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# COLLIMATOR and SCRAPER scans for protons\*

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D. Mirarchi, V.Previtali for the UA9 collaboration

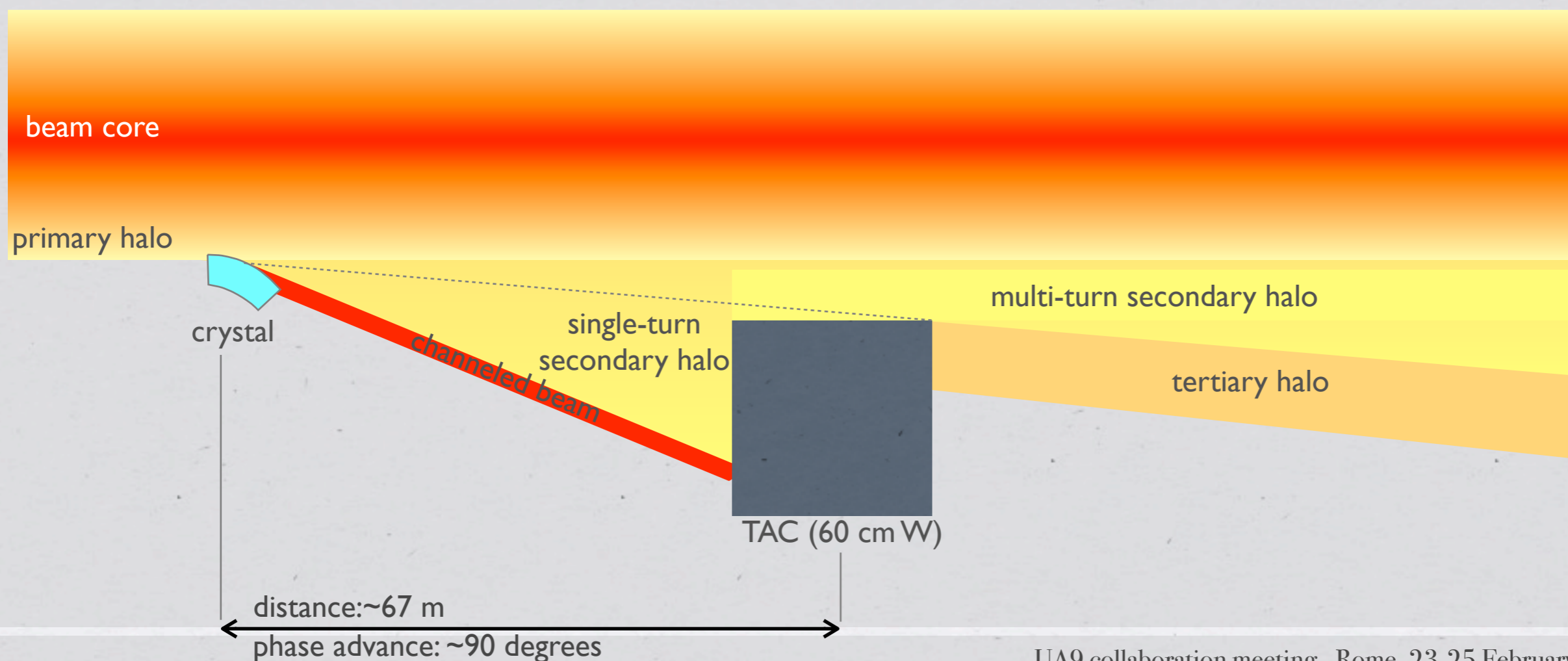
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\*for results with ion beam see D.Mirarchi's talk

# COLLIMATOR AND SCRAPER SCANS

## \* Measurement goal:

Crystal as primary collimator, 60-cm W absorber (TAC) as secondary collimator. The measurement aims at analyzing the downstream distribution.

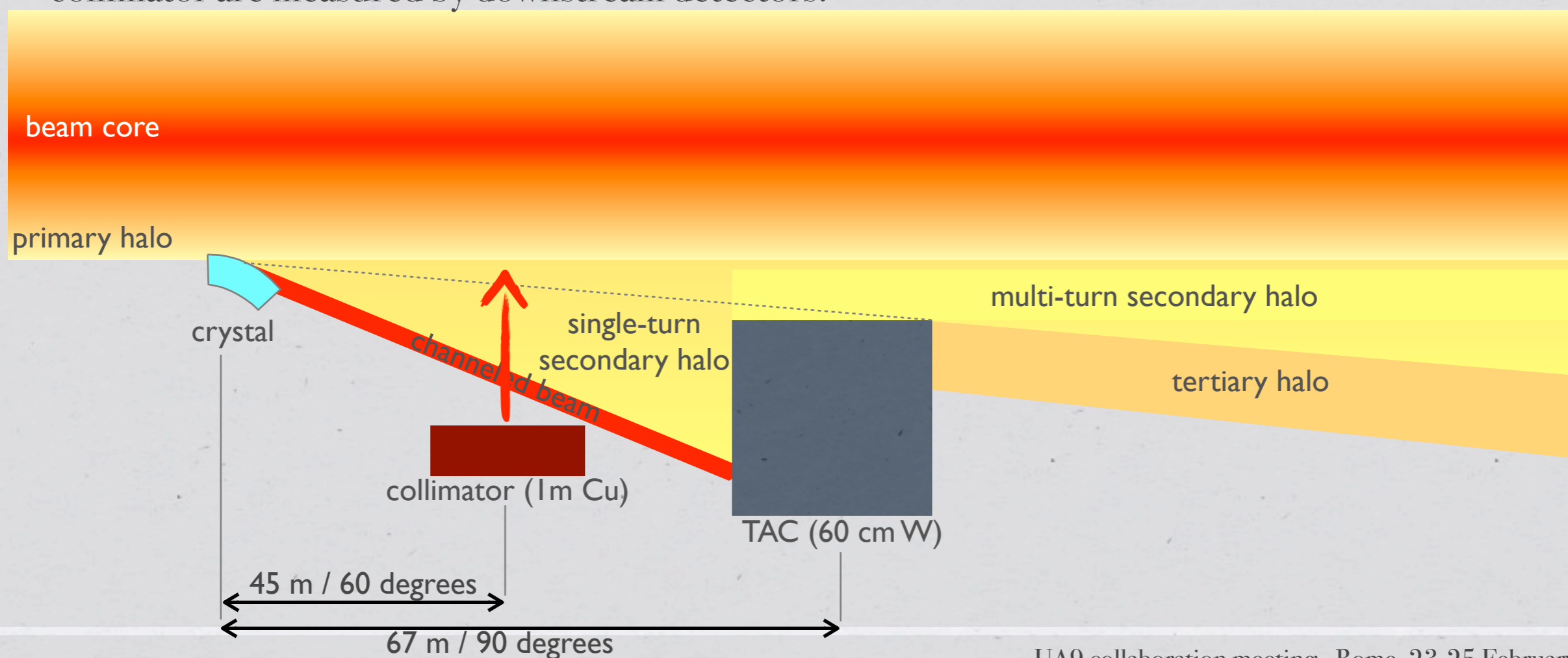


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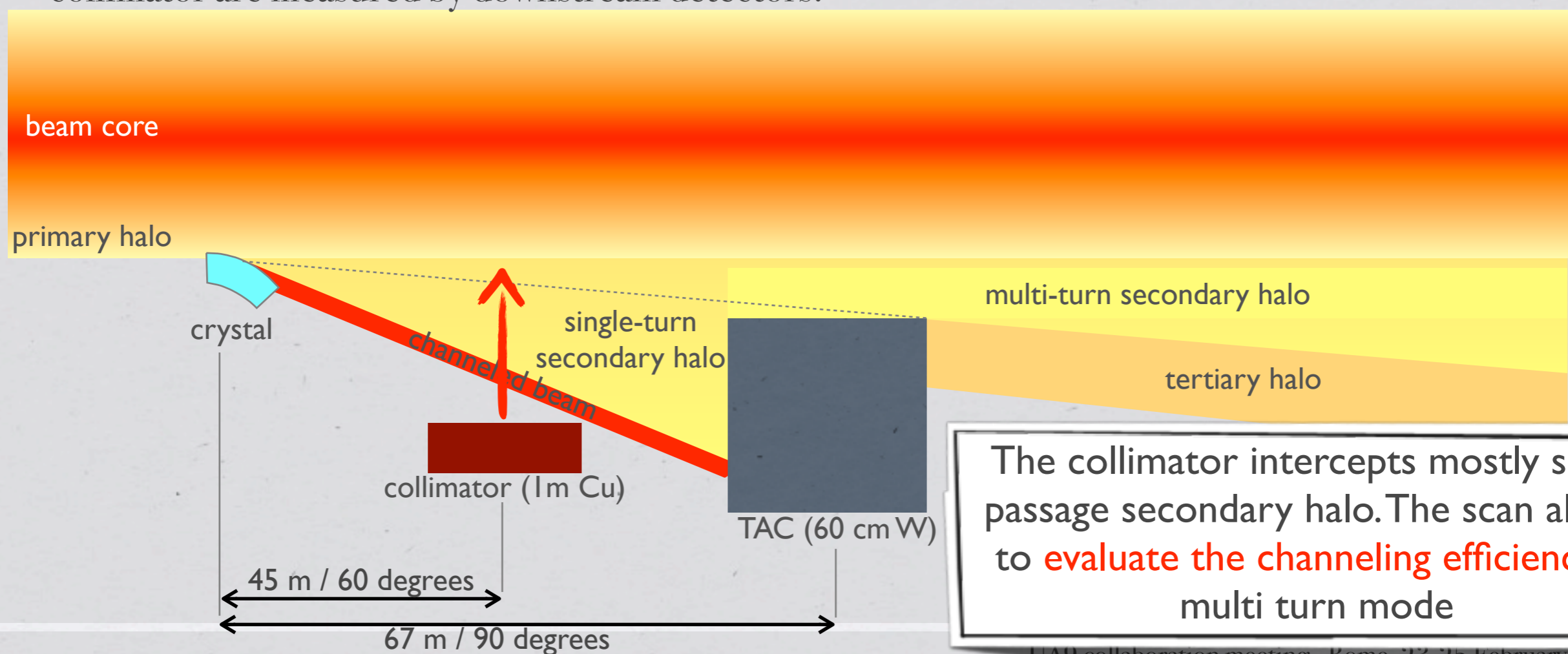


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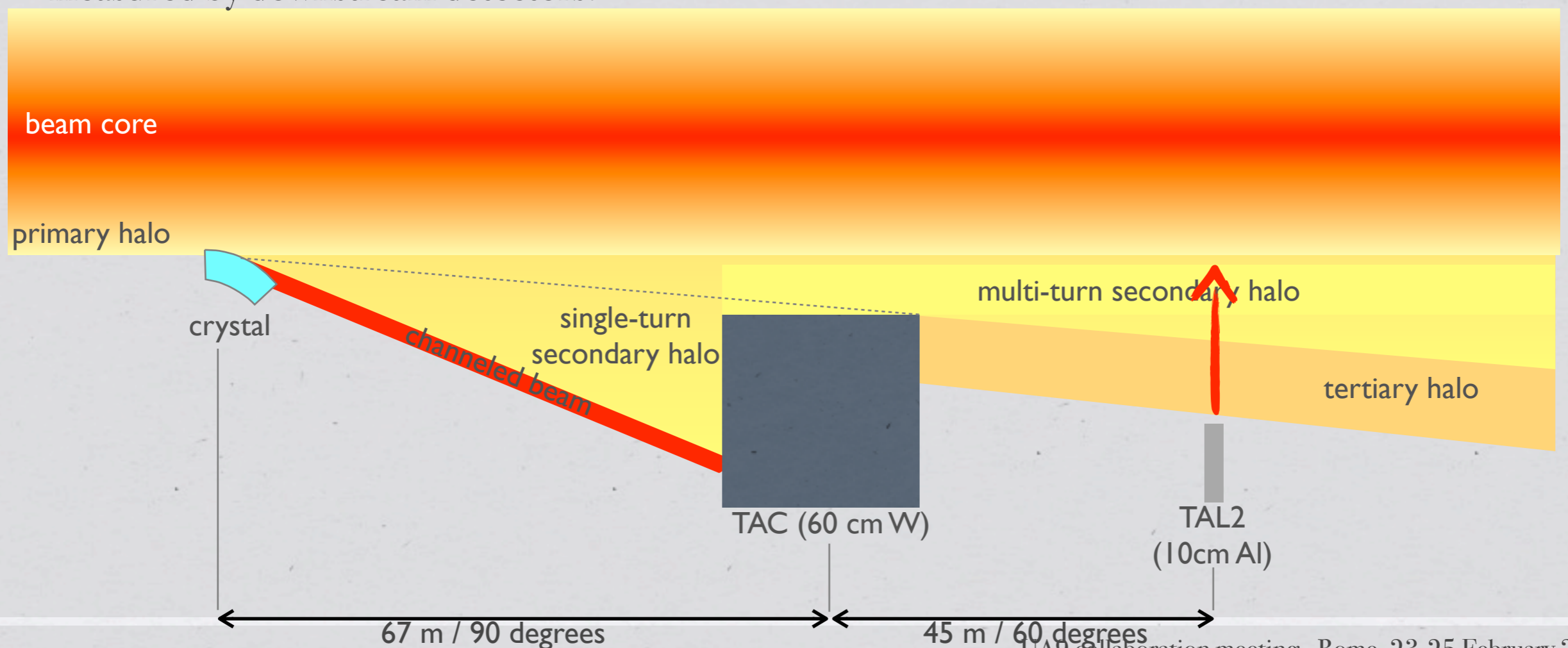


