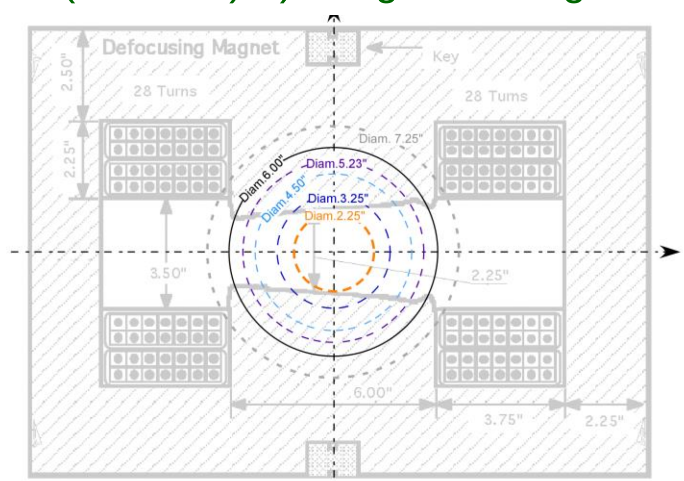
*Relatively small apertures restrict application of <u>standard</u> collimation methods*

The minimal **vertical** apertures $a_{min}=4.5\sigma_{rms}$ at 3 locations of each Booster periods:
1) junctions of F magnets with 0.5 m short drift sections between F and D magnets;
2) junctions of D magnets with the long straight sections; 3) at drift-tubes of RF-stations.

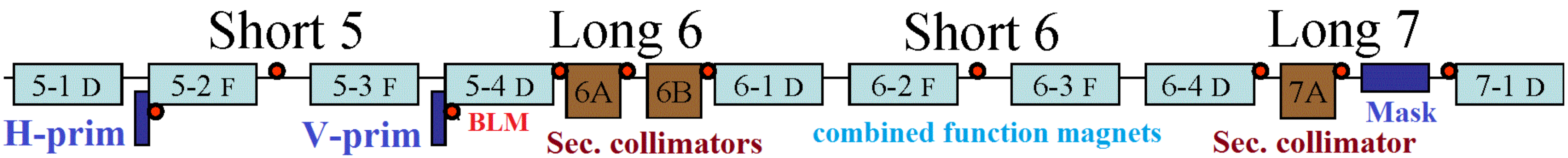
| element | $\beta_{hor}$ / $\beta_{ver}$, m | $\sigma_{rms}$ , mm | 3 $\sigma_{rms}$, mm | sizes of "good field" area | | |
|---|---|---|---|---|---|---|
| | | | | $2a$ / $2b$, inch | $a_h$ / $b_v$, mm | $a_{min}$ / $b_{min}$, in $\sigma_{rms}$ |
| F magnet | 33.75 / 10.82 | 8.2 / 4.6 | 24.6 /14.0 | 4.3"×1.64" | 54.6 / 20.8 | 6.6 / 4.5 |
| D magnet | 17.30 / 20.47 | 5.9 / 6.4 | 17.6 / 19.2 | 3.0"×2.25" | 38.1 / 28.6 | 6.5 / 4.5 |
| Long (RF-cavity) | 7.59 / 20.47 | 3.9 / 6.4 | 11.7 / 19.2 | Diam. 2.25" | 28.6 / 28.6 | 7.3 / 4.5 |

a) RF-cavities (Diam. 2.25"); b) regular beam pipes (D~3.25"); c) Correctors (D~ 4.5");
d) special aperture in S12 (Diam. 5.23" shifted horizontally by 2 cm outwards);
e) 0.5 m pipes between F and D magnets (D~6.00"); f) flanges of magnets (D ~7.25").



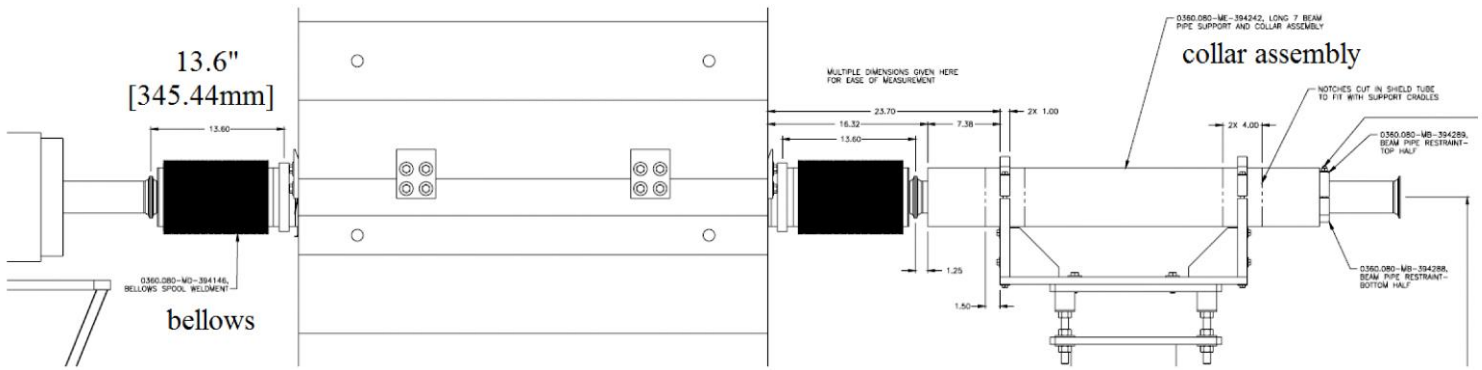



# Present Collimators in L06-L07

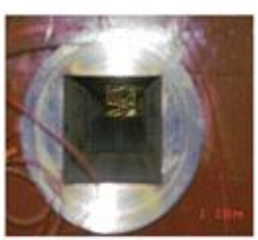


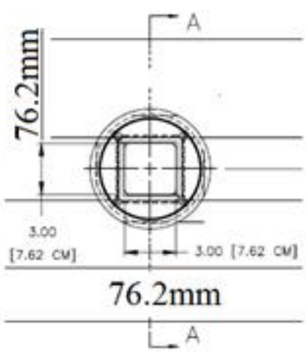

2003-04: designed & installed as a 2 stage collimation system (~not operational);
Used as **a single stage collimator system** (i.e. primary collimators are NOT used).

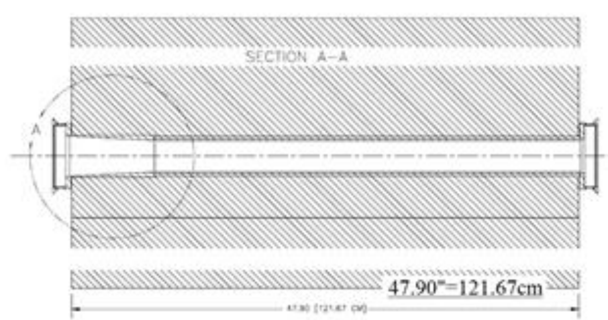
Design by "Bartoszek Eng.“: **3 identical** absorbers 6A, 6B, and 7A (10.6ton each)




Only transverse shielding (up to 8GeV): input/output bellows w/o any shielding

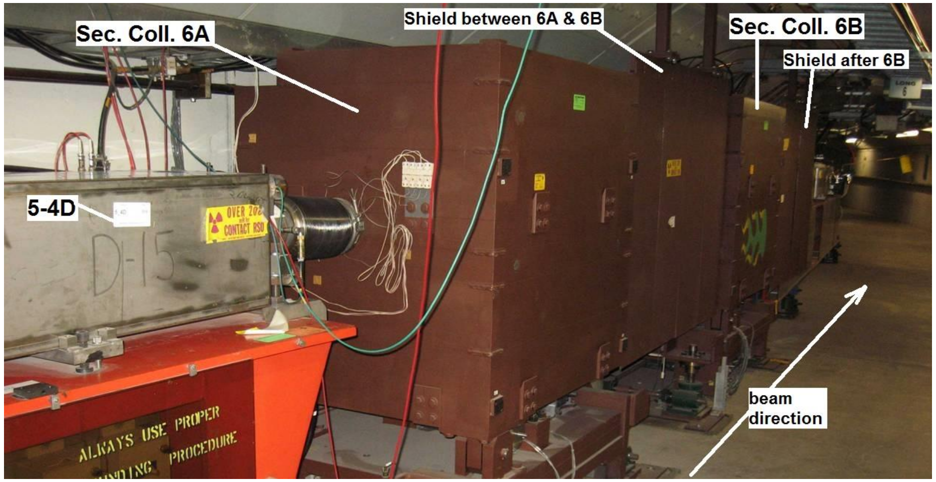


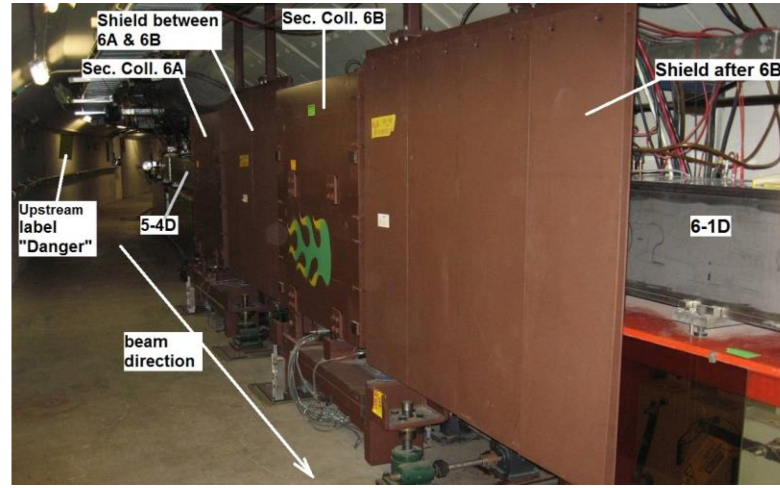



Jaws: the 1.22m long with square 3”x3” cross-section; upstream end is 2cm tapered

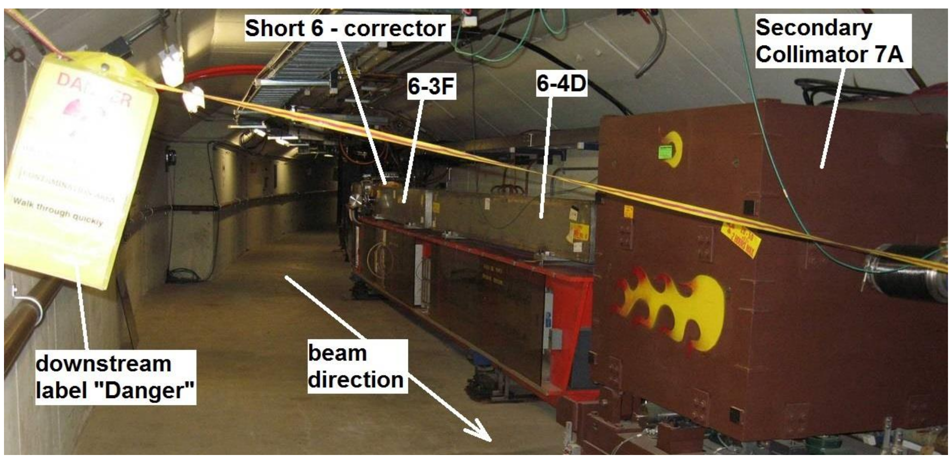
# Photos of Present Sec.Collimators




"L6" (~400mrem/h) at front of 6A; "SEC.COL 6A" (->700 mrem/h) between abs. 6A & 6B

"SEC.COL 6B" (~300mrem/h) behind of 6B

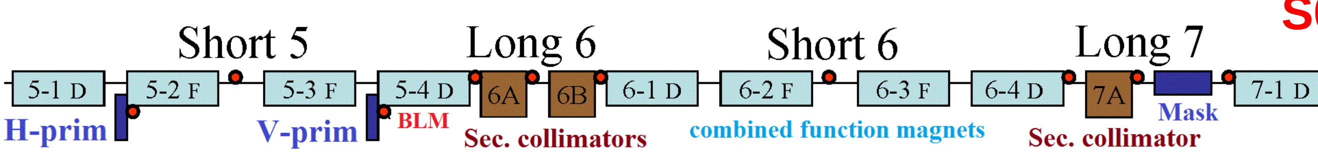



Except of absorbers, there is no any shielding for other Booster elements including primary collimators.

