Low Energy Studies

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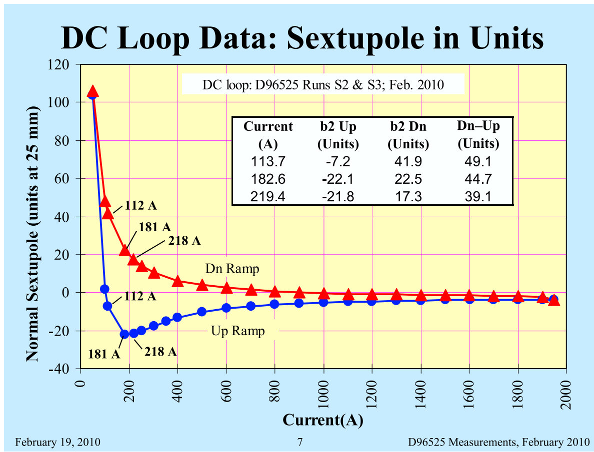
APEX workshop, November 19-20, 2012

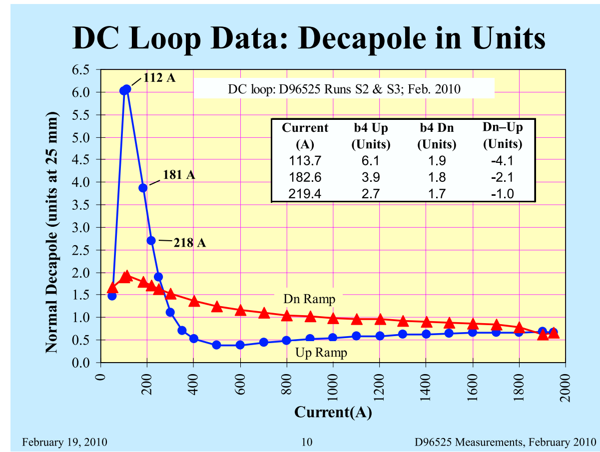
Outline

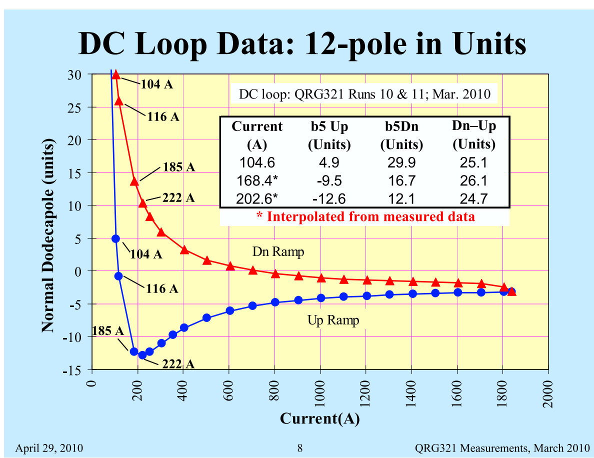
- Experience at $\sqrt{s} = 5\,\mathrm{GeV}$
- Plans for $\sqrt{s} = 15\,\mathrm{GeV}$ in Run-13 or 14
- STAR proposal to install an internal target in IR 6

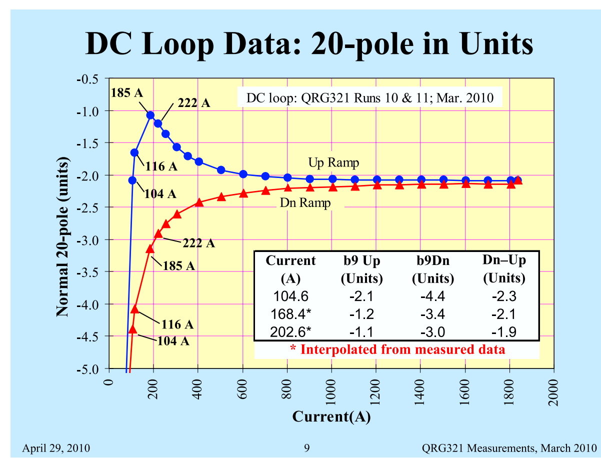
5 GeV

Multipole measurements









Multipoles at four different energies

	$\sqrt{s} = 5$ GeV	$\sqrt{s} = 7.7$ GeV	regular injection	100 GeV protons
sextupole	-7.2	-22.1	-10	-3
10-pole	6.1	3.9	0.4	0.7
12-pole	4.9	-9.5	-7	-3
20-pole	-2.1	-1.2	-1.9	-2.1