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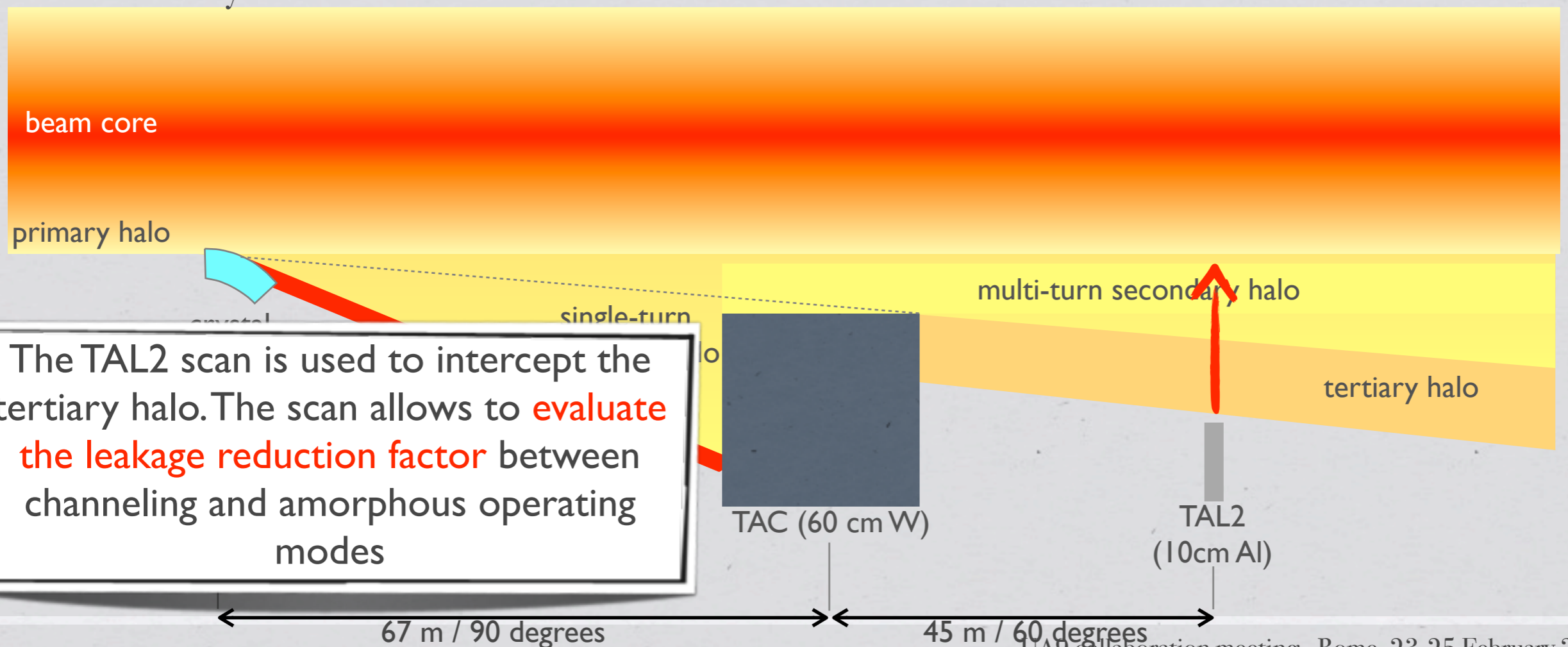


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The TAL2 scan is used to intercept the tertiary halo. The scan allows to **evaluate the leakage reduction factor** between channeling and amorphous operating modes

# COLLIMATOR AND SCRAPER SCANS: analogies and differences

## \* ANALOGIES

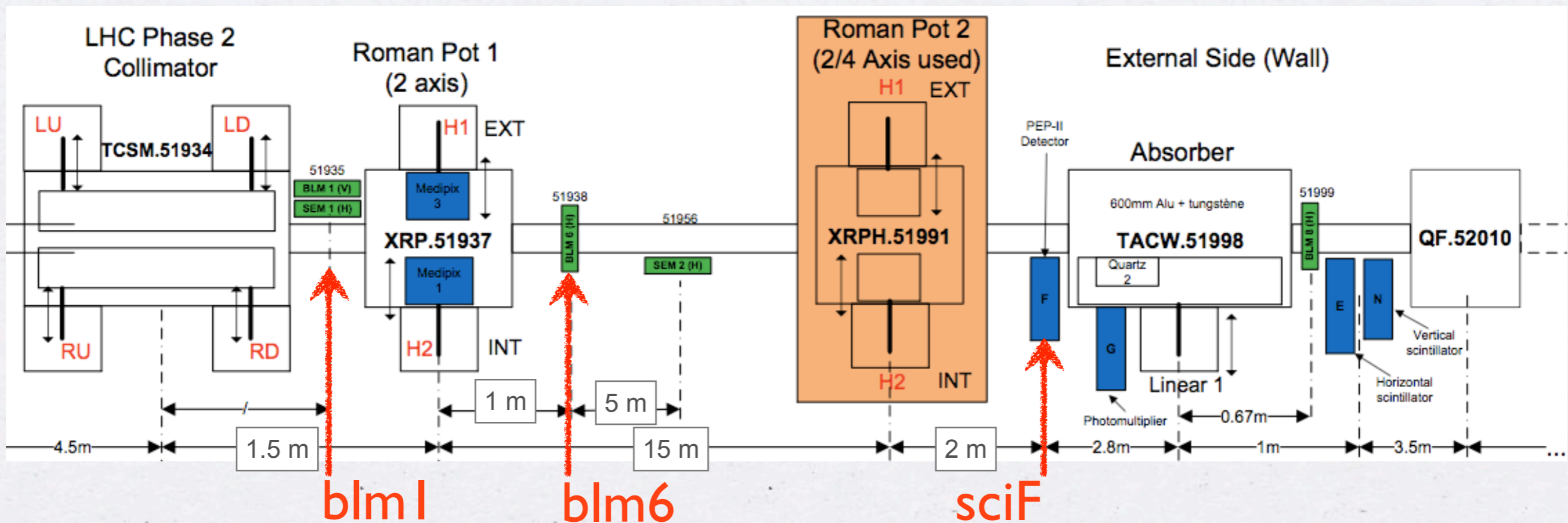
- \* a moving obstacle is used to make an integrated measurement of the halo distribution
- \* the intercepted halo population is considered proportional to the number of inelastic interactions at the device.
- \* the number of inelastic interactions at the device are considered proportional to the secondary showers measured by downstream detectors (BLMs and/or scintillators)
- \* Both detectors are normalized to the time derivative of the beam current.

## \* DIFFERENCES

- \* the collimator (1 m Cu) stops most of the impacting particles: when primary, it receives and stops almost 100% of the diffusing particles; this allows to normalize the measured losses.
- \* the TAL2 (0.1 m Al) is transparent for most of the particles: when intercepting the secondary halo, it acts mostly as a scatterer, thus disturbing the multi-turn dynamics. For this reason, only the tertiary halo is measured.

# COLLIMATOR SCANS

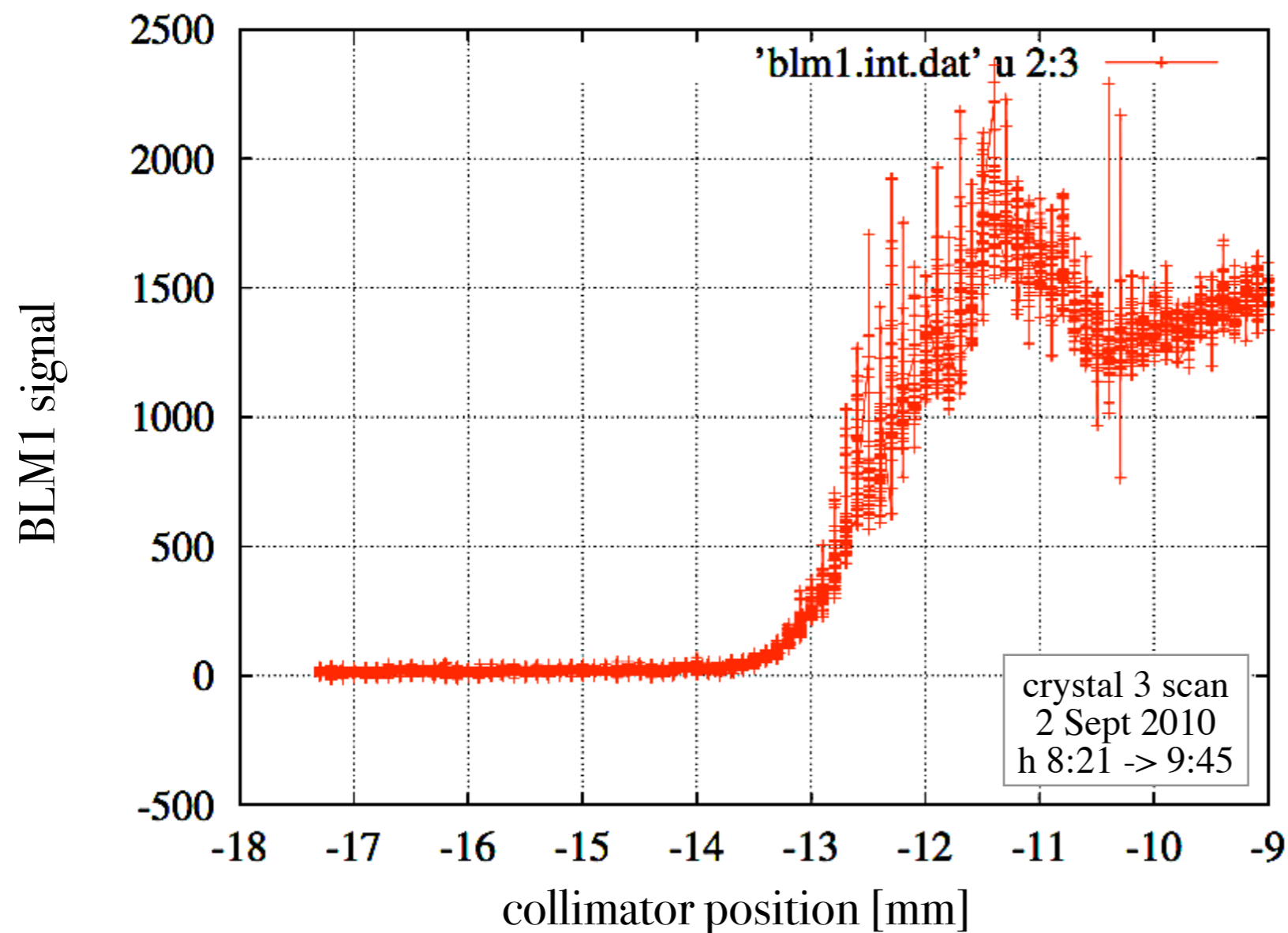
## DETECTORS LAYOUT



- BLM1 (ionization chamber) immediately downstream the LHC collimator
- BLM6 (ionization chamber) about 2.5 m downstream the LHC collimator
- sci F about 18.5 m downstream the LHC collimator center

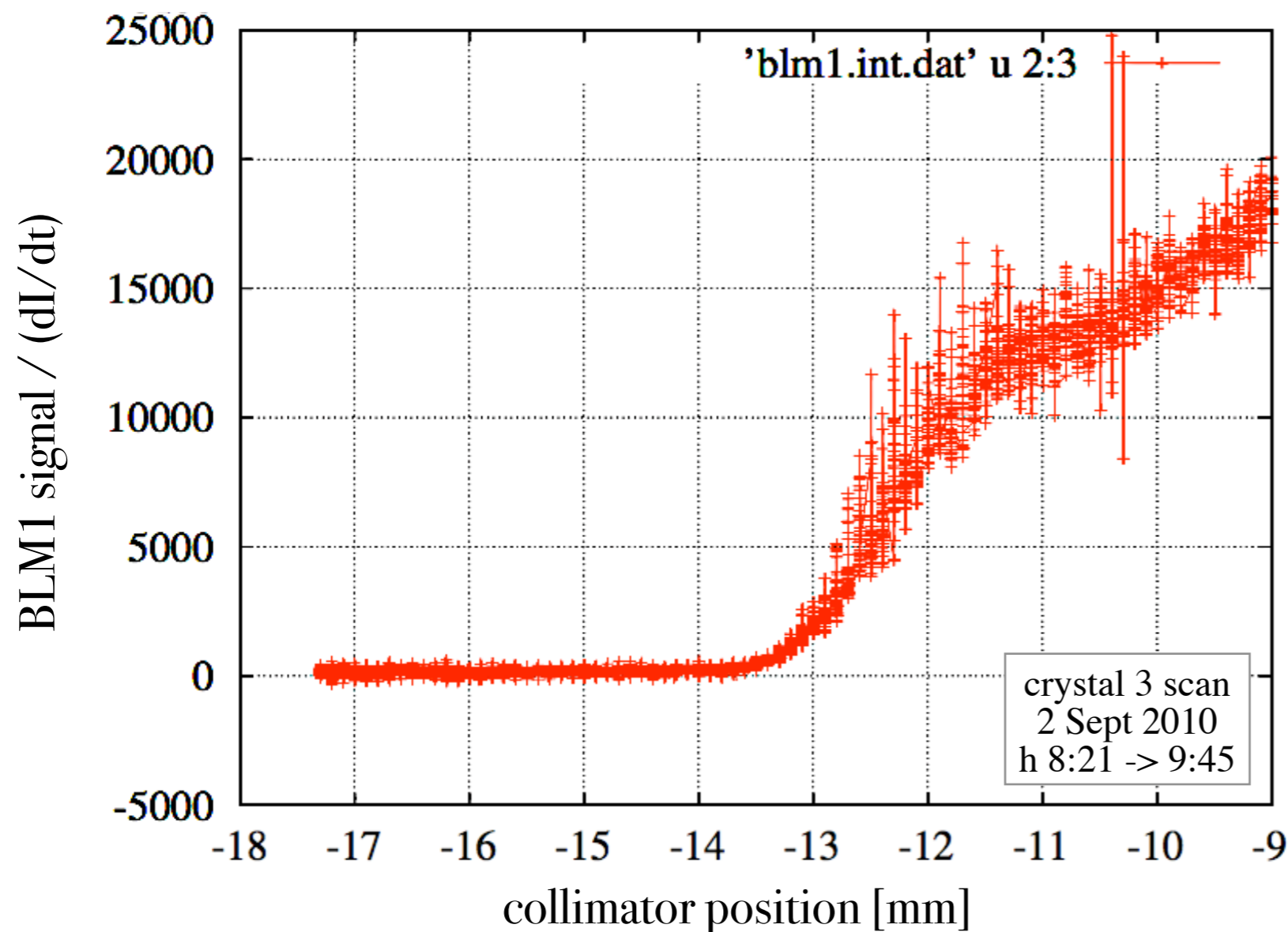
the main result of the collimator scan are the **channeling angle** and the **channeling efficiency** in multi turn mode, i.e. the probability for a multi turn particle to be, soon or late, channeled.