2 supplementary shielding assemblies (steel plates hanged up on hooks):
1) between 6A & 6B; 2) behind 6B

"S6" (~300mrem/h); "L7" front of 7A (~100mrem/h)

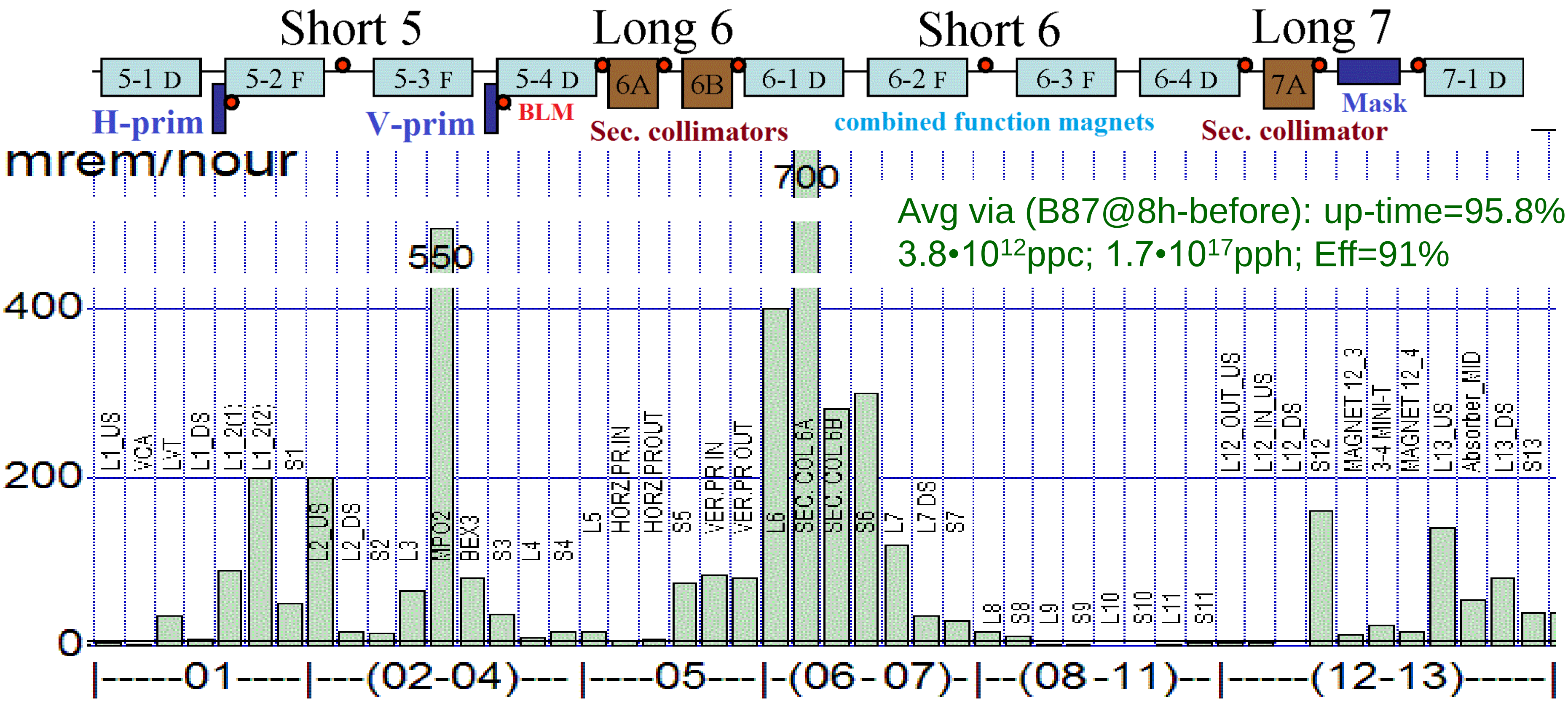
**"Contamination area: S05 ÷ ds of 7A" (~30m)**






*Shown residuals (2017) ->*

# Periods 1-13: 1-foot Res. Rad. Data (03/31/2017)




Highest in Collimation region: 1) "SEC.COL 6A" (->700 mrem/h) between abs. 6A & 6B; 2) "L6" (~400mrem/h) at front of 6A; 3) "SEC.COL 6B" (~300mrem/h) behind of 6B; 4) **"S6" (~300mrem/h) at short S06;** 5) "L7" (~100mrem/h) at front of 7A

*Relatively small (<50mrem/h) at primary (unused)* and DS of absorber 7A

A)"Boo never lost grad.magnets due to foil failure, but it may happen first here"!

B) Fermilab individ. job stop limit ~55mrem => rad. worker <5min!!! (700/60x5=58)

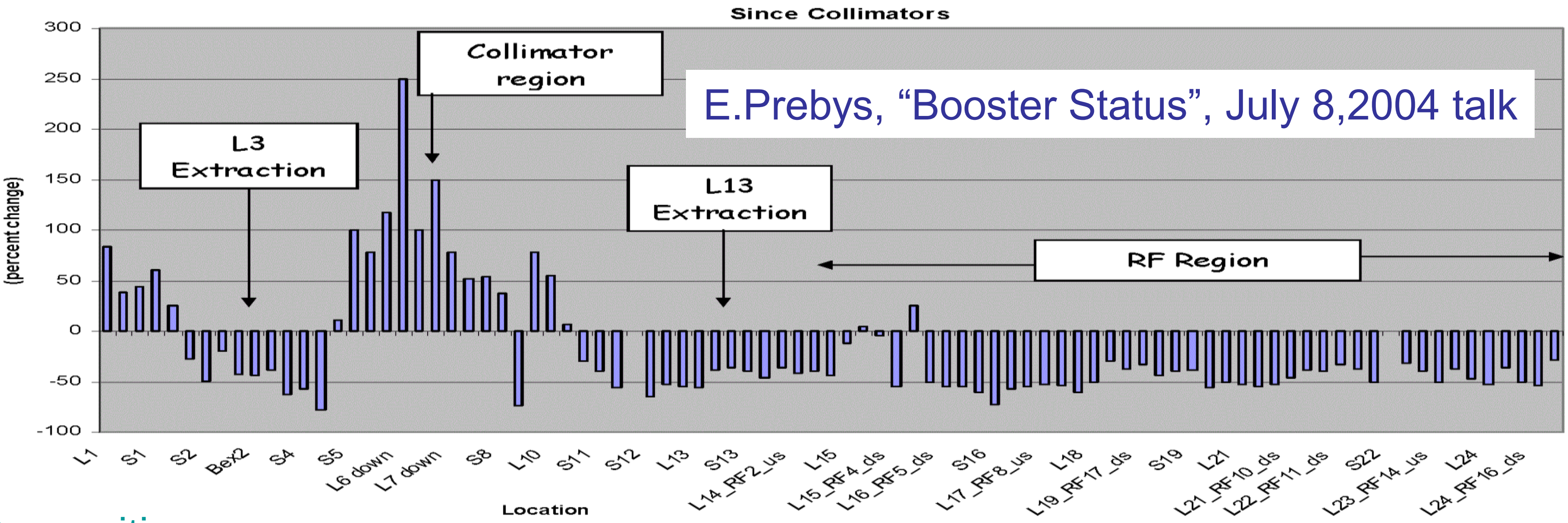
No immediate access of collimators => long cool-off times => high Boo down times

# Existing 1SC (since 2004) are useful

Plot (2004) shows a relative %-change in activation since collimators (1SC) operated:

1) **reduced activation** by 40÷50 % around much of the ring, particularly in **RF region**.

2) **increased activation** of ~ 50% in injection region (period 1) and of 50 ÷ 250 % in the **collimators regions** and immediately downstream (periods 6, 7, 8).



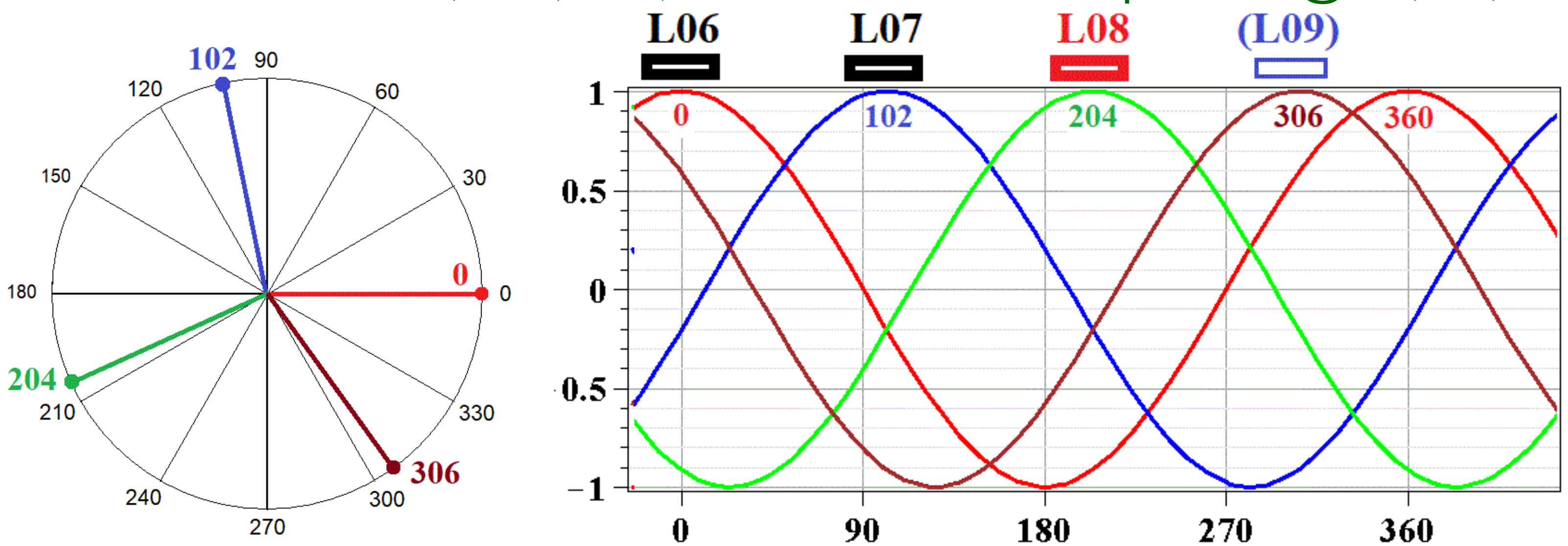

Supposition:

1) High radiation at collimators is mainly due to out-scattered protons at 1SC regime

2) a considerable part of the halo avoids the collimator apertures and directly hits apertures of RF stations due to a short phase length occupied by collimators.