10-pole is 50 percent larger at 5 GeV than at 7.7 GeV

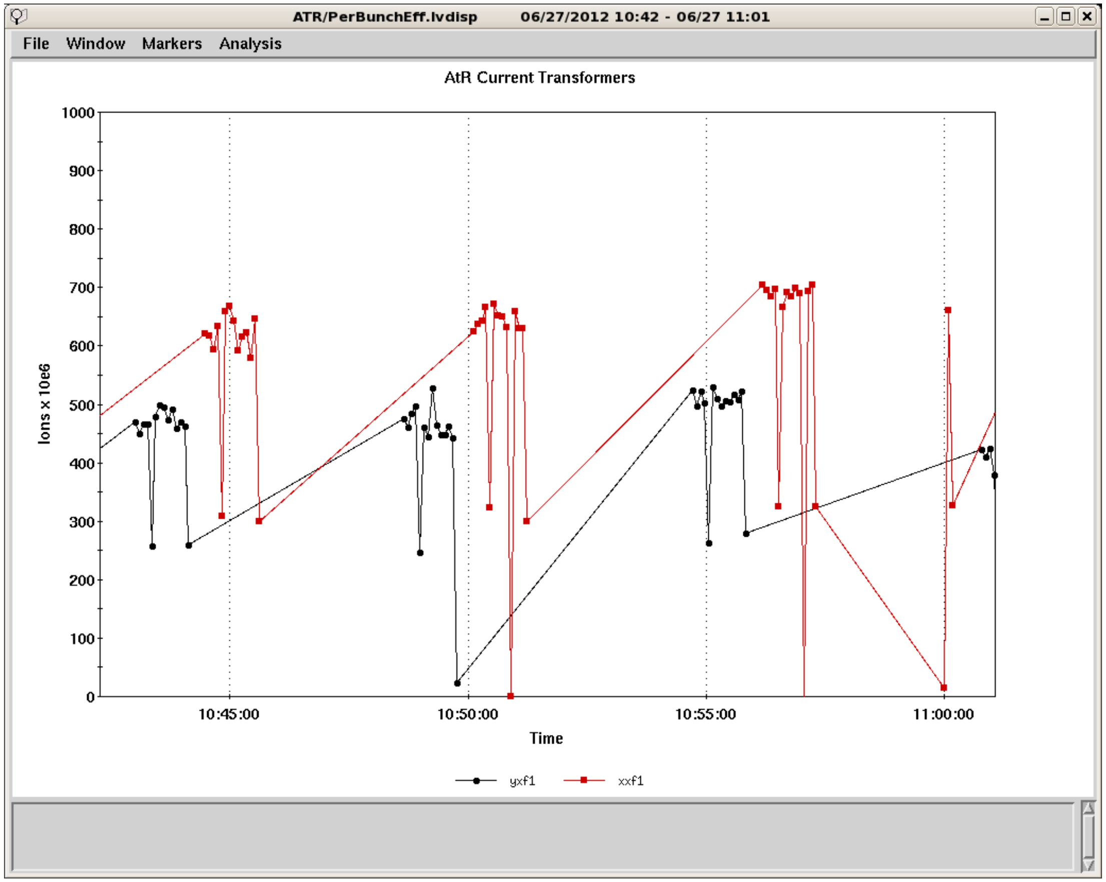
12-pole has opposite sign at 5 GeV, but is not larger than at the other energies

Sextupole and 20-pole are well within "normal range"

- Triplet multipoles are not known at these energies, but can be simulated (Animesh, Ramesh; in progress). At $\beta^* = 10\,\mathrm{m}$ they should not dominate the beam dynamics anyway, unless triplet quads perform much worse there than arc magnets