# collimator scan data analysis



1. remove a “zero” offset to the detector signal
2. plot the detector reading vs collimator position
3. normalize the detector data with the flux of particles on the crystal
4. normalize w.r.t. the reading when the collimator is primary
5. express the collimator position in terms of equivalent crystal kick

# collimator scan data analysis

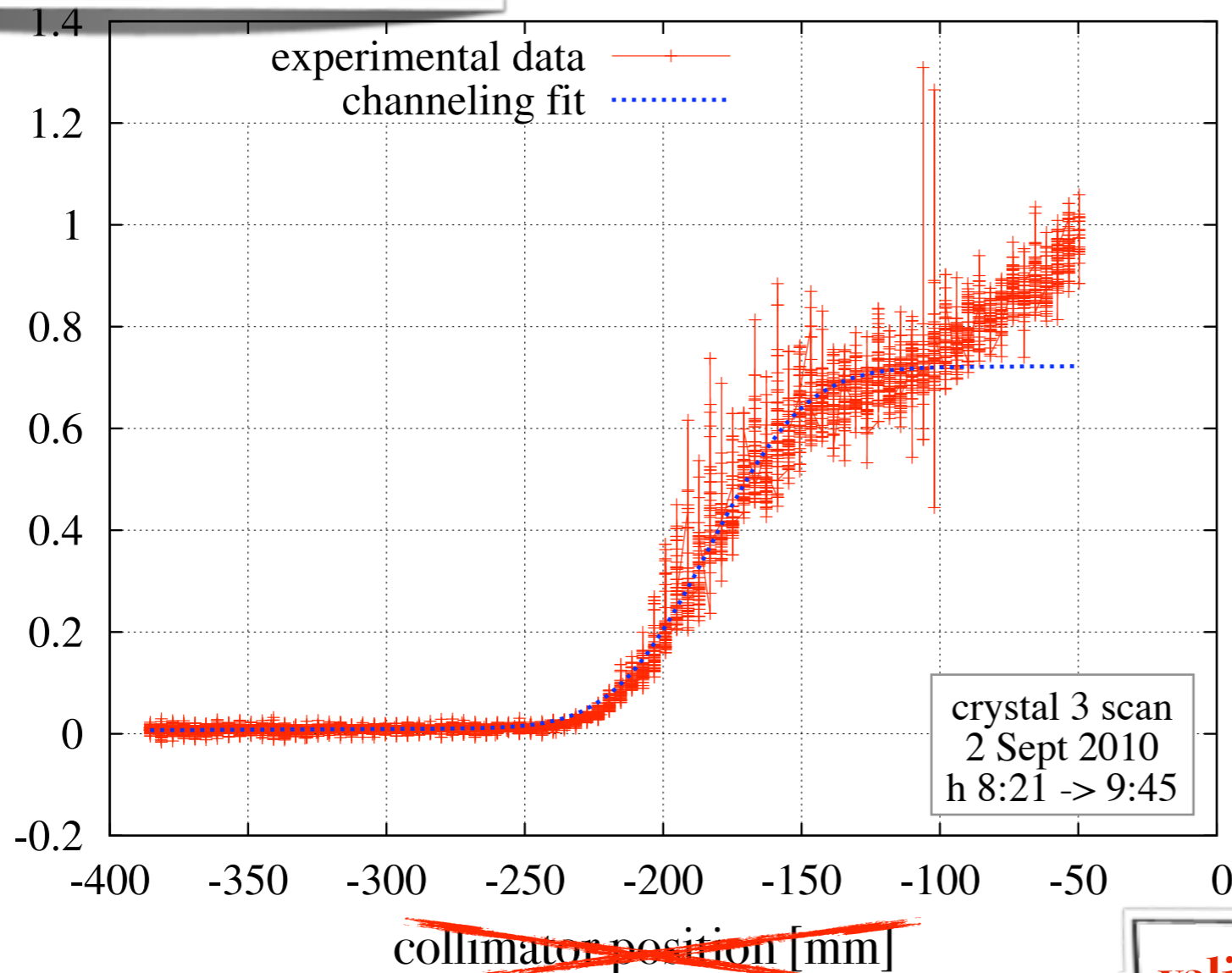


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# collimator scan data analysis

**valid only if we assume**

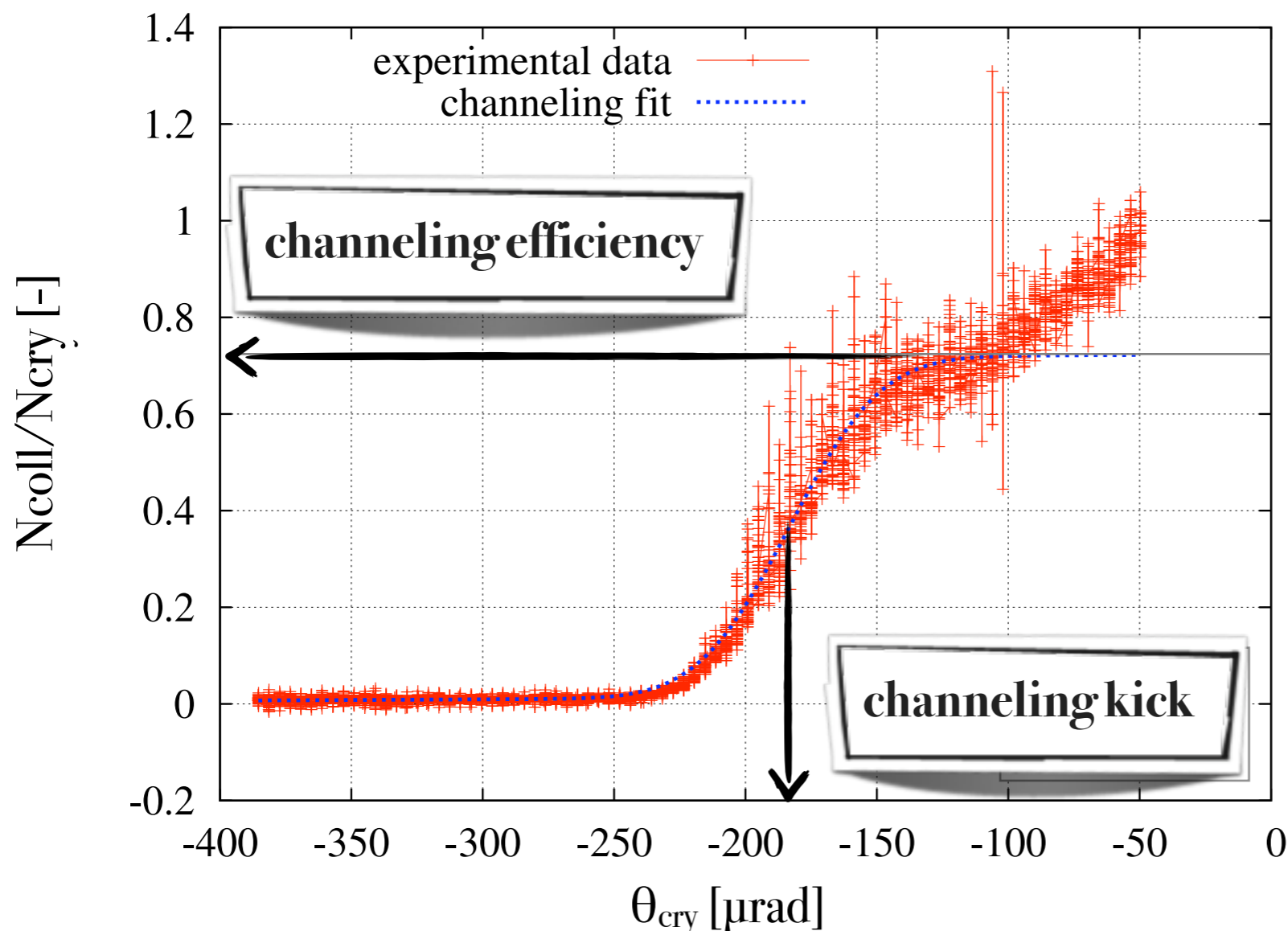
1. BLM signal  $\propto N_{\text{coll}}$
2. If  $a_{\text{coll}} = a_{\text{cry}} \Rightarrow N_{\text{coll}} = N_{\text{cry}}$



1. remove a “zero” offset to the detector signal
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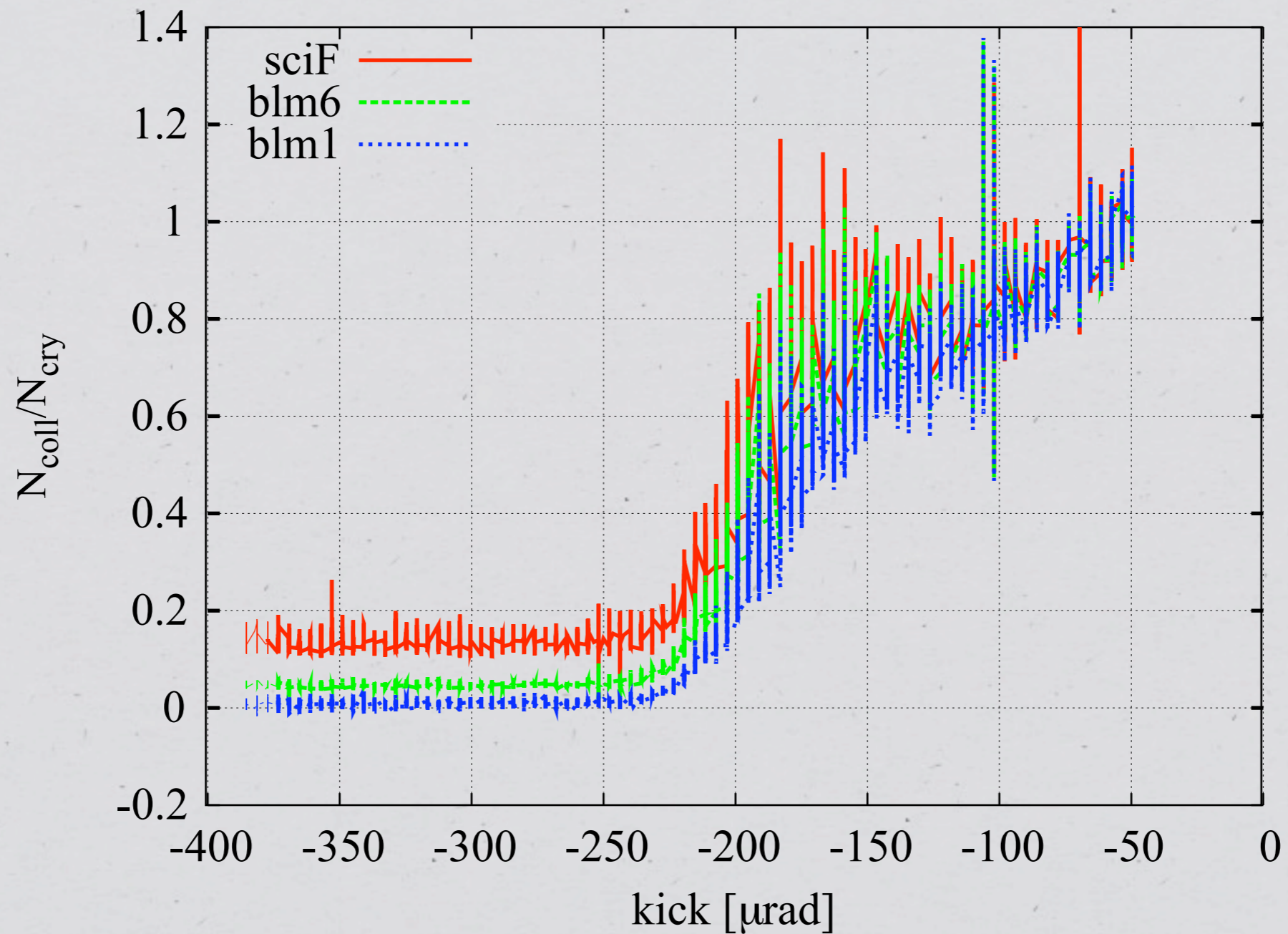
**valid only for large kicks  
(multi turn limit)**

# collimator scan data analysis

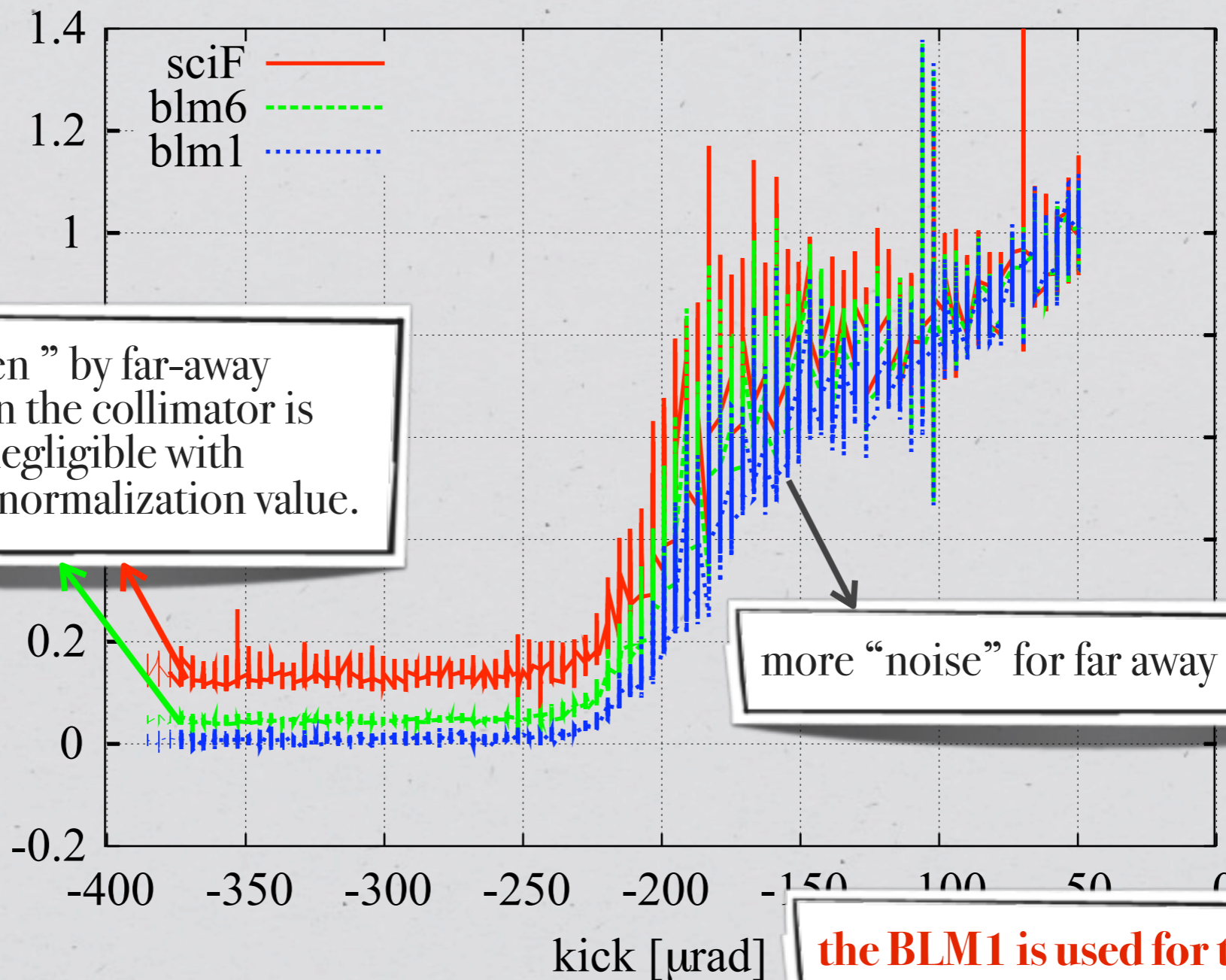


1. remove a “zero” offset to the detector signal
2. plot the detector reading vs collimator position
3. normalize the detector data with the flux of particles on the crystal
4. normalize w.r.t. the reading when the collimator is primary
5. express the collimator position in terms of equivalent crystal kick