# Feasiblity for extension of collimation system

Booster phase advance per period is 102 deg (close to 90deg).
4 “beamlets” around 0, 102, 204, 306 come to max amplitudes @ L6, L7, L8, L9




Additional collimators at L08 (and L09) could work together with existing collimators @ L06 & L07 @ **the same beam turn** and share portions of scraped halo particles.

The beam losses on 3 existing collimation units in L06 and L07 could be redistributed between 4 collimation units.

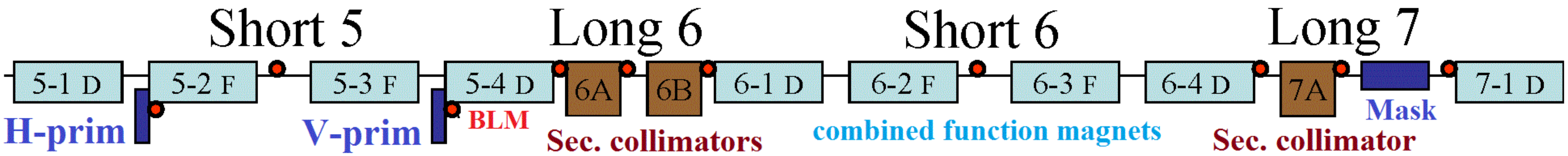
The new collimation unit in L08 will be used in conjunction with the existing collimators to reduce the load on each collimation unit. New collimation system could improve protection of RF-cavities via more effective blocking particles with fast increasing amplitudes (which presently “avoid” collimators and directly hit RF-apertures).

# L08 for new collimation unit

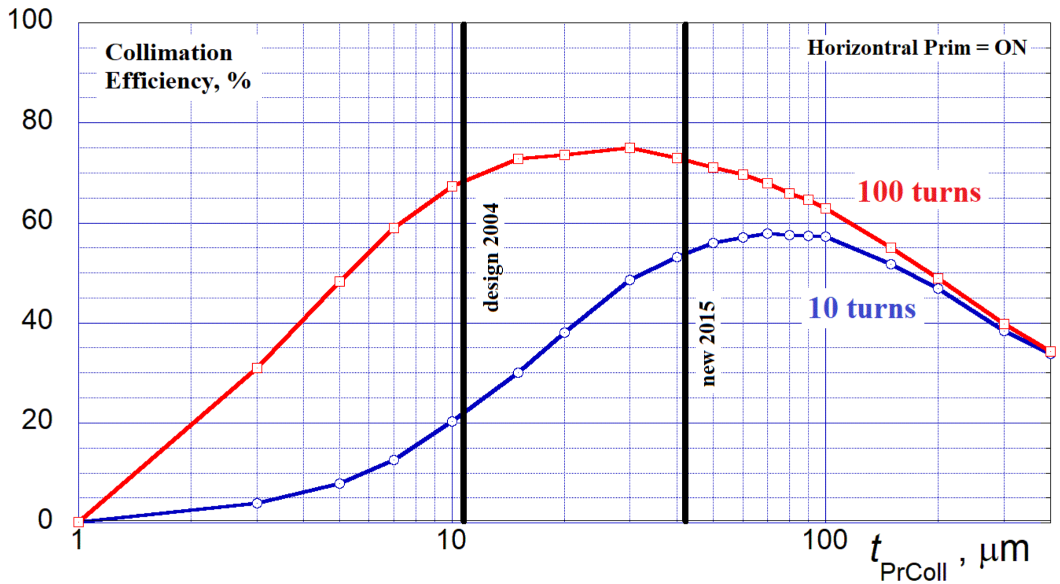
L06 L07 **L08**

TLM (Total Loss Monitors)


# 2016 Simulations for existing and New 2SC




V.Kapin (2015-2016) - MADX+MARS simulations & measurements for existing 2SC: with optimal foil collimation efficiency after ~10 turns ~60% (**first turn/pass < 50%**);




Collimation Efficiency = N_lost_on_colls/ N_Prim_jaws

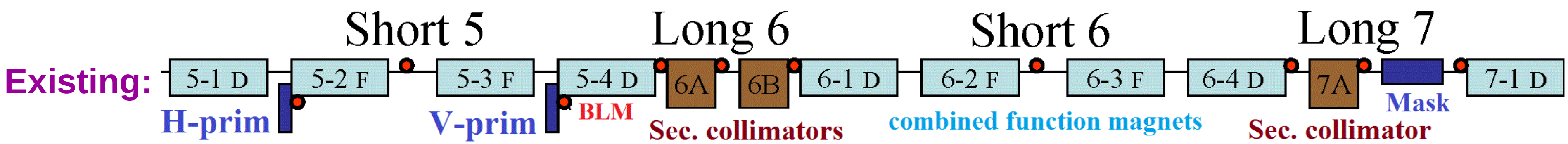
Max Coll-Eff -> 75% (100 turns)
-> 60% (10 turns)

*Simulations for ideal conditions:*
*constant energy,*
*zero closed orbit*
*w/o field non-linearities*

Reasons for low efficiency of 2SC (2004):

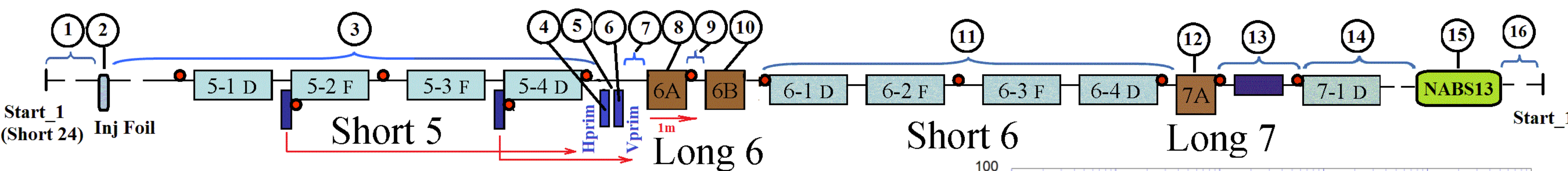
1) Small apertures –> Thick foil (400um Cu) -> 60% lost on magnet apertures
thin foil – protons escape/avoid Sec-coll (2mm-gaps)
2) Variable positions of "3sigma+c.o." trajectories during ~x100 turns
3) Experim. studies – no advantages for 2SC vs single stage collimation (eff ~50%)

# 2016 Evaluations of new alternative 2SC




V.Kapin (2017): MADX+MARS simulations –

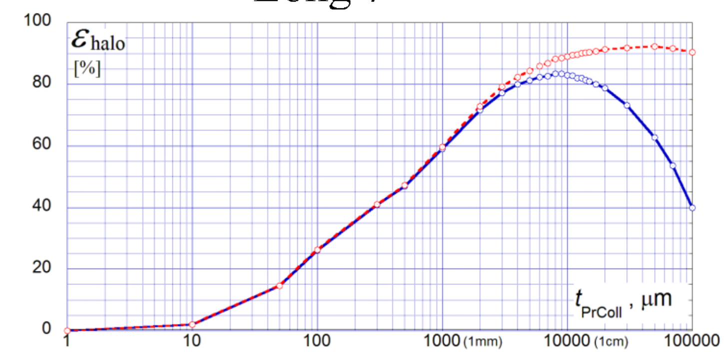
**"thicker" primary moved to Long6; 1 m-drift after scattering by primary:**




**Single path system (+ imaginary shielding L06):**
using existing MADX+MARS models for primary and sec. collimators in L06 & L07:

$\varepsilon_{eff}$=75% (***t*$_{Cu}$=4mm**) - w/o add. shielding;

$\varepsilon_{eff}$=~90% - additional shielding in all L06.




Red-curve: max $\varepsilon_{halo}$>90% if primary is also shielded ***t*$_{Cu}$~1 ÷ 10cm**

*Simulations demonstrated: losses are longitudinally redistributed inside of collimators (along L06) with increase prim. thickness **t** !!!*

*Recommendation (2017): New 2SC system could be installed in a free long section of periods 8,9,10, while old are kept w/o changes; further simulations require MARS model for thicker primary foils*

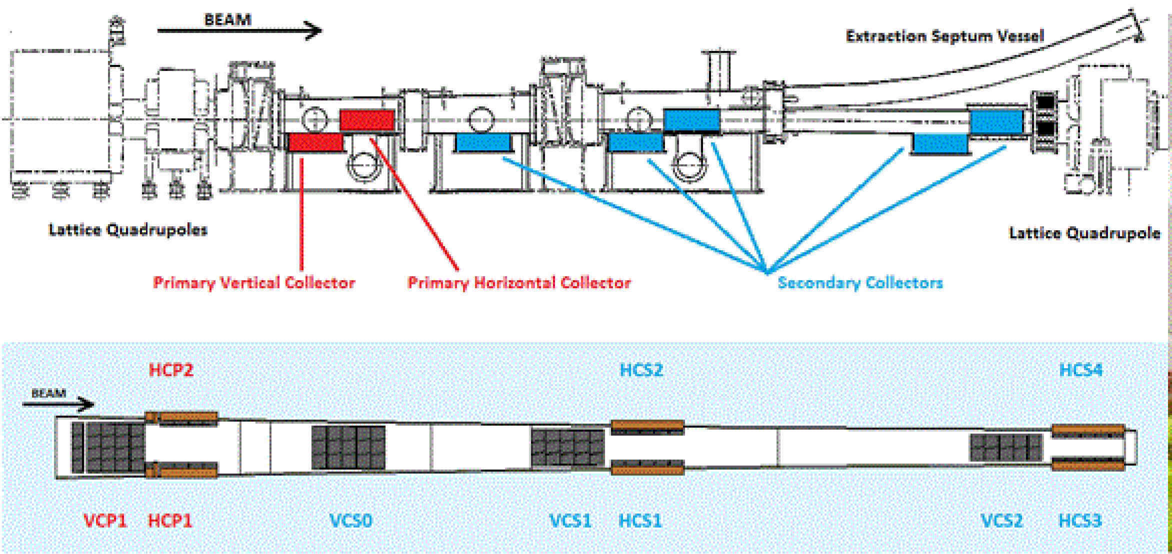
# ~Somewhat similar - 2SC at RAL RCS ISIS (SNS)