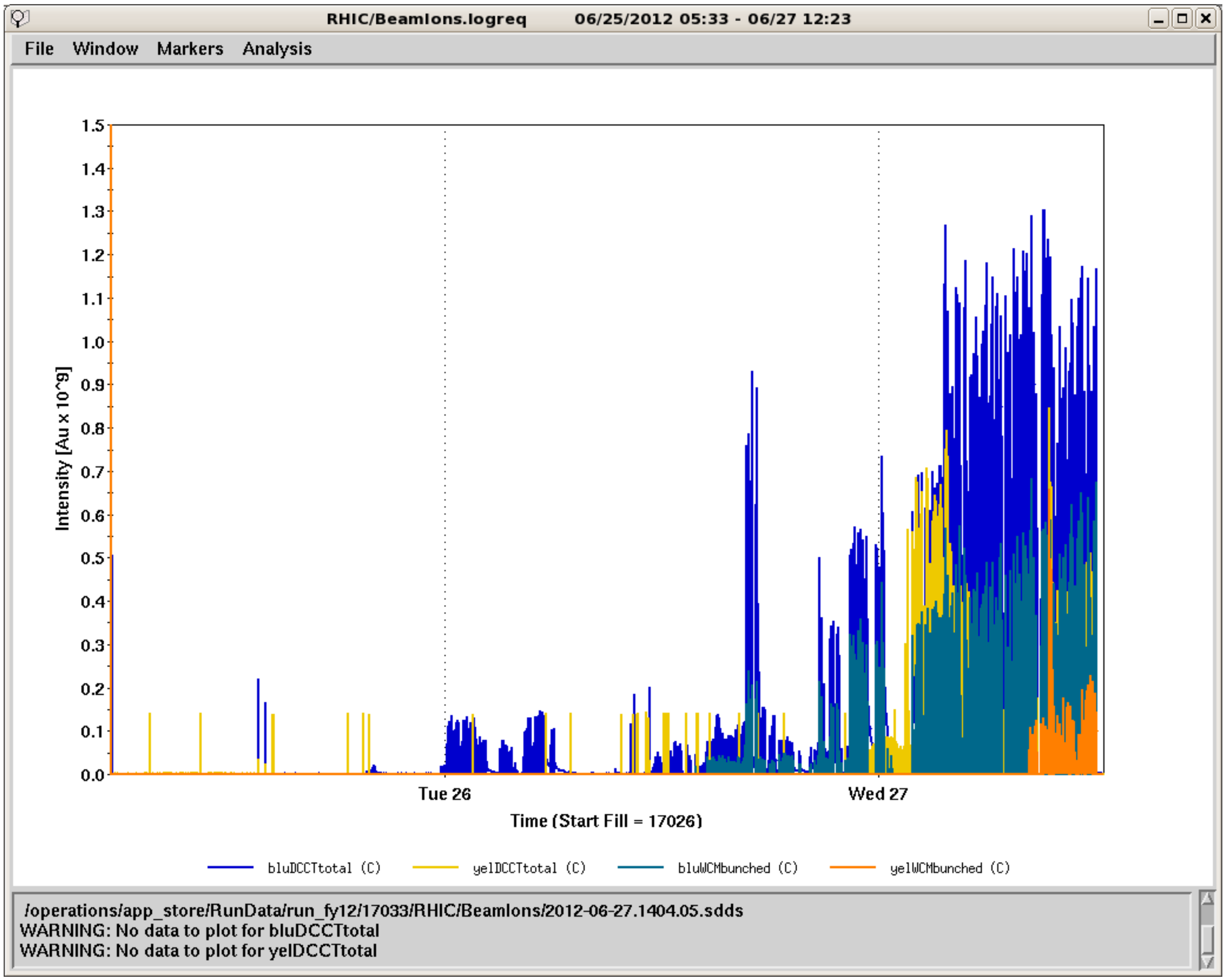
- Need tracking studies to determine whether 50 percent larger 10-pole and opposite sign for 12-pole can make such a big difference.