# detectors comparison



# detectors comparison



# COLLIMATOR SCAN SUMMARY

review of the results 2009-2010

- the main results of the collimator scan are the **channeling parameters**: channeling kick, width and efficiency
- the detectors data are normalized with respect to the flux of primary particles lost (BCT derivative)

scan n.	$\theta_{chan}$ [ $\mu$ rad]	$\sigma_{ch}$ [ $\mu$ rad]	$\eta_{chan}$ [%]
C1.1	173 $\pm$ 1	17 $\pm$ 1	75 $\pm$ 4
C1.2	199 $\pm$ 1	40 $\pm$ 1	65 $\pm$ 3
C1.3	198 $\pm$ 1	42 $\pm$ 1	64 $\pm$ 3
C2.1	165 $\pm$ 1	21 $\pm$ 1	85 $\pm$ 5

year 2009: crystal 1 and crystal 2 tested,  
efficiencies between 64 and 85%

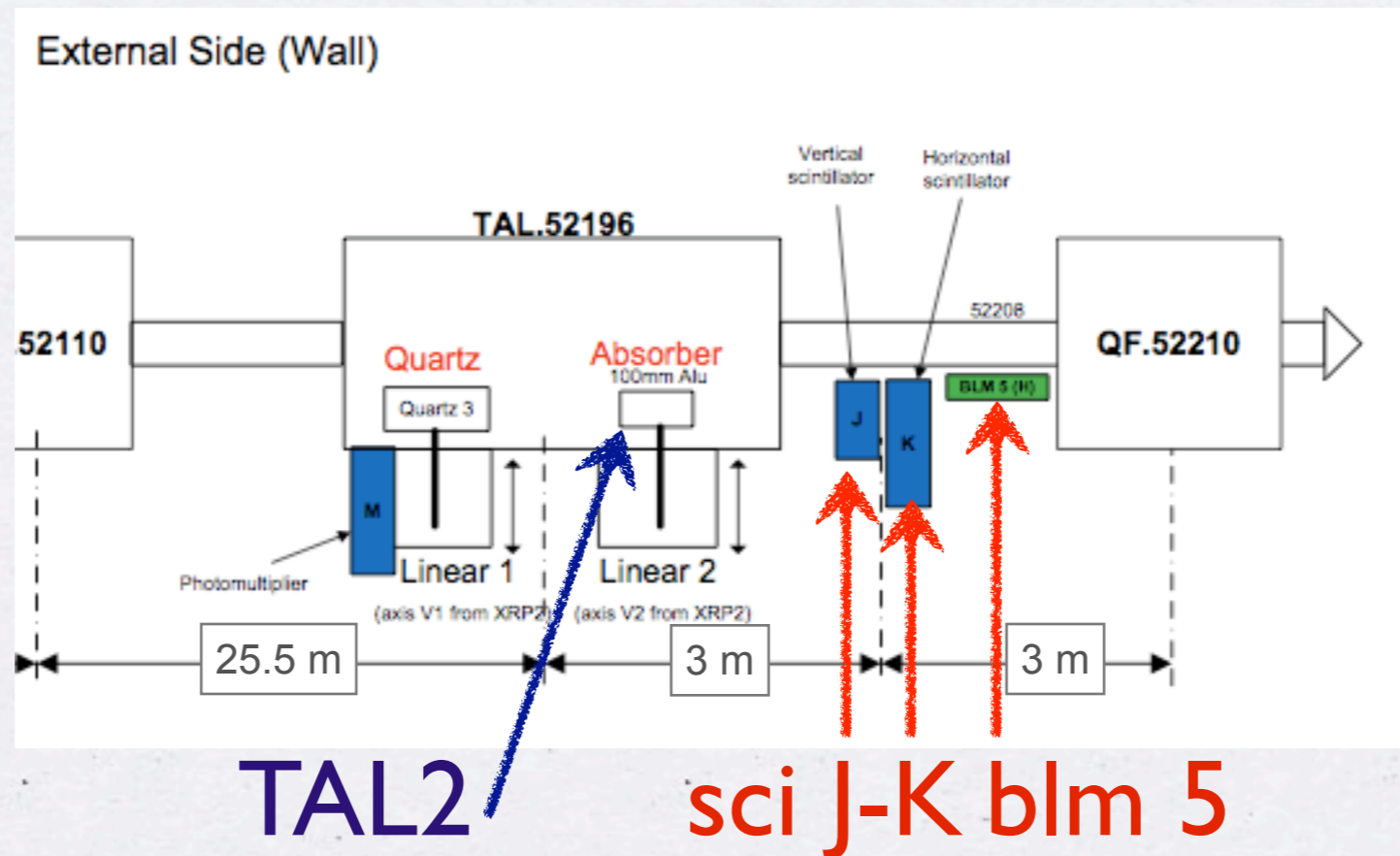
crystal	scan - time			emittance m rad	FLUX p/s	apertures		channeling parameters				
						crystal sx	TAC sx	ch.kick $\mu$ rad		ch.width $\mu$ rad		efficiency %
3	2-Sep	8:10	8:20	1.9E-08	8.0E+06	7.20	9.10	178 $\pm$ 3	29 $\pm$ 3	69 $\pm$ 7		
3	2-Sep	8:21	9:45	1.9E-08	6 to 16E+6	7.20	9.10	186 $\pm$ 2	25 $\pm$ 2	67 $\pm$ 6		

very long measurement

year 2010: collimator scans with protons have been done only with crystal 3.  
the results confirm multi-turn channeling efficiency about 70

# TAL2 SCANS

## DETECTORS LAYOUT



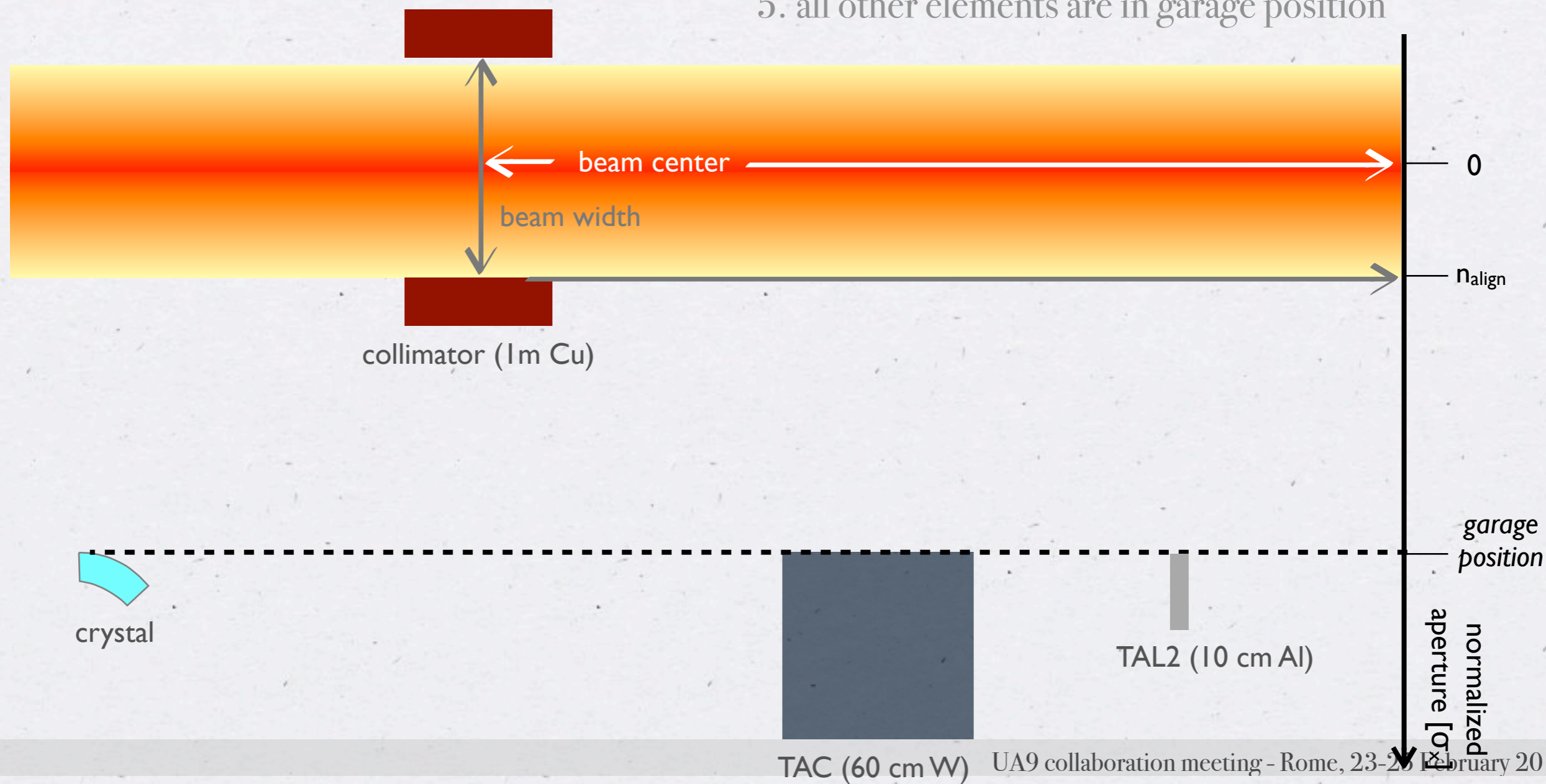
- sci J and sci K about 2 m downstream the scraper
- BLM6 (ionization chamber): immediately after sciK

the main result of the tal2 scan is the **halo reduction factor**, i.e. the ratio between the population of the tertiary halo (meaning escaping to the W absorber) in amorphous and in channeling

# beam based alignment

see D.Mirarchi talk  
for details and measurements...

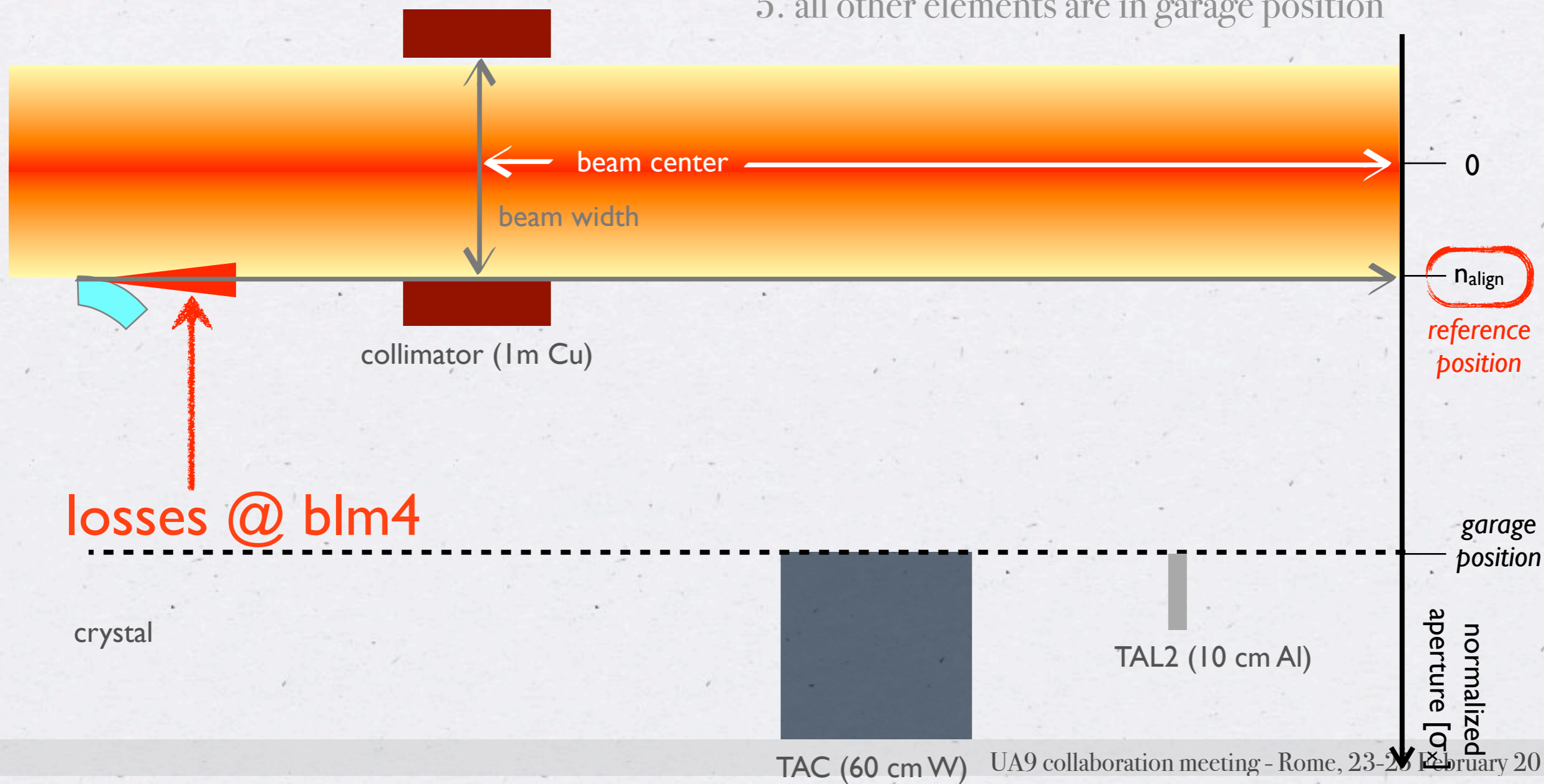
1. the beam edge is defined by the double-sided LHC collimator. The beam center and width are calculated.
2. the aligned position of the other elements is found looking at the losses generated when the element intercepts the primary halo.
3. the crystal is moved toward the beam center of about 0.5 mm
4. the TAC is moved outwards of about 1.5 mm
5. all other elements are in garage position