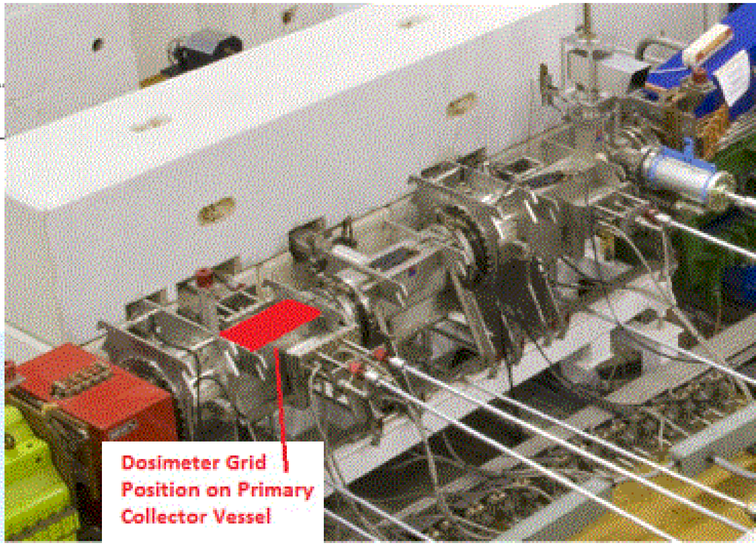
Search, if our not classical SC scheme has any analogy ? Yes !

It is not a classical 2SC as in colliders with (eff~99,xx%, ineff~losses~0.xx1%).
It is just **a local solution** for existing machine with eff~80-90% better than 1SC

It evolves from 198x till now (~35years; successful ?)
70MeV -> 800MeV, C=163m, 3xE13 ppp, 160kW->240kW
Collimation systems are located in one 5m drift section
**(10 movable beam collectors – 3 primary + 7 secondary)**

Elevation View of the Collectors in Super-Period 1




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

# Beam Scraping Rates per Collimator (2020)

Scraping rate table
by C.Bhat & D.Johnson

New "single path" collimation unit (in 2017 for PIP "Current") ;
it was re-targeted for PIP-I+ in 2018 ("Upgrade");

| Parameter | Current | "Upgrade" | PIP-II | Units |
|---|---|---|---|---|
| **Injected Beam Parameters** | | | | |
| Beam energy | 400 | 400 | 800 | MeV |
| protons per hour | 2.45E+17 | 2.80E+17 | 4.80E+17 | pph |
| **protons per sec** | **6.81E+13** | **7.78E+13** | **1.33E+14** | **pps** |
| protons per cycle | 4.54E+12 | 5.19E+12 | 6.67E+12 | ppBc |
| reo rate | 15 | 15 | 20 | Hz |
| beam energy/cycle | 290.4 | 331.9 | 853.3 | Joules |
| beam power | 4.4 | 5.0 | 17.1 | kW |
| **Acceleration Efficiency --> Beam Loss** | | | | |
| Assumed eff @ inj energy | **95** | **96** | **98** | % |
| lost particles/cycle | 2.27E+11 | 2.07E+11 | 1.33E+11 | pLpBc |
| lost particles/sec | 3.40E+12 | 3.11E+12 | 2.67E+12 | pLps |
| Joules lost per cycle | 14.5 | 13.3 | 17.1 | Joules |
| Power Lost | 217.8 | 199.1 | 341.3 | Watts |
| **Fraction of power loss going into collimators (from residusial activation)** | | | | |
| Fraction | **0.50** | **0.50** | **0.50** | |
| loss/cycle into all collimators | 1.13E+11 | 1.04E+11 | 6.67E+10 | pLpBc |
| loss/sec into all collimators | 1.70E+12 | 1.56E+12 | 1.33E+12 | pLps |
| Energy into all collimators | 7.3 | 6.6 | 8.5 | Joules |
| Watts into all collimators | 108.9 | 99.6 | 170.7 | Watts |
| Watt distibuted around ring | 108.9 | 99.6 | 170.7 | Watts |
| **Parameters/collimator (assume even distribution)** | | | | |
| Nbr Collimators | **3** | **4** | **4** | |
| Scraping rate | 3.78E+10 | 2.59E+10 | 1.67E+10 | pLpBc/coll |
| **Scraping rate for MARS** | **5.67E+11** | **3.89E+11** | **3.33E+11** | **pLps/coll** |
| Incident beam energy/collimator | 2.4 | 1.7 | 2.1 | Joules |
| Incident beam power /collimator | 36.3 | 24.9 | 42.7 | Watts |

Now, it is planed for PIP-II:
energy & pph –> twice higher:
400->800MeV; 2.4->4.8E17pph

=1.33E14 x 60 x 60

=6.67E12 x 20

=1.6E-19 x 800E6 x 4.8E17

=853 x 20 x 1E-3

Inefficiency=0.02=2%

= 6.67E12 x 0.02

= 1.33E11 x 20

=1.6E-19 x 800E6 x 2.67E12

=17.1 x 20

SRMARS (@Safety=X%) -> ?
~ under discussions

= 6.67E10 / 4

= 1.67E10 x 20

= 8.5 / 4

= 2.1 x 20

# 2017 – 3 “Conceptual” designs developed

Design principle – movable prim. & sec. collimators have a minimum lost particle load:
1) Rather thin primary;
2) Stationary (unmovable) sec. collimator in front movable sec. collimators.

3 designs ~4.2m each – modular structures = 2 parts “A”+”B”:
A) Prim coll. Chamber ended with Stationary (unmovable) collimator ;
B) Sec. collimators assembly

*Part “A” – similar in all 3 designs;* ***below are features of part “B” designs:***

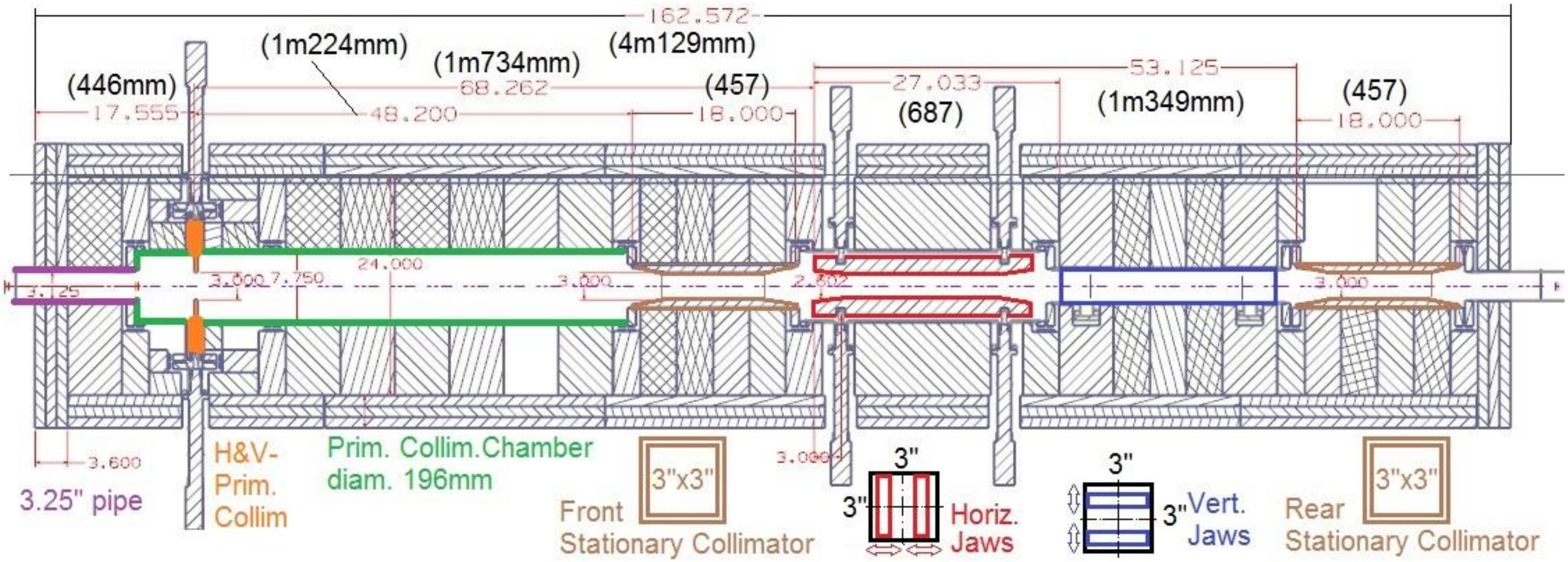
1st design : “Square jaws with large bellows” –
similar to the existing system with additional shielding =>
(vacuum gaps between bellows and shielding) – rejected (as L-shapes in 2003)

2)“Longitudinally separated H and V Jaws inside vacuum chamber” –
(shown on the next page) – accepted as simplest

3rd design “Square jaws (w/o Sylphons) inserted in vacuum” – “flying jaws” -
most close-to ideal implementation with non-trivial motion mechanism for square jaws
inserted in vacuum vessel – rejected as too complicated mechanical assembly

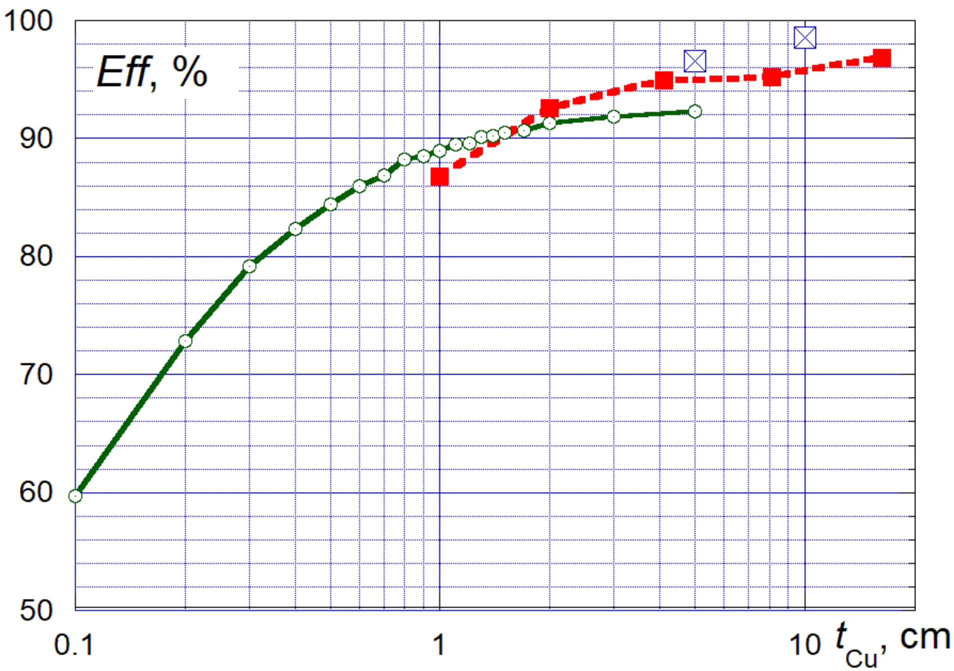
# Conceptual Design (no.2) of Collimation Unit

2)"Longitudinally separated H and V Jaws inside vacuum chamber" – simplest configuration without large vacuum gaps, but horizontal jaws are too close to primaries (possible coll. efficiency reduction? ) – accepted as simplest




**MARS simulations** has been performed for this configuration in 2018 (400MeV) - 3 Beam-Docs reports:
BD-6919-v1(12-Dec-2018, ScrRate=3.9E12 p/s), BD-6589-V2(14-Aug-2018 , ScrRate=3.9E12 p/s), BD-6589 (22-May-2018, ScrRate=4.7E12 p/s).