Bunch intensities in X and Y-arc

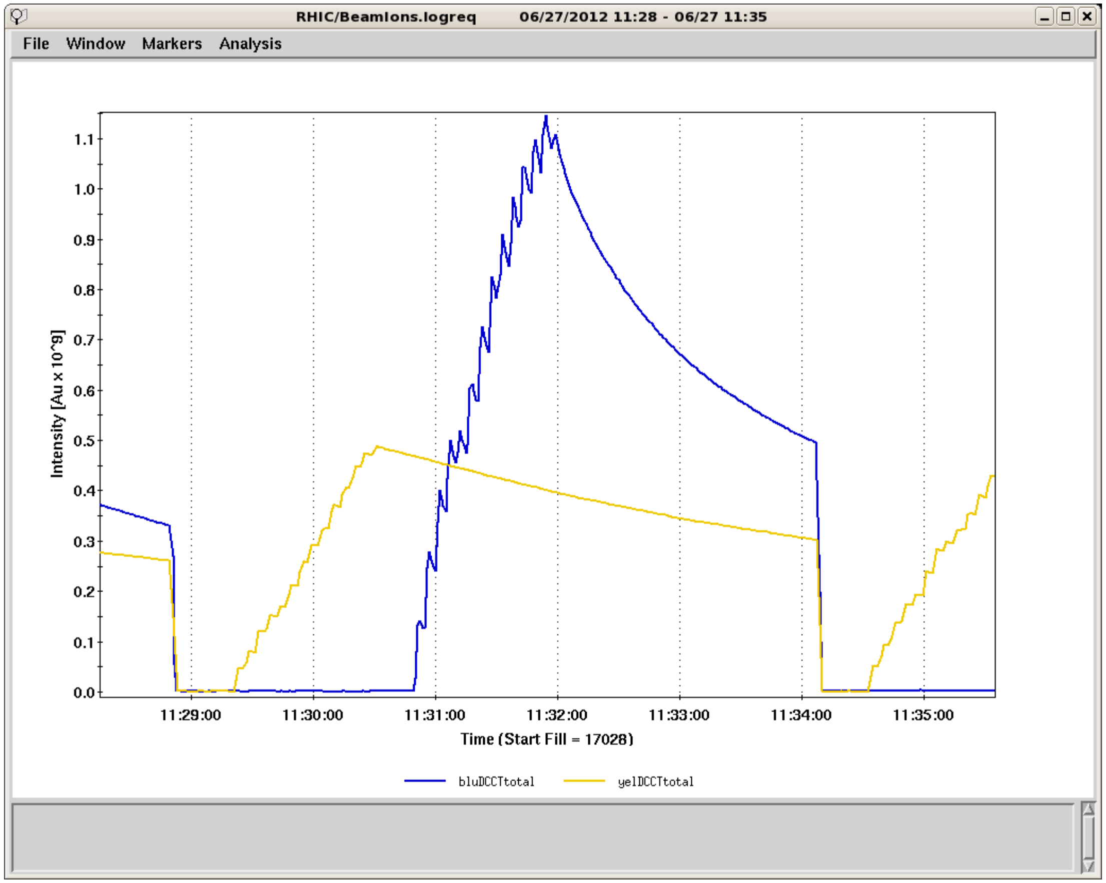


Two bunches per AGS cycle

Beam intensities in RHIC



A typical store



Two minute store length

Some issues at 5 GeV

- Chromaticity control was the key compared to 2010. Ended up with setpoints around 100 units (did not fix the b2 model)

- Injection kicker reflection affects circulating bunches in Yellow

- AGS bunches are too long to fit into the RHIC bucket

- Poor injection efficiency into RHIC. 27 bunches with 3.5e8 in AtR translate into 1.3e9 total intensity in RHIC

At these tiny intensities space charge and IBS should be negligible.

APEX idea

- Known multipole errors at 5 GeV are not particularly large
- Intensities were tiny
- Yet the lifetime was very short (1-2 min)
- Low energy beam has large emittance and therefore samples multipoles at large amplitudes
- APEX idea: Measure beam lifetime at injection as function of emittance

15 GeV

Machine configuration

- We successfully ran at 7.7 and 11.5 GeV in Run-10
- $h = 360$, so we can provide collisions at both STAR and PHENIX
- $\beta^* = 3.5\,\text{m}$
- 6-, 10- and 12-poles are smaller than at 11.5 GeV; 20-pole is similar to store value