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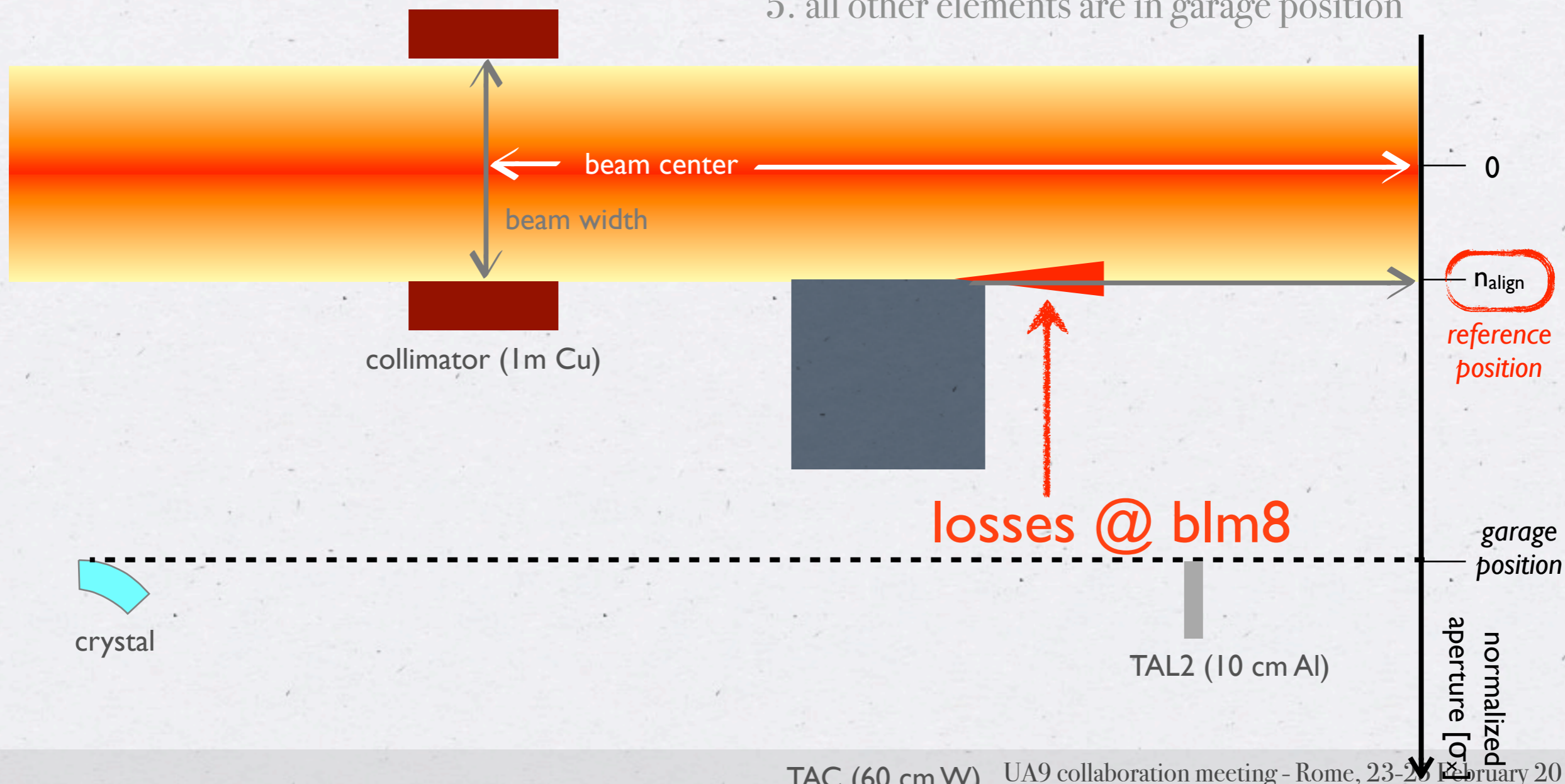
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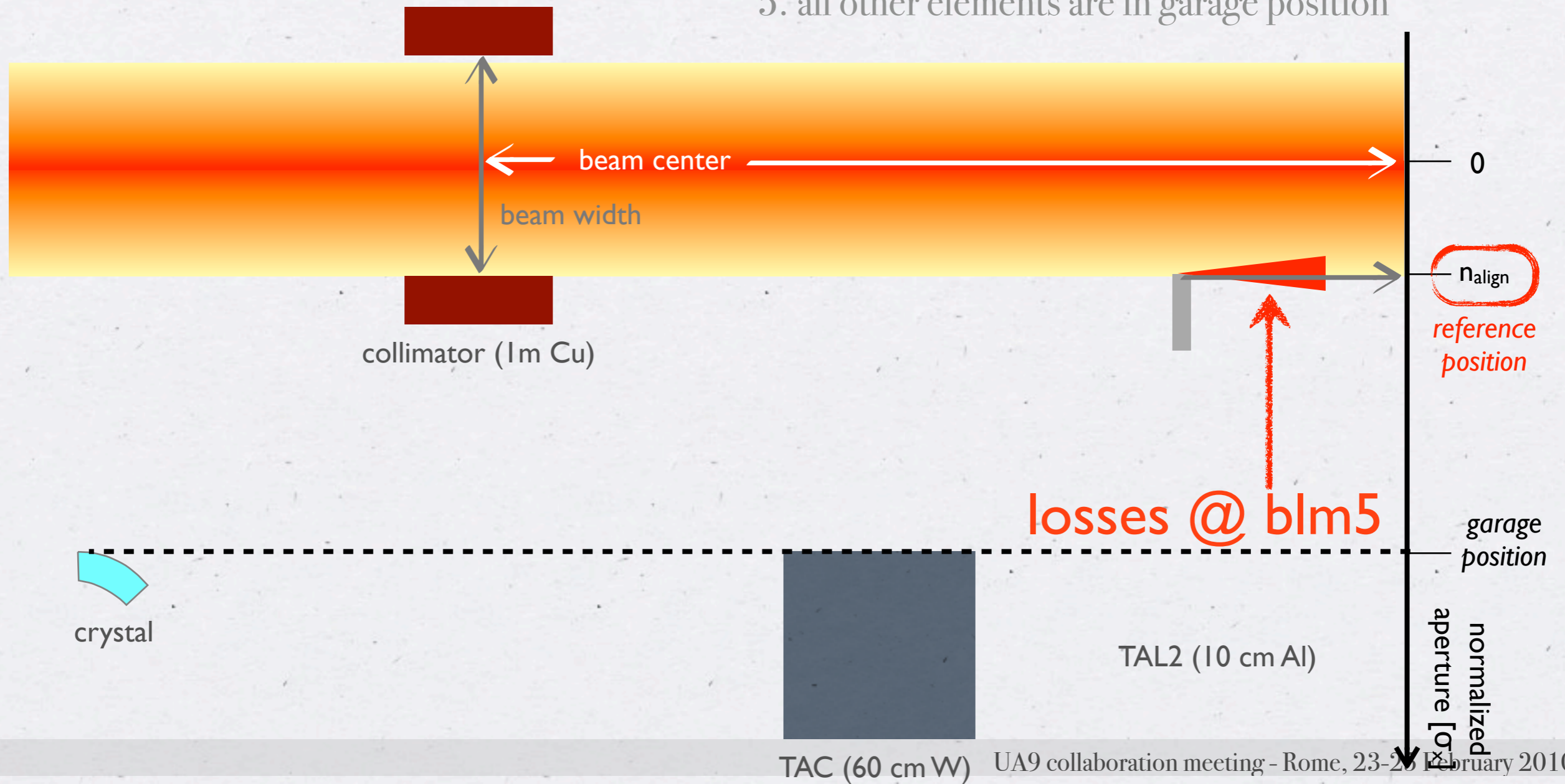
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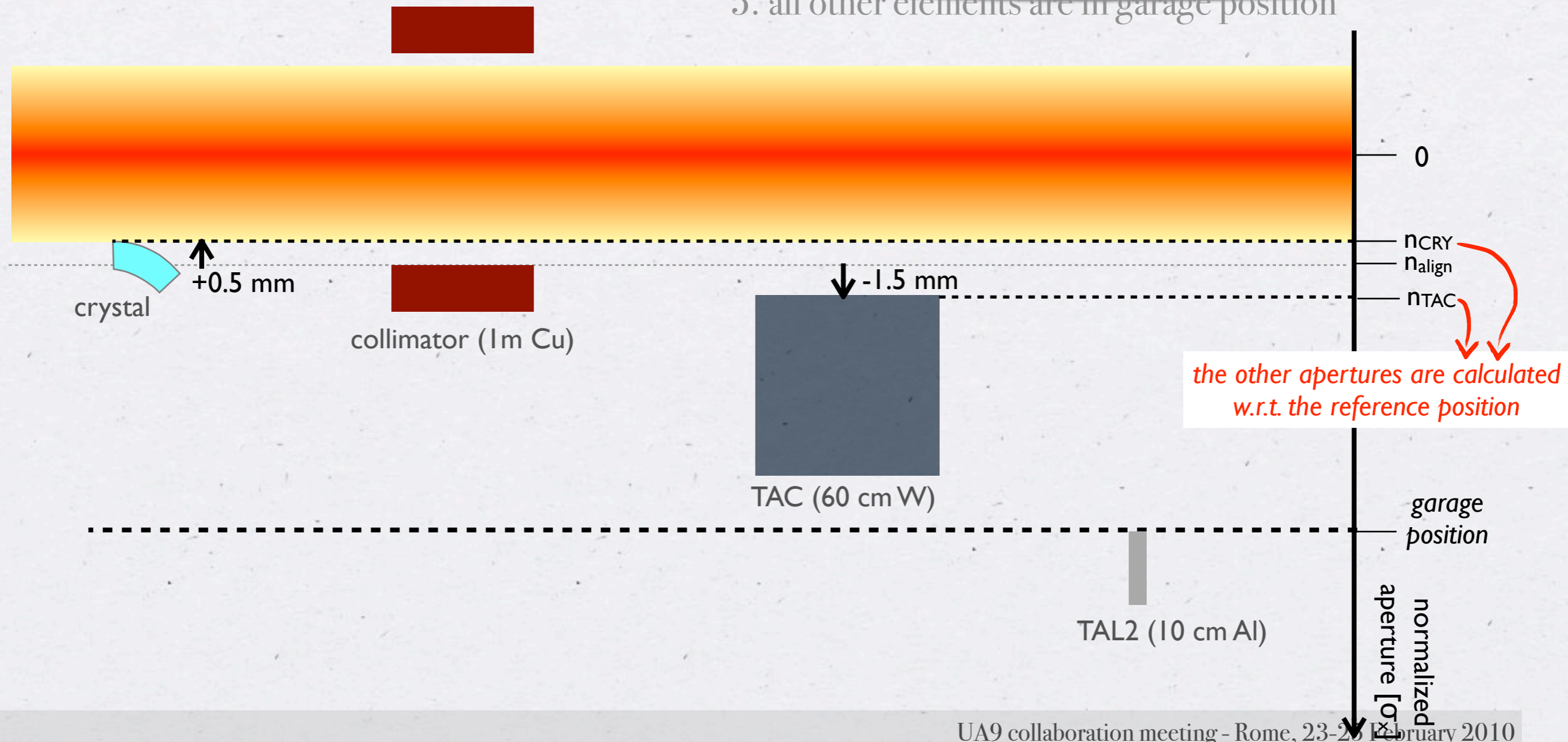