# Collimation Efficiency with MARS for Conceptual Design




Comparisons:
a) initial VK's "MADX+MARS in L06"
b) MARS - Conceptual Design (400MeV)
c) MARS – Prelim Design (800MeV)

Quite good agreement –
Eff>90% for thickness t(Cu)>2cm
dhalo=10um (VK) vs 1mm (MARS)

Eff_%@2016_VK_tests_L6
Eff_%_@2018MARS_ConceptDesign(400MeV)
Eff_%_@2020MARS_PrelimDesign(800MeV)

**Number of Protons* Inside Aperture ($N_{pa}$) at Marker Positions**

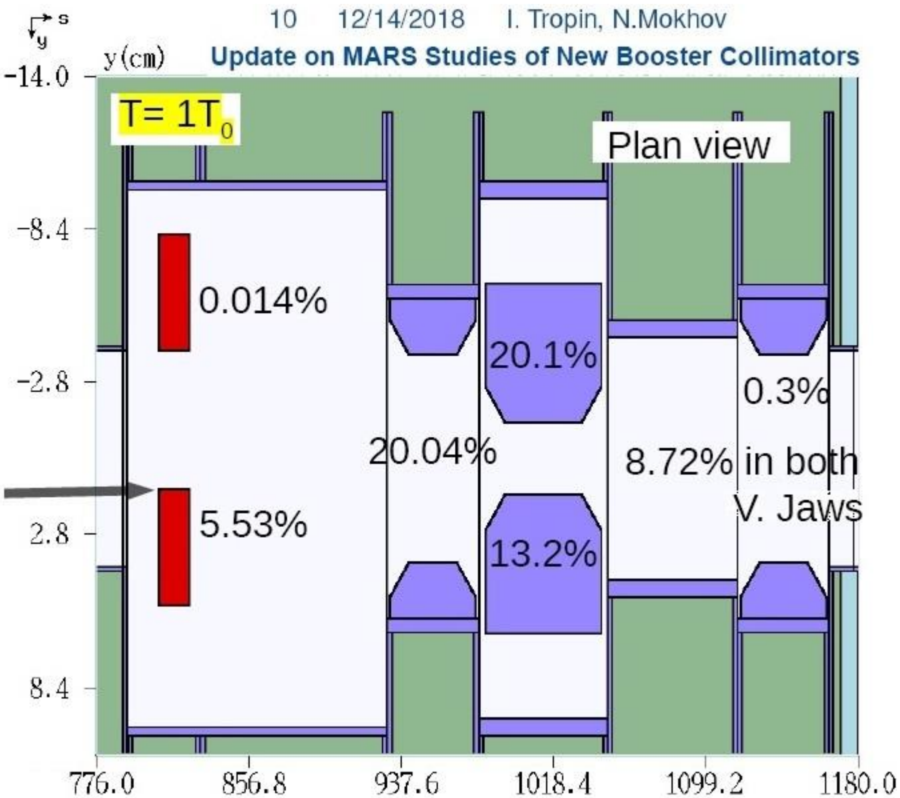
Results normalized per single proton hitting the collimator jaw

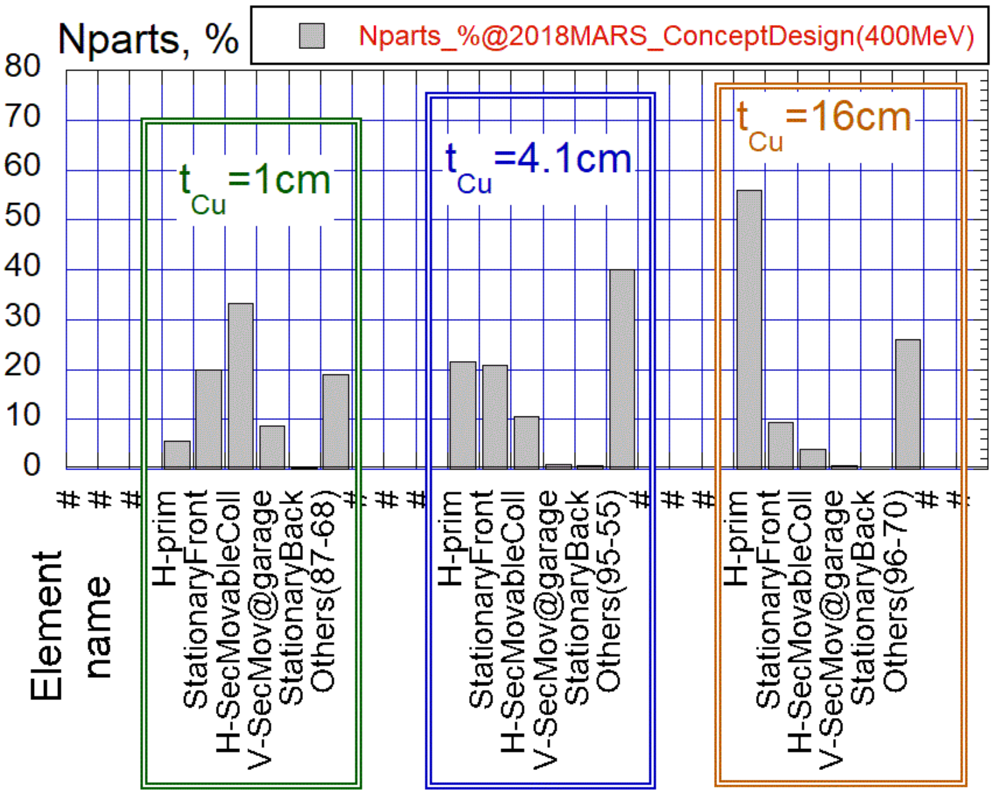
| Collimator type | Jaw thickness, $T_0$ = 1.016 cm of Cu | | | | |
|---|---|---|---|---|---|
| | $T_0$ | $2T_0$ | $4T_0$ | $8T_0$ | $16T_0$ |
| Coll. Assy Exit | | | | | |
| Horizontal | 0.132 | 0.0742 | 0.051 | 0.048 | 0.042 |
| START_9 | | | | | |
| Horizontal | 0.0336 | 0.019 | 0.016 | 0.0103 | 0.0095 |

8 12/14/2018 I. Tropin, N.Mokhov **Update on MARS Studies of New Booster Collimators**

**I.Tropin N.Mokhov, "MARS &for 2018 Concept Design"**, BD-6919, 12/12/2018
from conclusion:
one can conclude that the thickness *t* of primary collimator jaw has to be 4cm < t < 15cm of Cu.

# Loss Distributions on Elements – MARS @ Concept Design

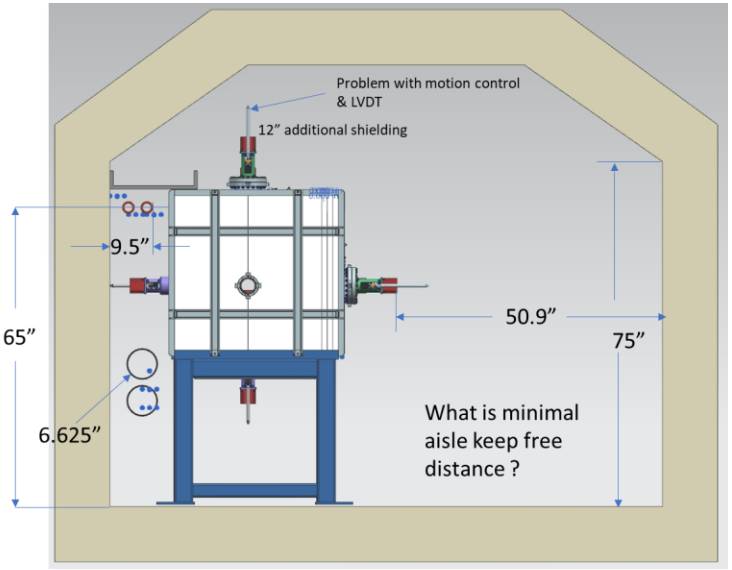


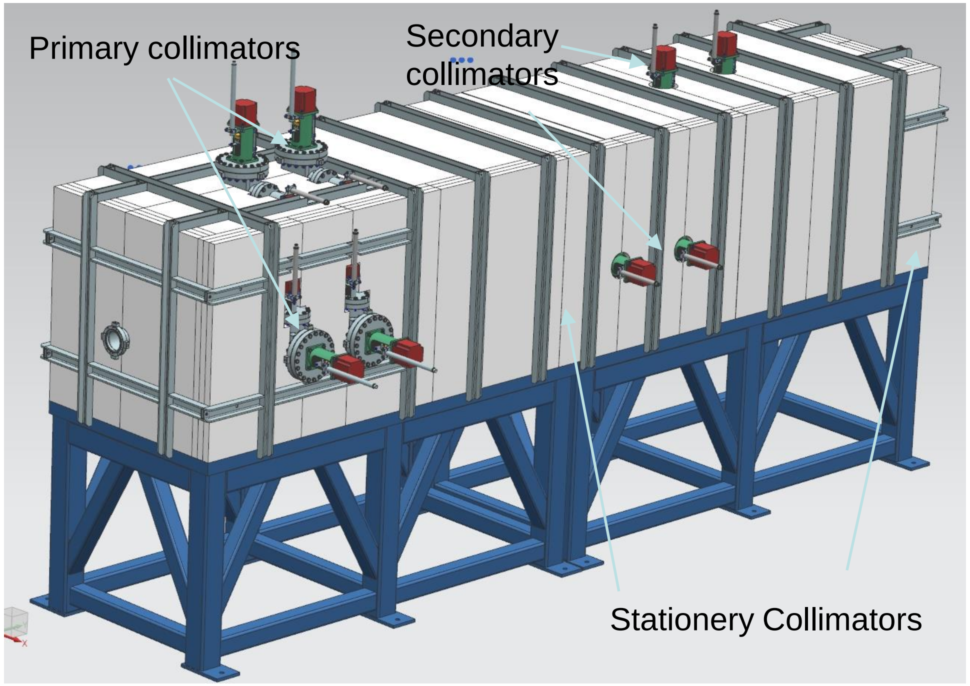




*As predicted by VK's preliminary simulations, losses are longitudinally redistributed inside ("sucked in") of collimation unit with increase of primary thickness **t** and start to dominate on movable primary collimators !!!*