No major issues expected

Internal target at STAR

Motivation

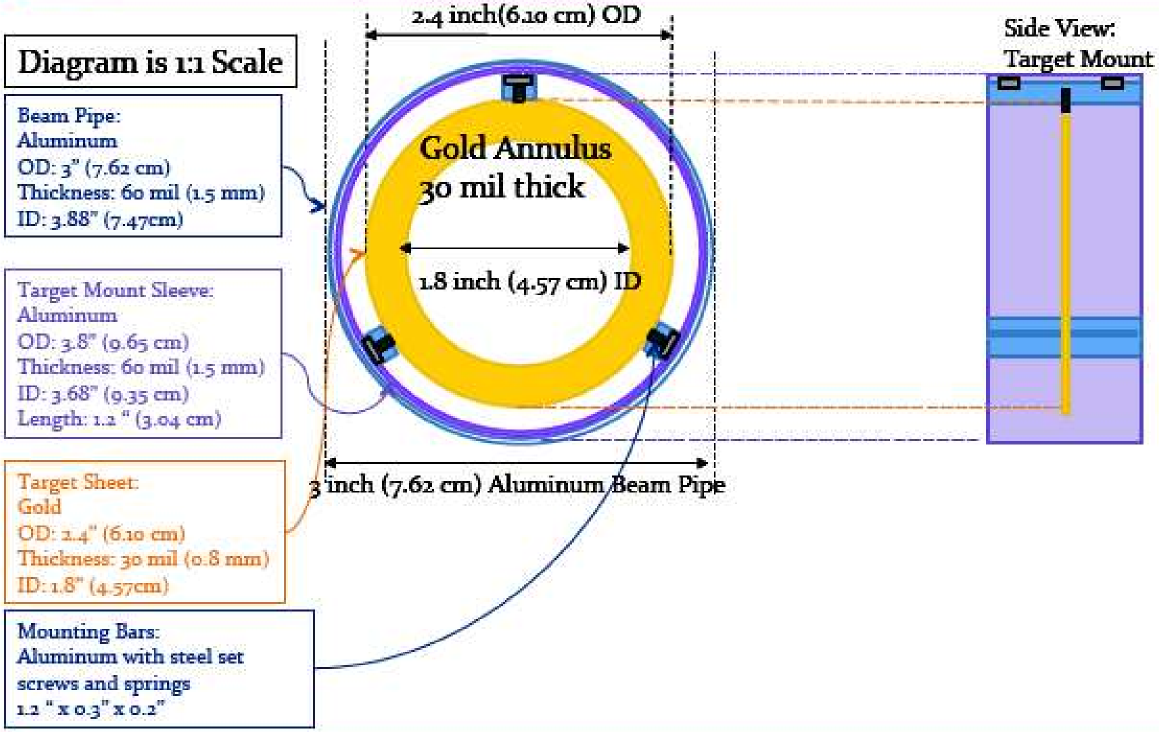
- At $\sqrt{s} = 5\,\text{GeV}$ approximately 100 days of running are required to meet the STAR luminosity goal, assuming that luminosity scales quadratically with energy

- To shorten this time substantially for a first glimpse at the physics at 5 GeV, the STAR BES group proposes installation of an internal target in the STAR beampipe, about 1.7 m from the IP

- Detector simulations look promising

- Need to make sure that this does not impact regular RHIC running

Gold Target



Target mounting sleeve slides inside the beam pipe.

Courtesy Grazyna Odyniec

Operational concerns

- Target impedance: $|Z/n| \approx 0.002\,\Omega$ - no problem (M. Blaskiewicz)

- Target needs to be bakeable at 150 degrees C (M. Mapes)

- Rate control will be an issue, similar to HERA-B. May need some noise excitation (through the BBQ system?) and/or slow "resonant extraction"

Maximum β^* requirement

- The internal target is in the shadow of the Q1 beam pipe if

$$\beta^* \leq \frac{T^2 d^2 - D^2 t^2}{D^2 - T^2},$$

with T=0.06 m (Q1 aperture), D=0.02 m (target aperture), t=25.36 m (distance IP6-Q1), and t=2.04 m (distance IP6-target)

- Using these parameters, the target is in the shadow of Q1 as long as

$$\beta^* \leq 8.7\,\mathrm{m}$$

The situation at store energy

- During a physics store with $\beta^* = 0.6\,\text{m}$, we have $\beta_{\text{target}} = 7.54\,\text{m}$ and $\beta_{\text{Q1}} = 1072\,\text{m}$