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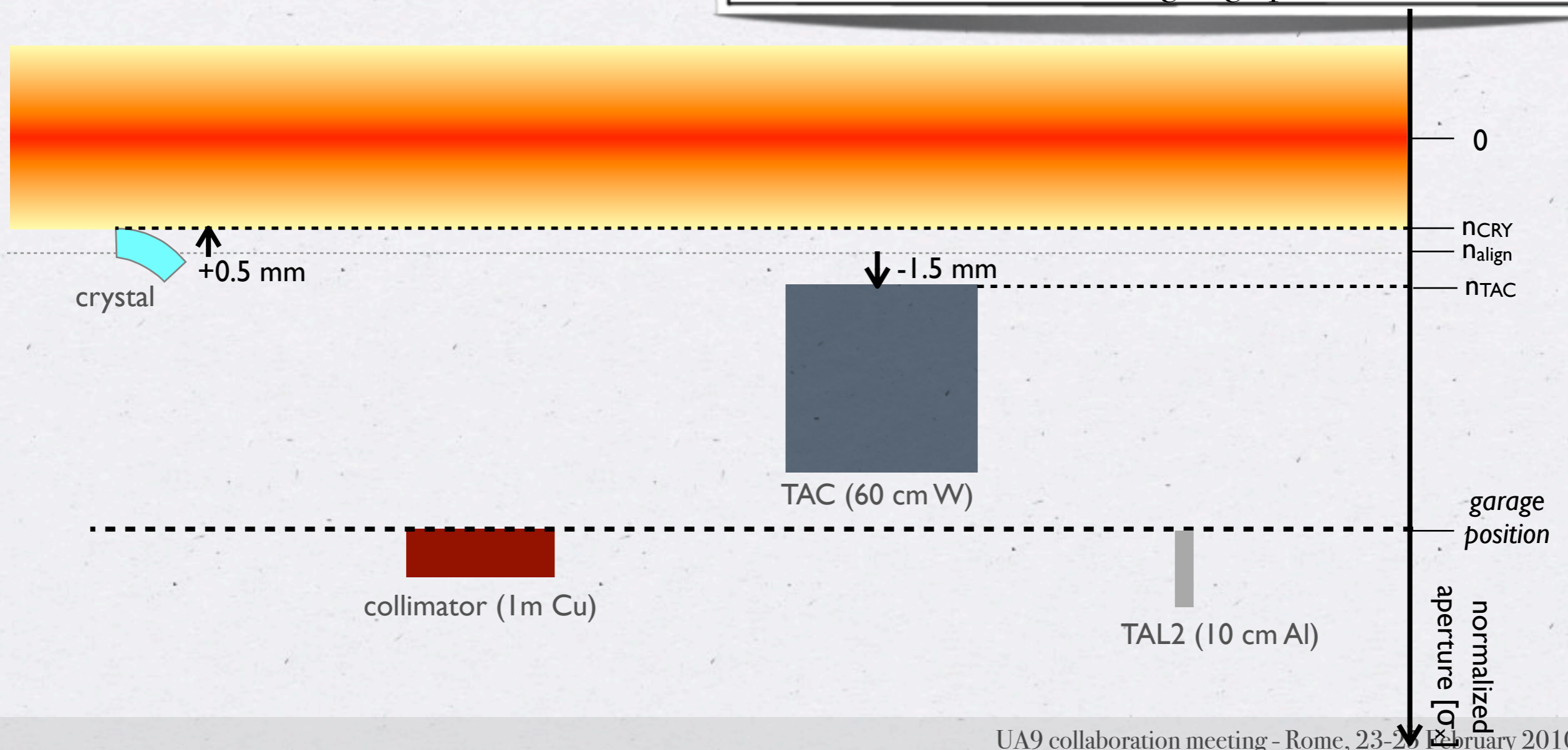


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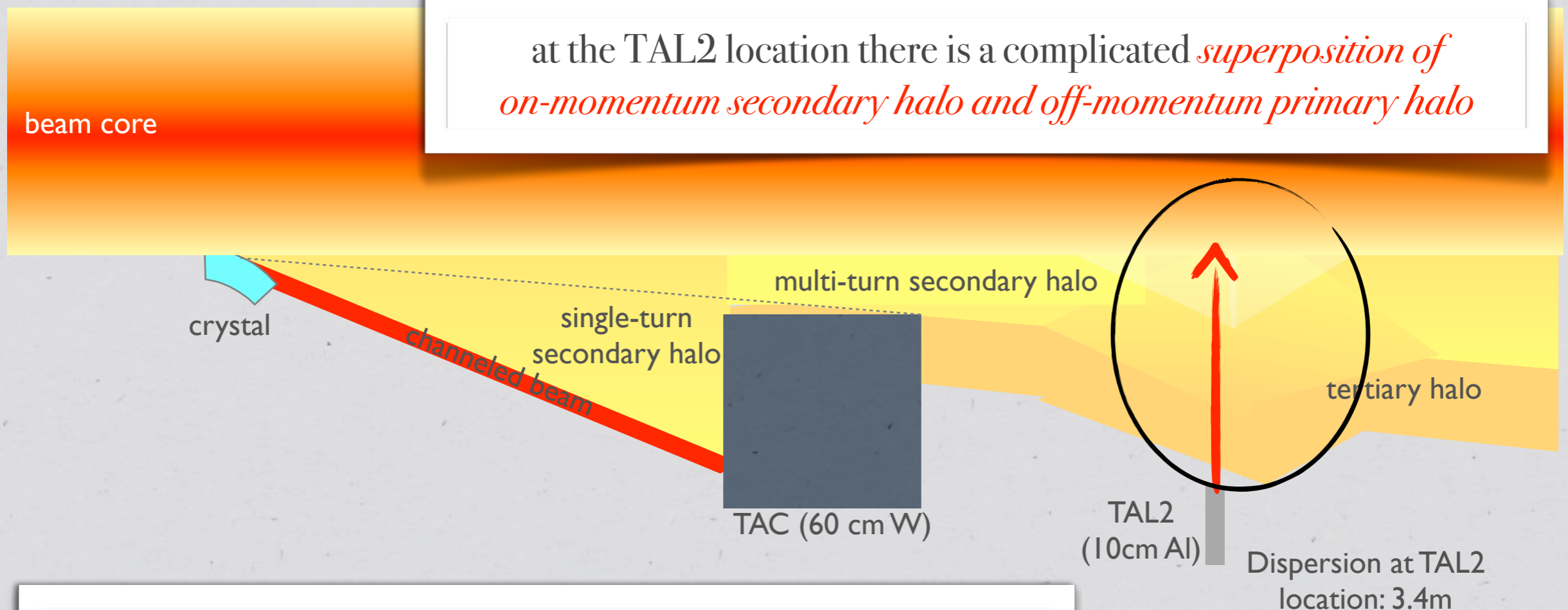
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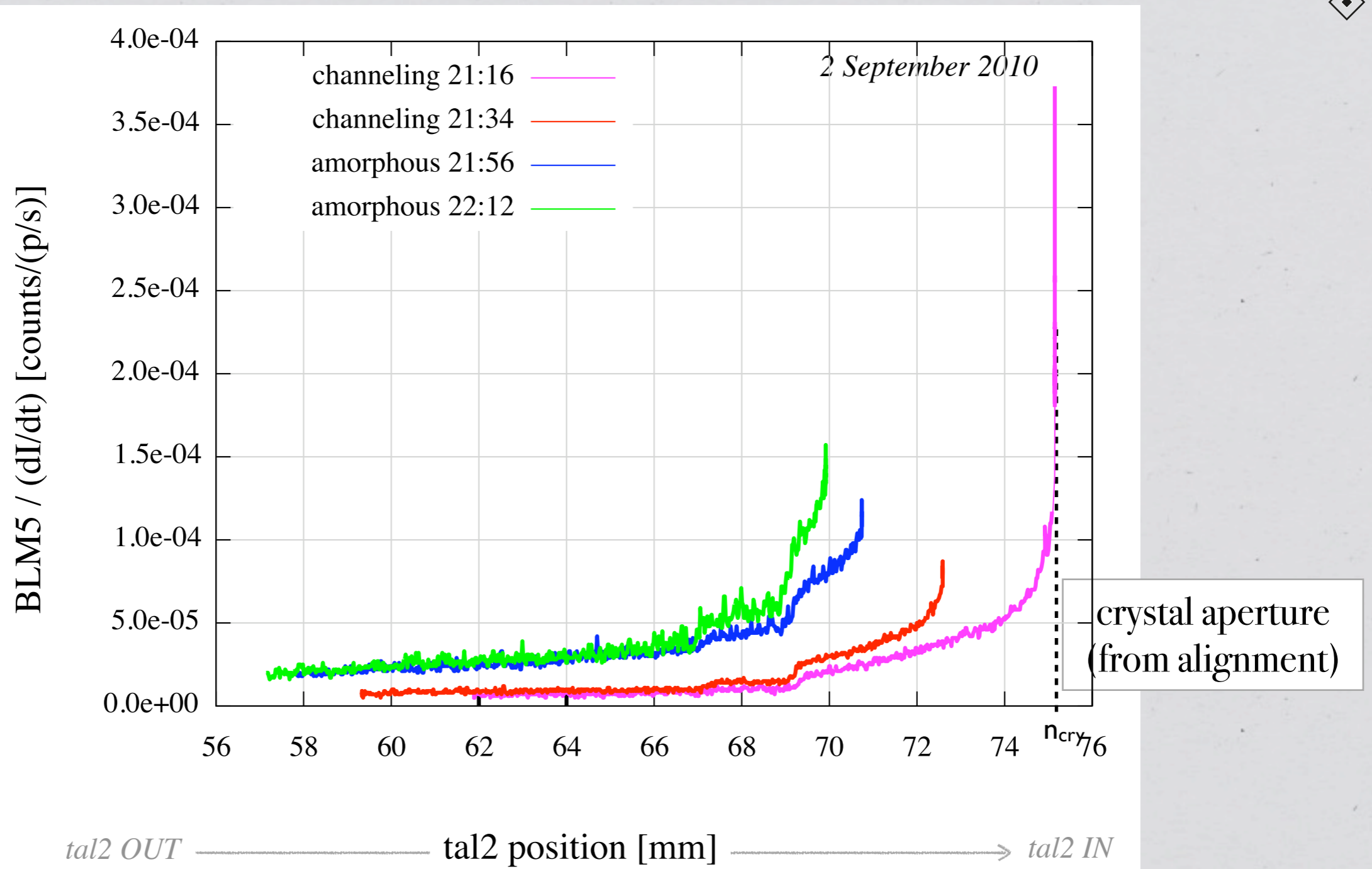
The TAL2 scan is located in a *highly dispersive region* (meaning: particles are strongly sorted with respect to their momentum). e.g. :A particle with the designed momentum and a particle with the same betatronic amplitude but on the separatrix of the RF bucket (limit for stable particles) would have a transverse position (and then generate losses) about 4 mm more outward than an on momentum particle!!

at the TAL2 location there is a complicated *superposition of on-momentum secondary halo and off-momentum primary halo*

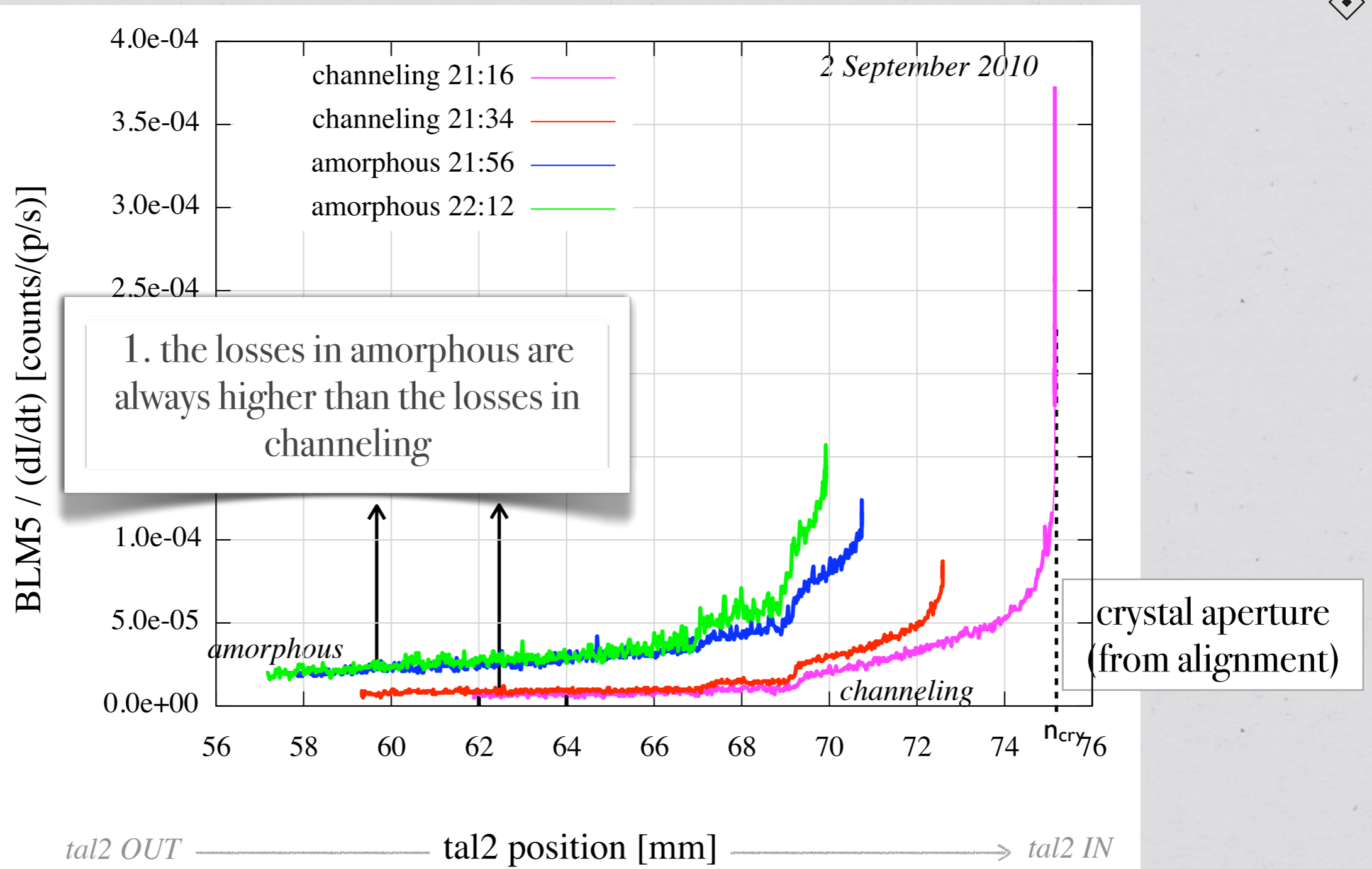


*it is very difficult to understand if the losses at the TAL2 location correspond to on momentum or off momentum particles, both during the TAL2 alignment and during a TAL2 scan*