# 2019-20: Preliminary Design of new Collimation Unit

V.Kapin, V.Sidorov, "New Booster Collimation Unit - Preliminary design",21-Jan-2020, BD-7953



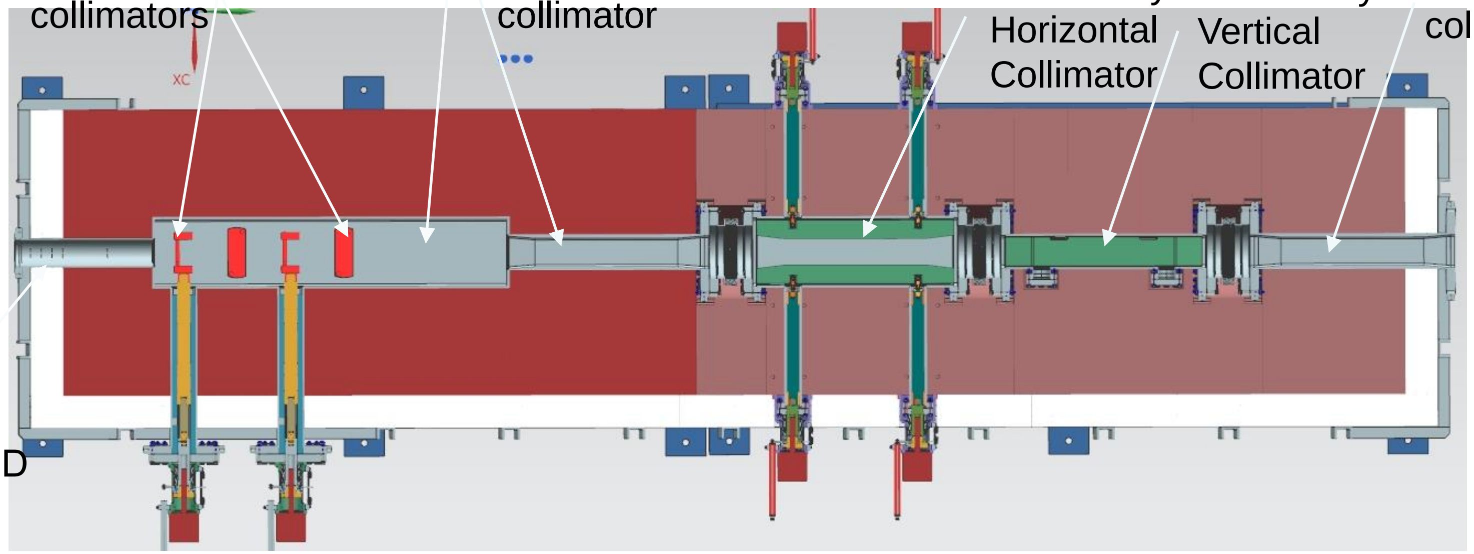



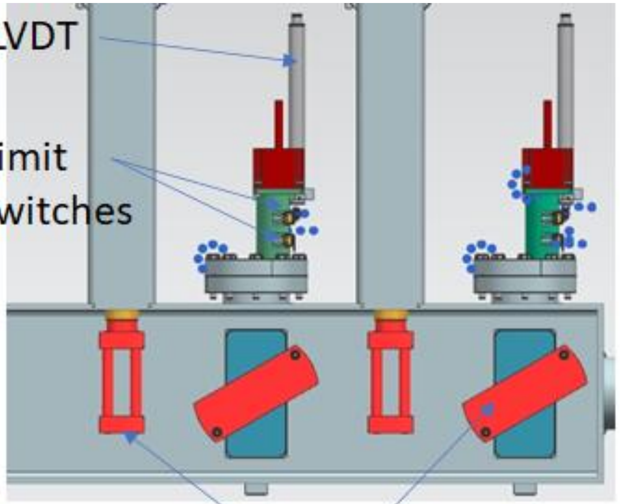

***Additional features:***

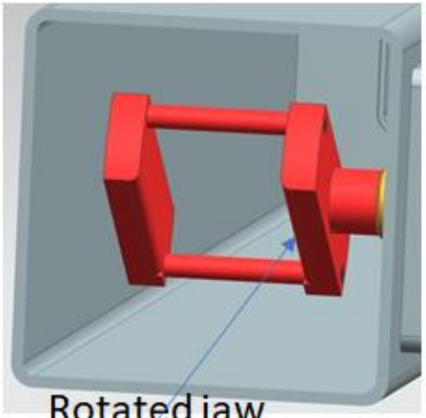
1) **Changeable thickness** of primary collimators via **a rotation of the primary jaws** (formulation of principle by VK, mechanical implementation by VS) – **up to a 60 deg**–rotation angle ensures a double thickness of primary jaws (2"-> 4")
2) **Two Additional** (supplementary) H&V primary collimators with options: a) **collimation from opposite sides** to reproduce existing mode by A&B collimators in Long 6; b) further double thickness (**totally 4-times! -> 8"**), if from the same side
3) Introduce **3 bellows** - separate service for secondary movable collimators (Bellows must have internal *RF shields to avoid impedances* ! – by Chandra)

# 2019-20: Preliminary Design of new Collimation Unit

V.Kapin, V.Sidorov, “New Booster Collimation Unit - Preliminary design”,21-Jan-2020, BD-7953



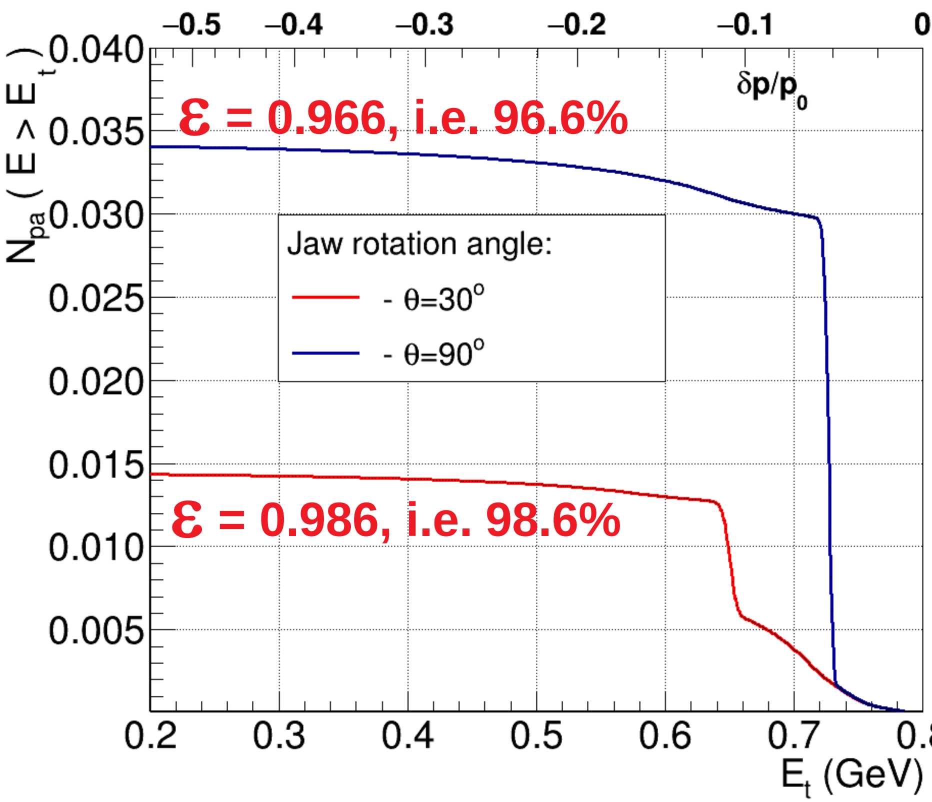

**Changeable thickness** of primary collimators along the beam direction via **a rotation of primary jaws**

# Resent MARS results for Preliminary Design

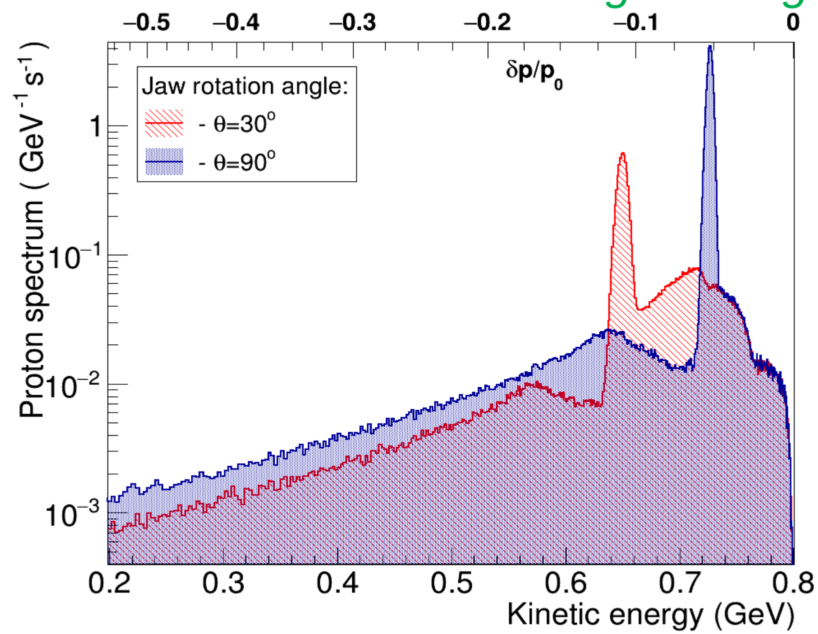
I.Tropin & N.Mokhov, "MARS studies of New Booster Collimator": BD-8359-V3(5), 5-May-2020.

*VK: these Efficiencies was included in prev. plot*

**Collimation inefficiency $N_{pa}$**
**Collimation efficiency $\varepsilon = 1-N_{pa}$**




*VK: proton spectrum at exit shifted 0.71MeV->0.66MeV vs 90deg->30deg*




MARS: thickness - max @ θ=30° and min @ θ=90°.

VK comment: comparison of new unit Eff.(>90%) with Eff. (~50%) of existing 1SC:
dhalo=10um (VK evaluations in 2017) vs 1mm (MARS 208-2020) ?