- Aperture at Q1 would have to be

$$\begin{aligned} t &= \sqrt{\frac{\beta_{\text{Q1}}}{\beta_{\text{target}}}} \cdot D \\ &= \sqrt{\frac{1072\,\text{m}}{7.54\,\text{m}}} \cdot 0.02\,\text{m} \\ &= 24\,\text{cm} \end{aligned}$$

  to be able to hit the target

- This is four times the actual aperture

Beam sizes for a 20π beam

	β^* [m]	γ	$\sigma_{\text{detector pipe}}$ [mm]	σ_{target} [mm]	σ_{triplet} [mm]
injection	10	10.5	1.806	1.819	4.857
$\sqrt{s} = 15\,\text{GeV}$	3.5	8.1	1.331	1.393	8.803
store	0.6	107	0.400	0.485	5.779

At large β^*, the beam is nearly parallel, and it becomes very difficult to hit the target without hitting the detector beam pipe, if both have the same aperture

$\Rightarrow$ The target aperture needs to be reduced, to $r = 19\,\text{mm}$

- With a $r = 19\,\text{mm}$ target aperture, an orbit angle of at least $(20{-}19)\,\text{mm}/(2.04{+}1.65)\,\text{m} = 271\,\mu\text{rad}$ would be required to accidentally hit the 20 mm detector beam pipe, in this case at the other end

- This orbit angle translates into an offset of 6.9 mm at the entrance of Q1, which is easily detectable by the triplet BPMs, and therefore avoidable

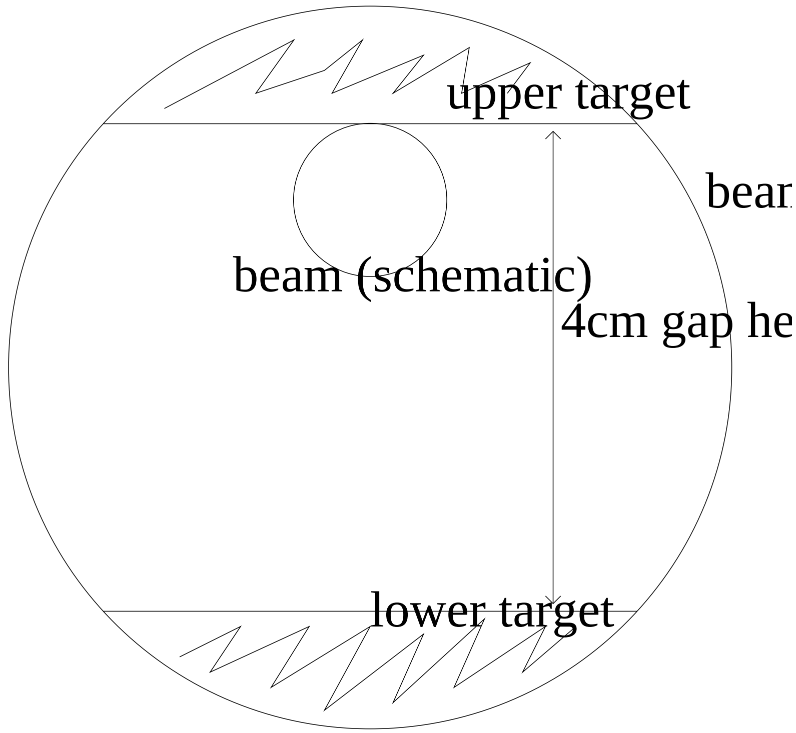
Abort kicker misfires

- In the case of an abort kicker prefire, about 20 bunches get lost in an uncontrolled fashion before the remaining kickers abort the beam

- This could lead to local melting of the target

- Since the abort kicker kicks in the horizontal plane only, the easiest and safest way to avoid damaging the target would be a modified target geometry

Modified target geometry



Beam orbit most likely needs to be raised or lowered to get out of triplet shadow and have halo interact with target

APEX idea

- Uniform rate may be difficult to achieve. Once halo is scraped away, target rate becomes very sensitive to orbit jitter

- Need to artificially increase diffusion into tails, plus probably apply resonant extraction to overcome jitter sensitivity

- With high time-resolution BLMs at the collimators, this could be tested during APEX this run

Summary

- Lifetime at 5 GeV not yet understood
- Rate control with internal target may be an interesting beam dynamics challenge