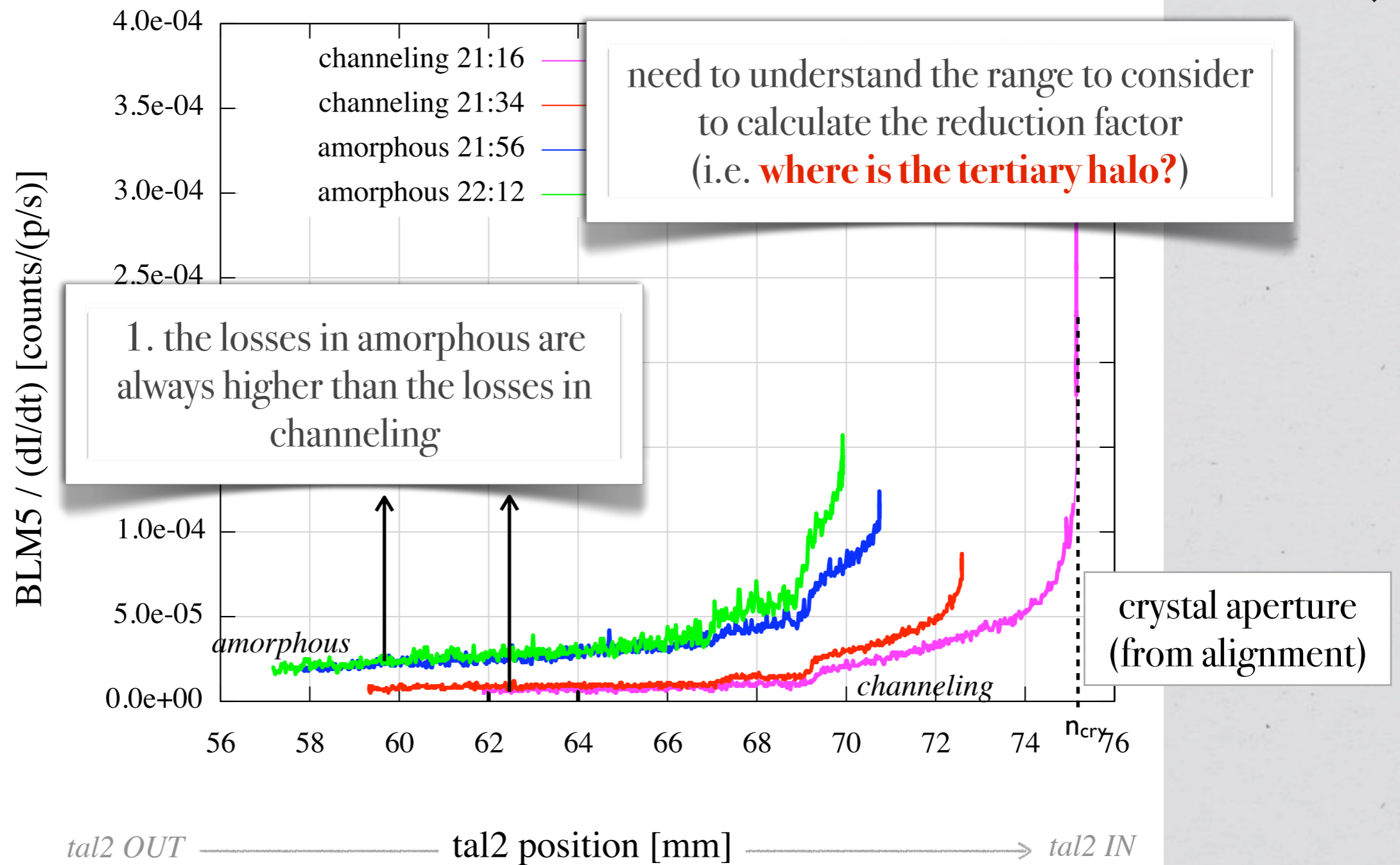
# a full set of TAL2 scans



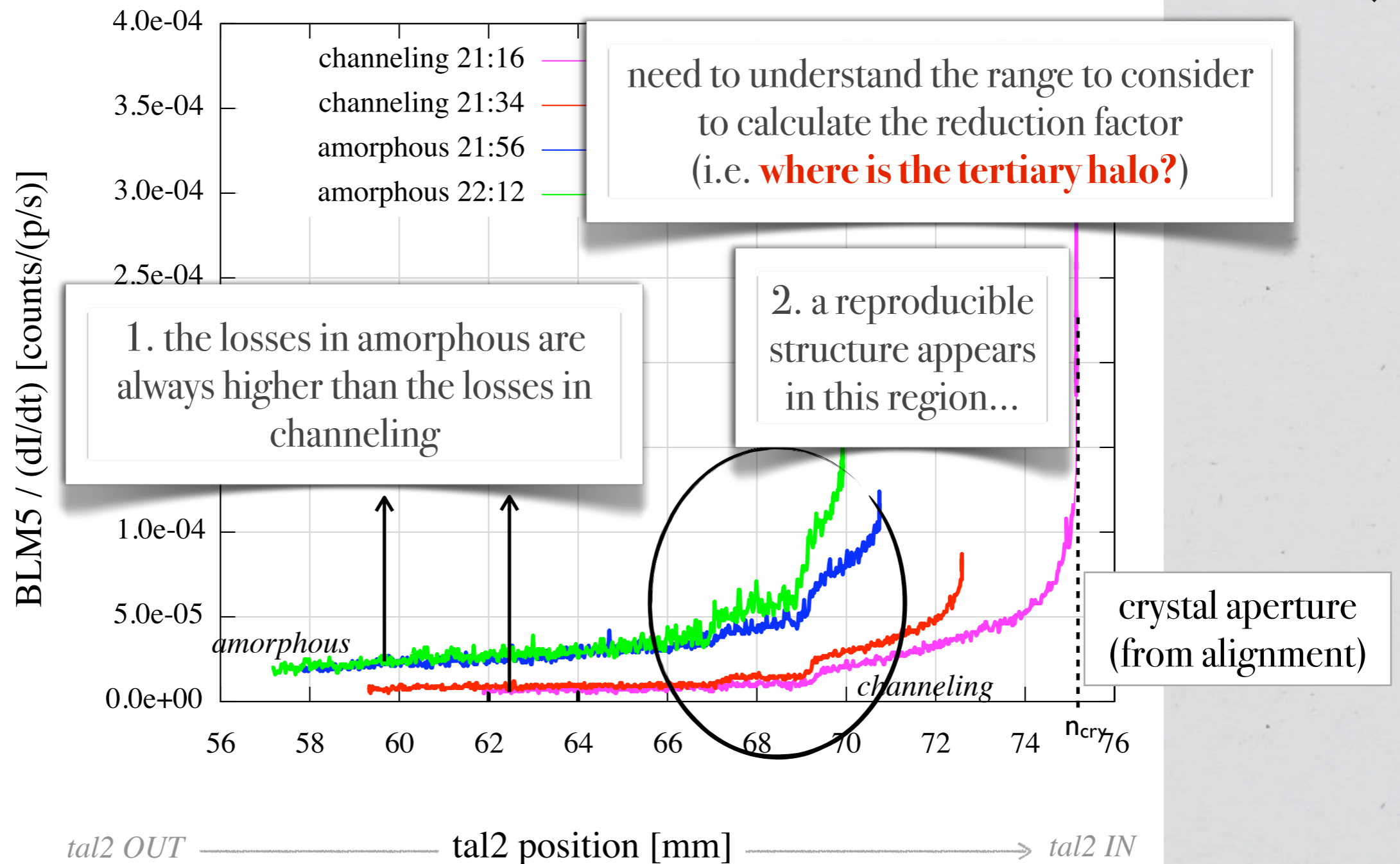
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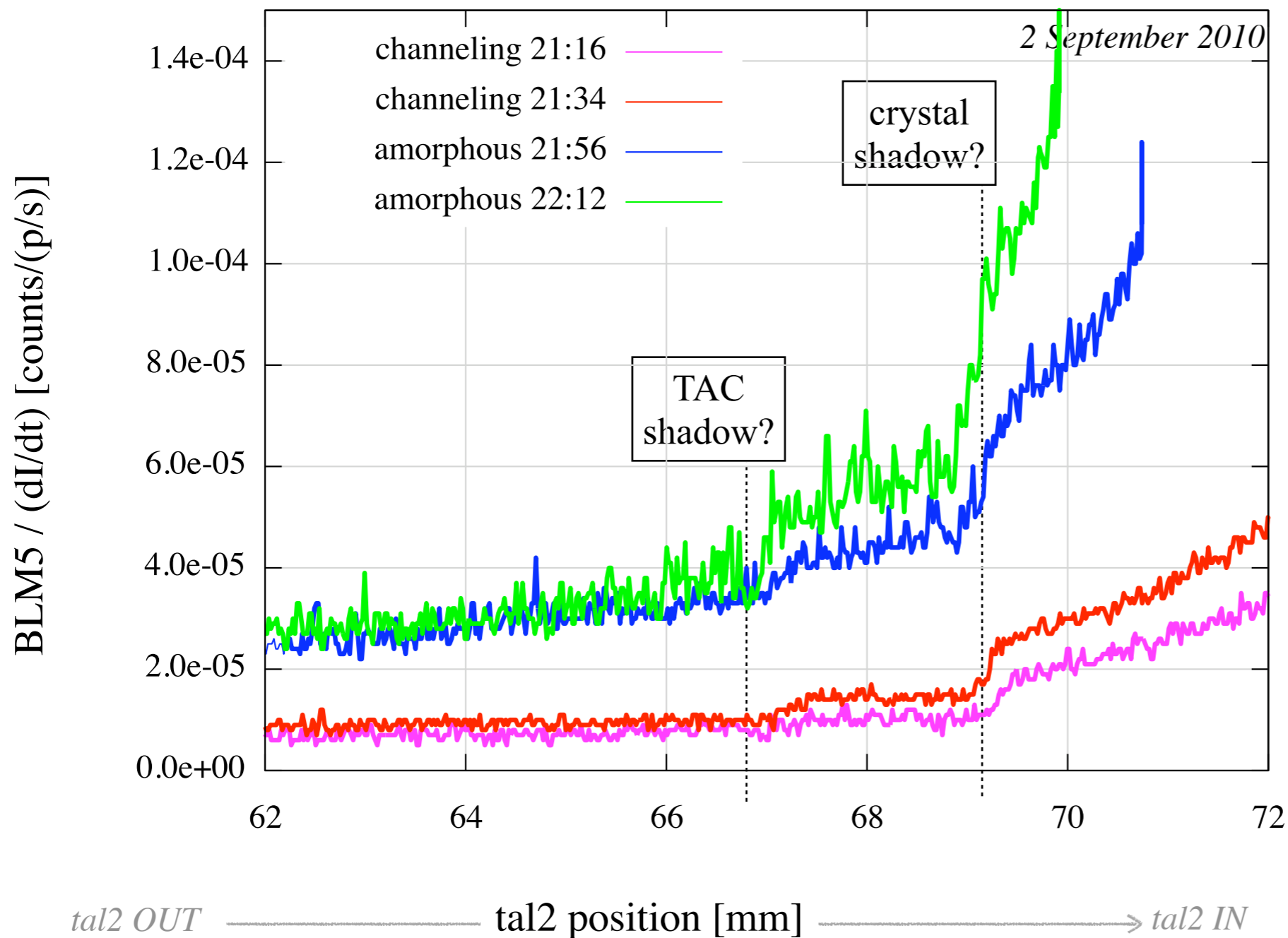
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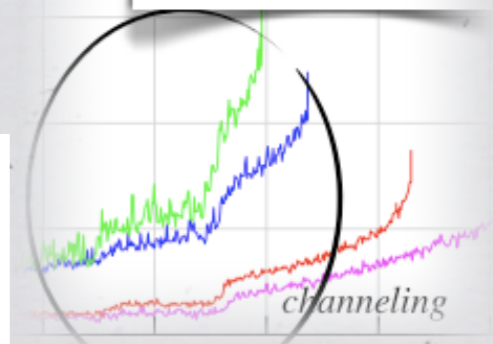
# a full set of TAL2 scans



# a closer look...



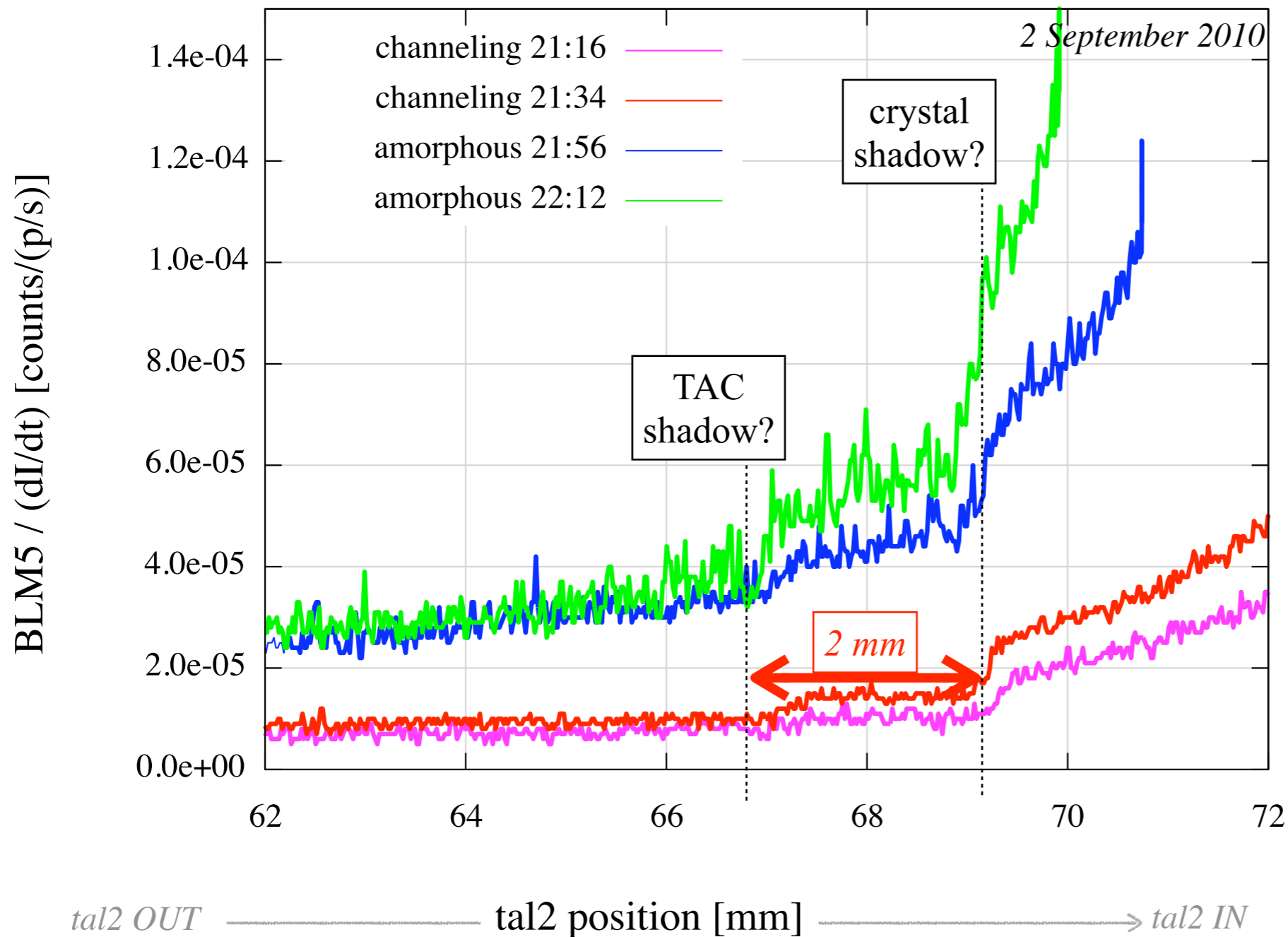
2. a reproducible structure appears in this region...