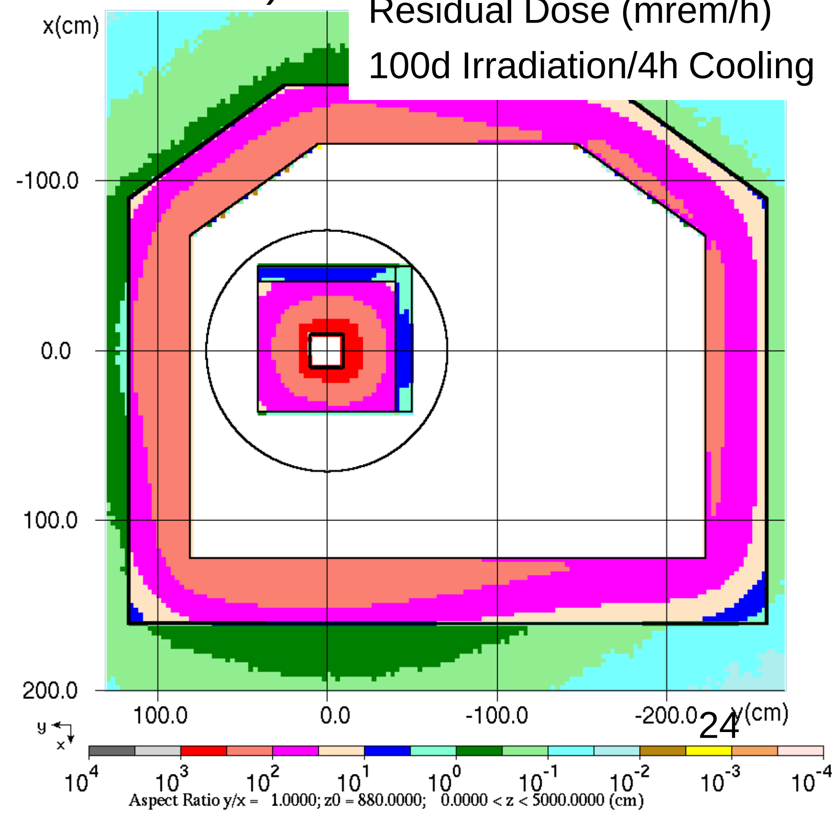
# Resent MARS results for Preliminary Design

I.Tropin & N.Mokhov, “MARS studies of New Booster Collimator”: BD-8359-V3 (5-May) -> V5(1-Jun), 2020.

Scraping rate per jaw –REVISED (by D.Johnson) ->1.5E12 (V3) -> 0.3E12 (V5) !!!

- … the collimation efficiency of the new Booster unit **for 800-MeV protons can be as high as 96-98%**. … the main **contribution** to the collimation inefficiency is due to beam protons **punching** through the primary collimator jaw.
- To increase efficiency – ***if needed*** - the primary collimator jaw thickness of about 20 cm would do a better job (*VK – use two rotated at max =4”*).
- **…stainless steel** instead of **copper** for primary jaws can be more practical (cost, stiffness and lower neutron production), but: ***smaller scatt. angle, lower thermal cond.***.
- Residual dose rates on the collimation unit components are **typical for similar systems at the Fermilab accelerator complex**.
- Prompt dose at the berm is 0.05, 0.25 and 5 mrem/h for distance (concrete + dirt) 18.7, 16.5 and 12.5 feet, resp.

Residual Dose (mrem/h)
100d Irradiation/4h Cooling



# Conclusion (”before” PDR)

- Booster features do not allow an effective classical 2SC scheme
- Used so far 1SC scheme has low efficiency (~50% @ 10um halo)
- Suggested an unique “non-classical” self-contained 2SC unit has a collimation efficiency more than 90% ( >> of existing 1SC)
- Preliminary design of 2SC unit has been developed (V.Sidorov reps)
- MARS simulations for Preliminary design of 2SC unit showed high collimation efficiencies up to 95% (I.Tropin reports)
- Instrumentations for tuning, control and safety are available

Many thanks to all people helping on these studies during the last 5years!

**After PDR (“shielding”)**: *Our next steps - the detailed civil construction detail on concrete, shielding, dirt, elevations and relative positions from FESS so we can know where the tunnel and surface structures... (care by D.Johnson and MARS group)*

# "After PDR" conclusions and options for collimation

*"preliminary assessment was positive"*

- ❑ Specify … the **original** collimation system is in for the simulations and **projected efficiencies** and incorporate original collimation system in the commissioning plan
- ❑ We appreciate options with **fixed thickness** primaries

***VK:***
*1)Need to add simulations of Coll. Eff for halo 10um and 100um at t={1,..16cm}*
*2) below:*

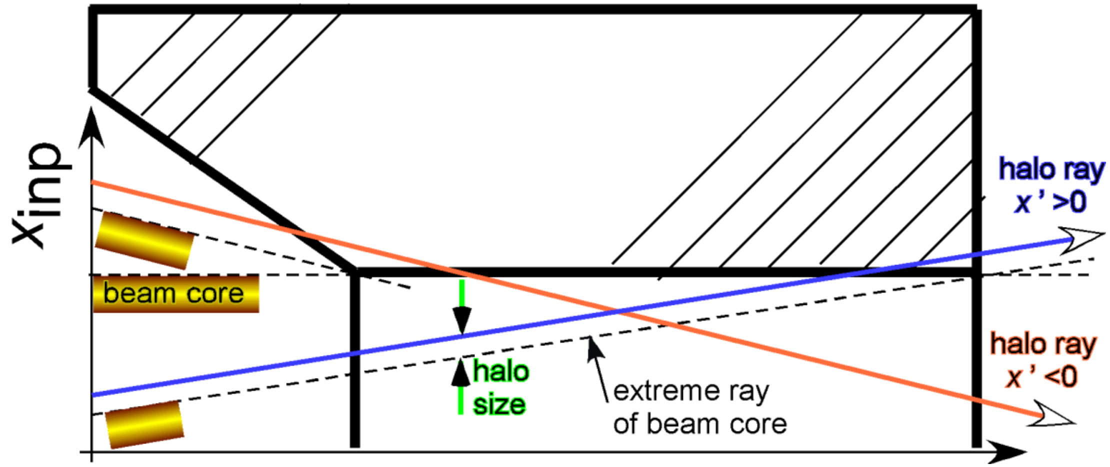
## Possible cures and options

- There could be up to 3 primaries jaws ("sandwich") in each plane (thin+thick+thick) – provide "an angle alignment" along beam envelope
- Exclusion of "jaw rotation" (reliability ?!) – several options: a) temporary (removable) for tuning/testing before a global shutdown in ~2025; b) use rotation mech. only on some of primaries, e.g. in the first thin; b) remove mech. (just handy flange turning – care 4 resealing > dismountable rod)
- Minimize 2 mm gap between secondary jaws and 3-sigma beam envelope: it was used initially for "correct" (conservative) comparison with classical 2SC (c.o.); It may narrow (reduce) Tropin's energy peak (p+ punching through the primary jaw)
- Thick second and third primaries from "primary sandwich" could be aligned within gap << 2 mm and used as sort of "secondaries" to suppress punching protons

# Backup slides

# 1SC simulations for one absorber

*V.Kapin, BD-5222(2016),*
*V.Kapin et al., NAPAC'16.*



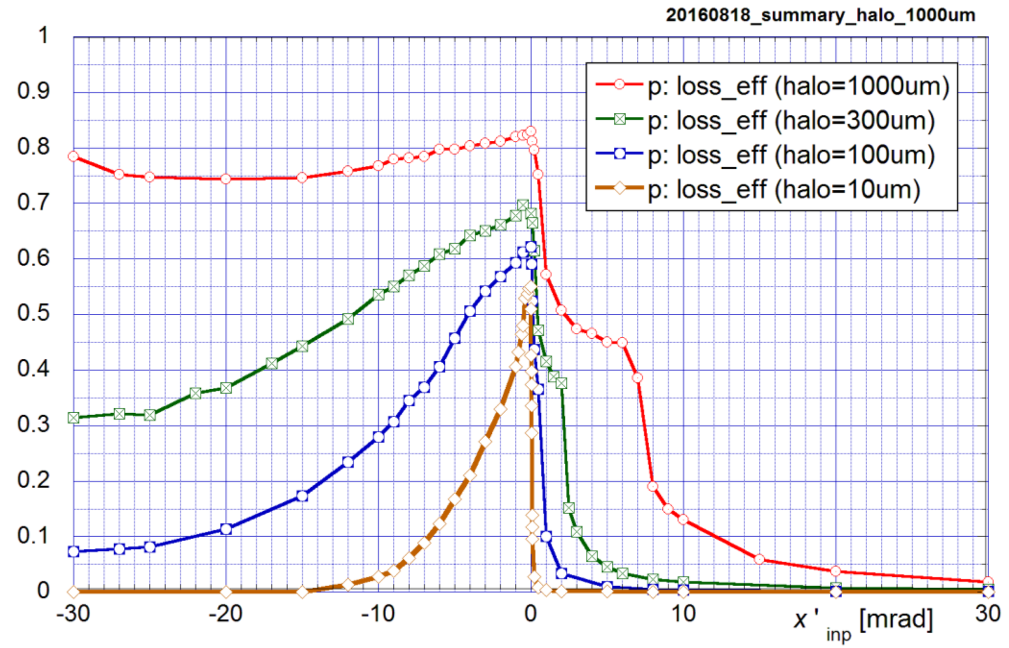

For **x'>0** beam hits **back** jaw

For **x'<0** beam hits **front** jaw

Condition:

beam touches jaw w/o losses

halo ray (10^4 protons with identical coords);
dependence on slope
x'=dx/dz [mrad] at given halo sizes




"1SC Eff."=
(N protons lost in collimator)/
(N=10^4 parts in incident beam)

V.Kapin, (for new Collim. Unit) "Collimator setting (5-Apr-2018)", in Beam-Doc-6661:
"the halo size δhalo could be equal to 10μm, 100μm, 1000μm(1mm).

# 1SC efficiency depends on several params.

1SC depends on impact parameter & angular alignment of jaw

M. Seidel example: Out-scattering reduces to 0.4 within [+-0.05mrad]

M. Seidel The Proton Collimation System of HERA DESY 94-103 June 1994 Dissertation

**2. 3. 3 Simulation Results**

In this chapter we present simulations made with a single collimator jaw. Tracking simulations of the complete system are presented in chapter 3. The most obvious result is the strong dependence of the absorption efficiency (and also the rms-deflection angle) on the angular alignment of the jaw (see also [SEI92]). If the jaw is misaligned as depicted in Fig. 2.15 the effective collimator length is reduced.

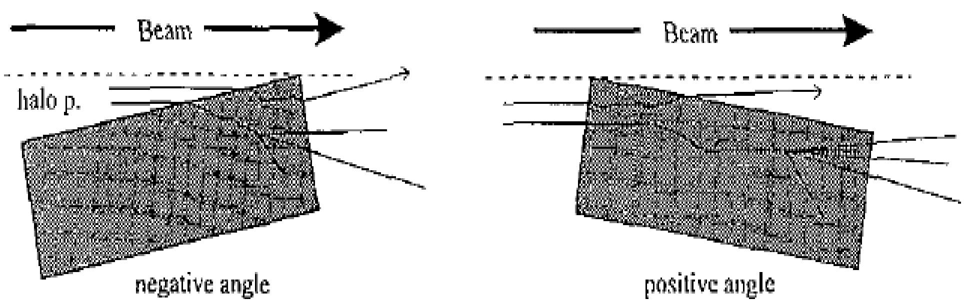
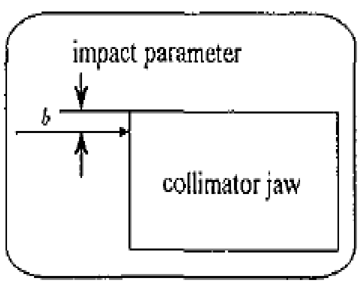



Fig. 2.15: Reduction of the effective jaw length due to angular misalignment.



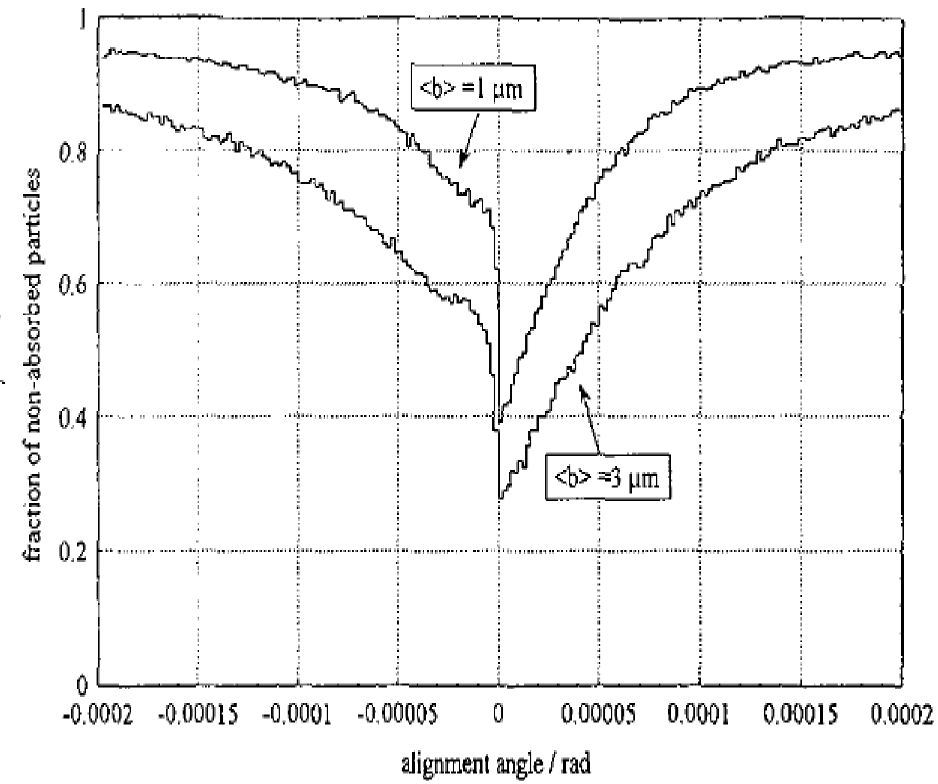




Fig. 2.16: The out-scattering probability as a function of alignment angle for two different exponential impact parameter distributions.

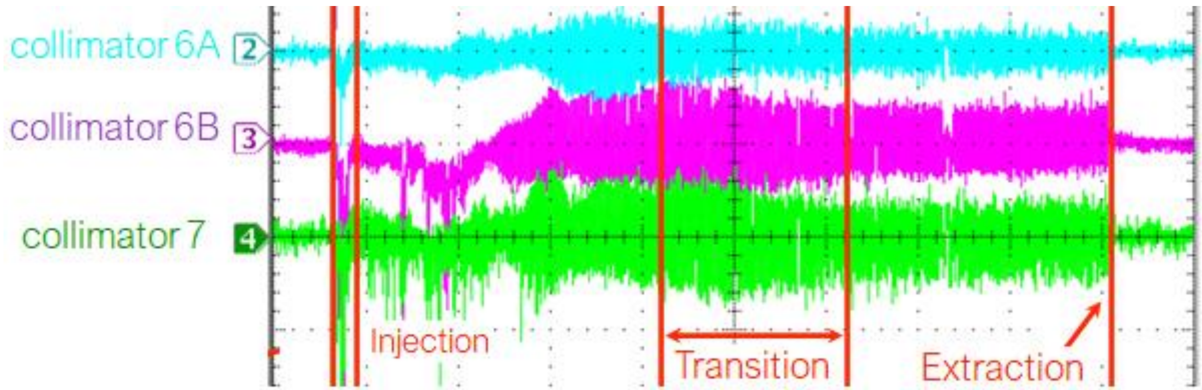
Collimation efficiency may also depend on particular features of **jaw configuration** of secondary. collimators

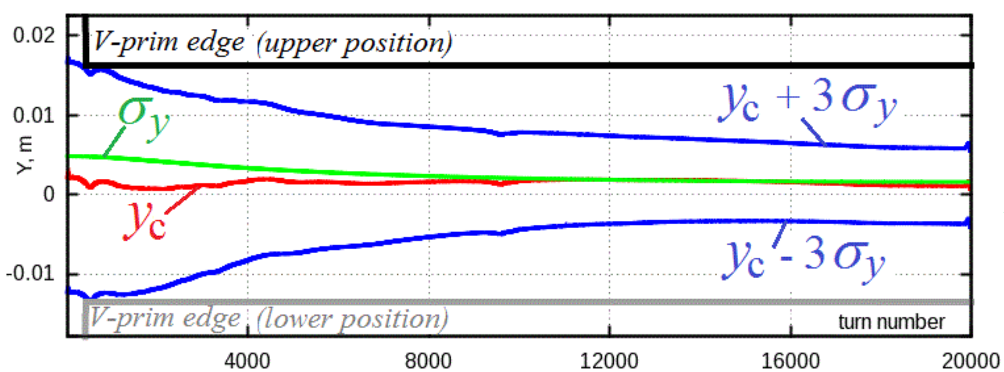
# Beam Instrumentation used and needed

***List is similar to existing collimators in L6 &L7:***

a. BPM up and downstream (additional upstream and existing in Corr-Package ) - easy find beam positions at jaws thanks to straight trajectories of beam centroid
b. Fast bunch by bunch loss monitors (R.Tezarek) – up to 3 – for tuning of coll-tuning
c. Slower standard ion chamber loss monitors – with standard Booster applications B136 (within one Boo cycle) and B88 (> 1min averaged - normalized to alarm)
d. Standard correctors for orbit control (CPs exist @ S7, end of L8, and S8)

FLMs (Fast Loss Monitors) by R.Tezarek provide new opportunities for high resolution (ns)

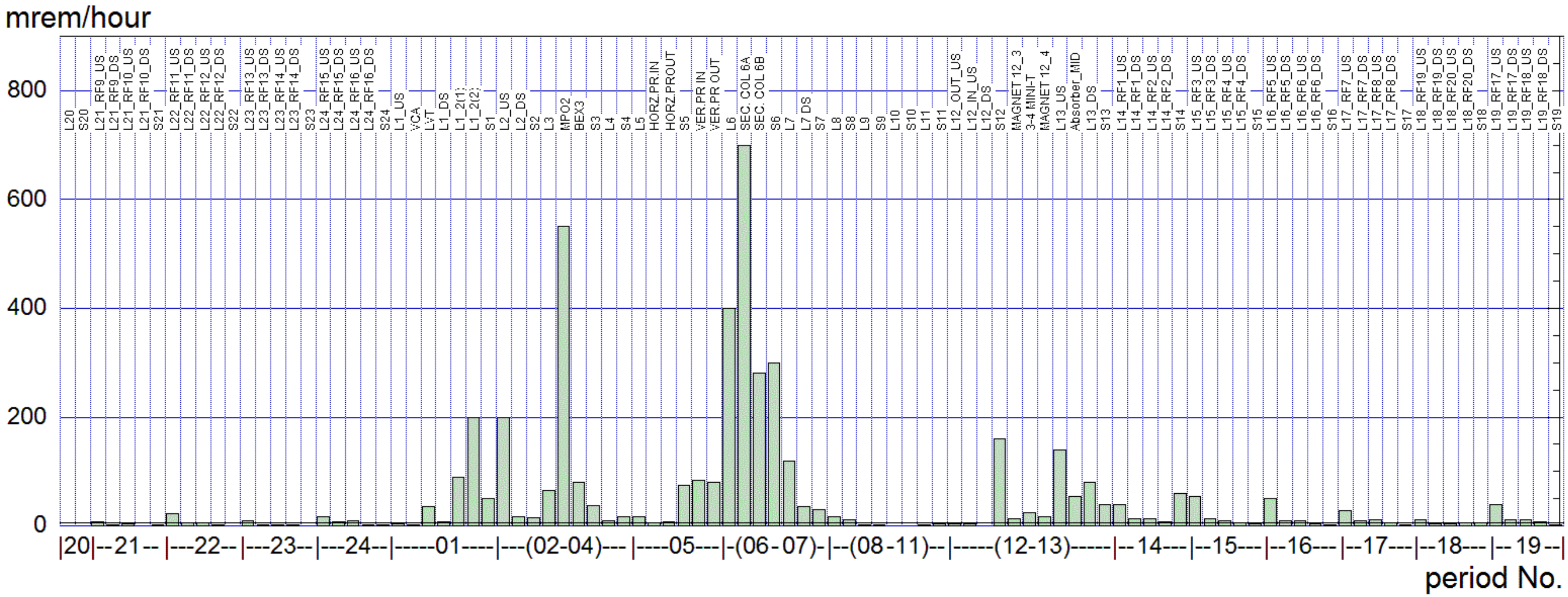



*BPMs (B38): Measured C.O orbit yc along Booster cycle plus "ideal" 3-sigma beam envelope;*
*Example: primary collimator jaws touches beam from the bottom*

# 1-foot Residual Radiation Data (03/31/2017)

Avg via (B87@8h-before): up-time=95.8%; 12ev/sec; $3.8 \cdot 10^{12}$ppc; $1.7 \cdot 10^{17}$pph; Eff=91%




High radiation levels in the following regions (see Boo layout slide #3):

1) Injection - period 01 (up to 200 mrem/hour );
2) Extraction – around period 3 (up to 550 mrem/hour);
3) Collimation – periods 5-7 (up to 700 mrem/hour)
4) Notching – periods 12 & 13 (up to 150 mrem/hour)

Relatively small radiation in “RF” periods 14-24 (< 200 mrem/hour), however RF stations require a frequent maintenance works -> exposure of rad. workers