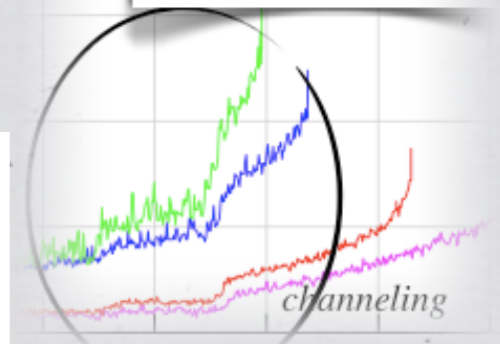
two shoulders always observed

are these correlated to the crystal and TAC positions?

# a closer look...



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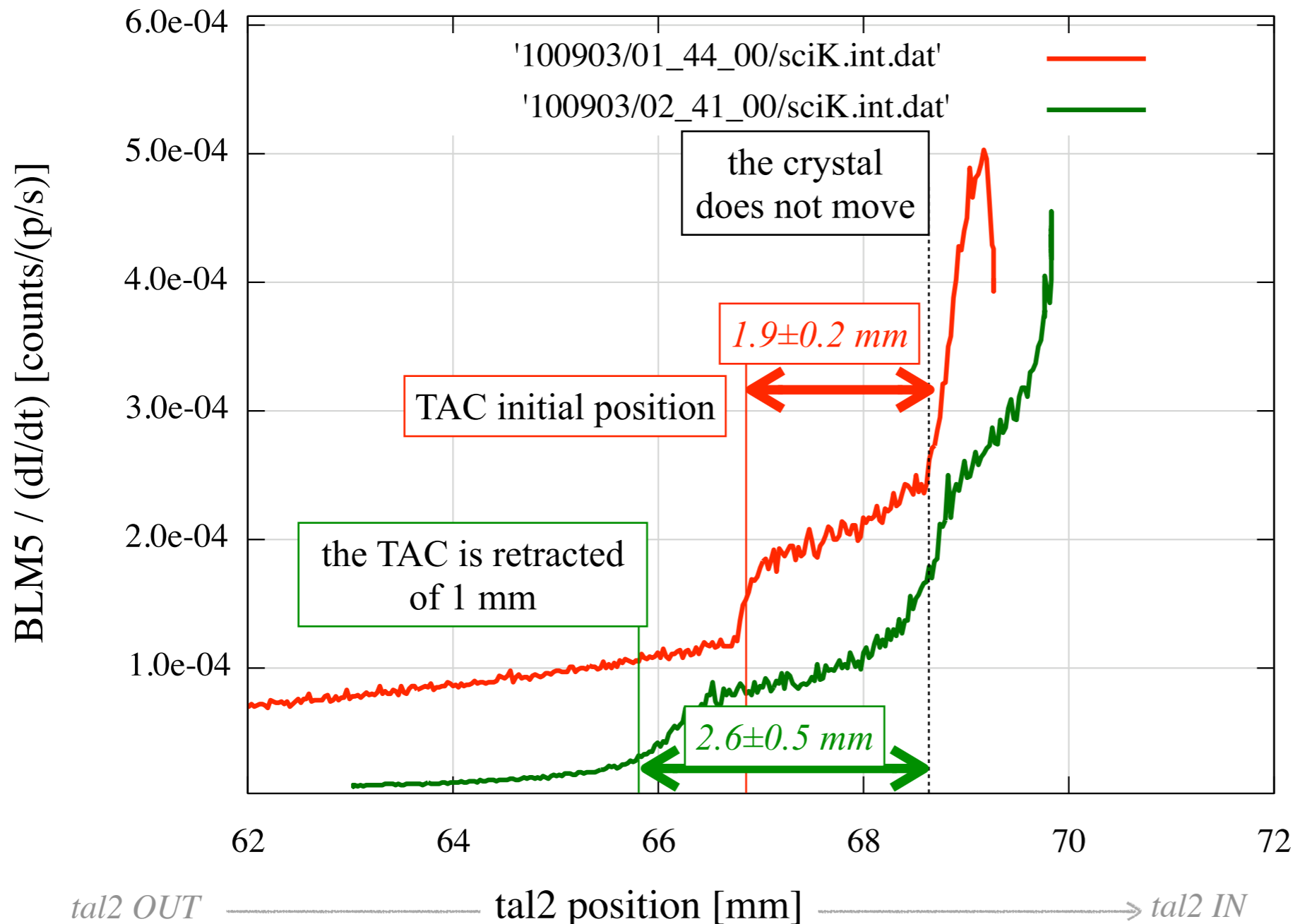


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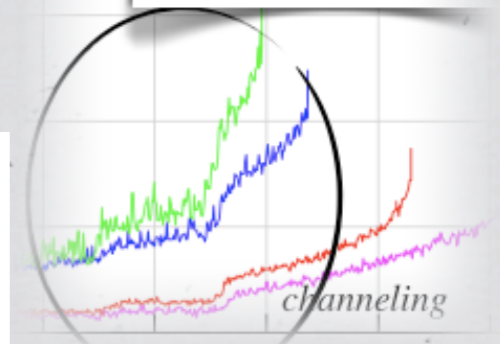
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1- the distance between the two "shadows" is the expected one

# a closer look...



2. a reproducible structure appears in this region...



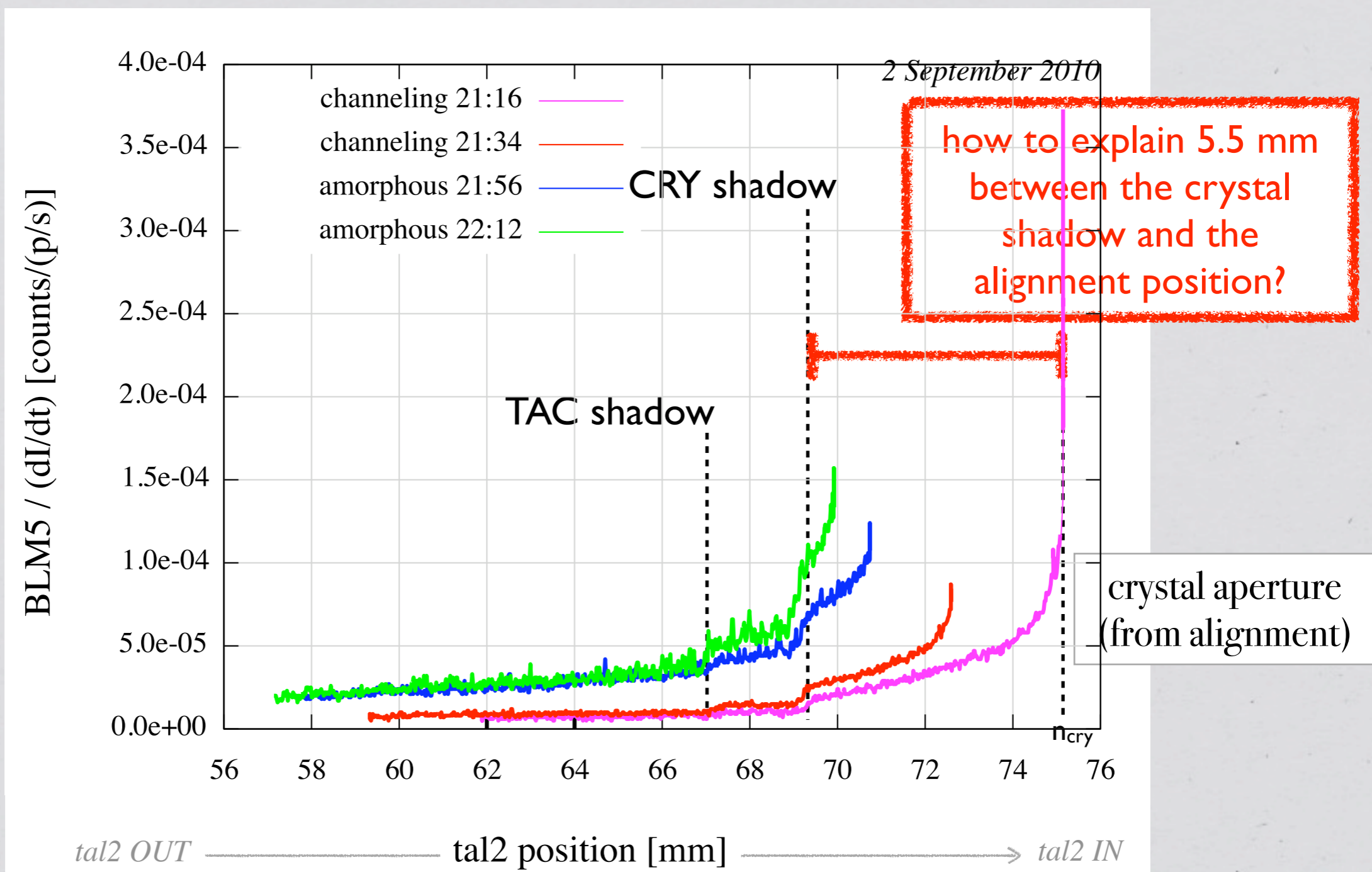
two shoulders always observed

are these correlated to the crystal and TAC positions?

1- the distance between the two “shadows” is the expected one

2- when the TAC is retracted, the second shoulder moves accordingly

however...



# off-momentum halo: the hypothesis

- \* the two shadows are indeed related to crystal and TAC positions

1. the distance between the two “shadows” is the expected one  
2. the “shadows” move when we move the elements

- \* if the shoulders were generated by on-momentum particles:

- \* we should find the alignment position for the crystal

1. the distance between the alignment position and the cry shadow is  $> 5$  mm

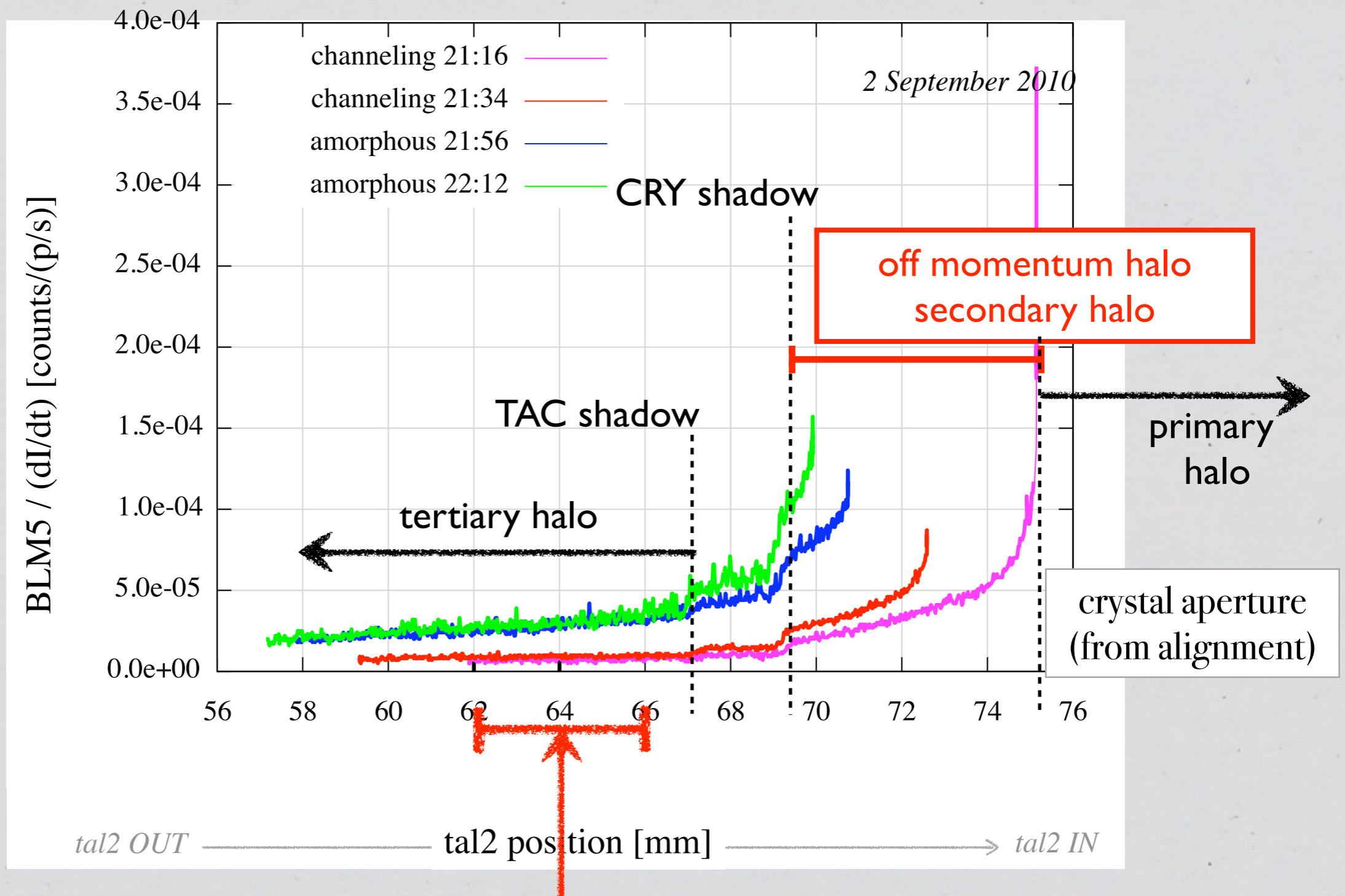
- \* after the crystal shadow we should scrape the primary beam

2. channeling and amorphous curves do not overlap  
3. the losses downstream the crystal do not decrease  
4. there is no variation in the beam intensity (BCT) even entering 5 mm more than the crystal shadow

*considering the dispersion value at TAL2 (3.4m) and the distance between the crystal shadow and the primary halo (5.5 mm), we got that the shadows must be generated by particles with a  $dp/p = 1.6E-3 = 4\sigma_p$*

# further investigations...

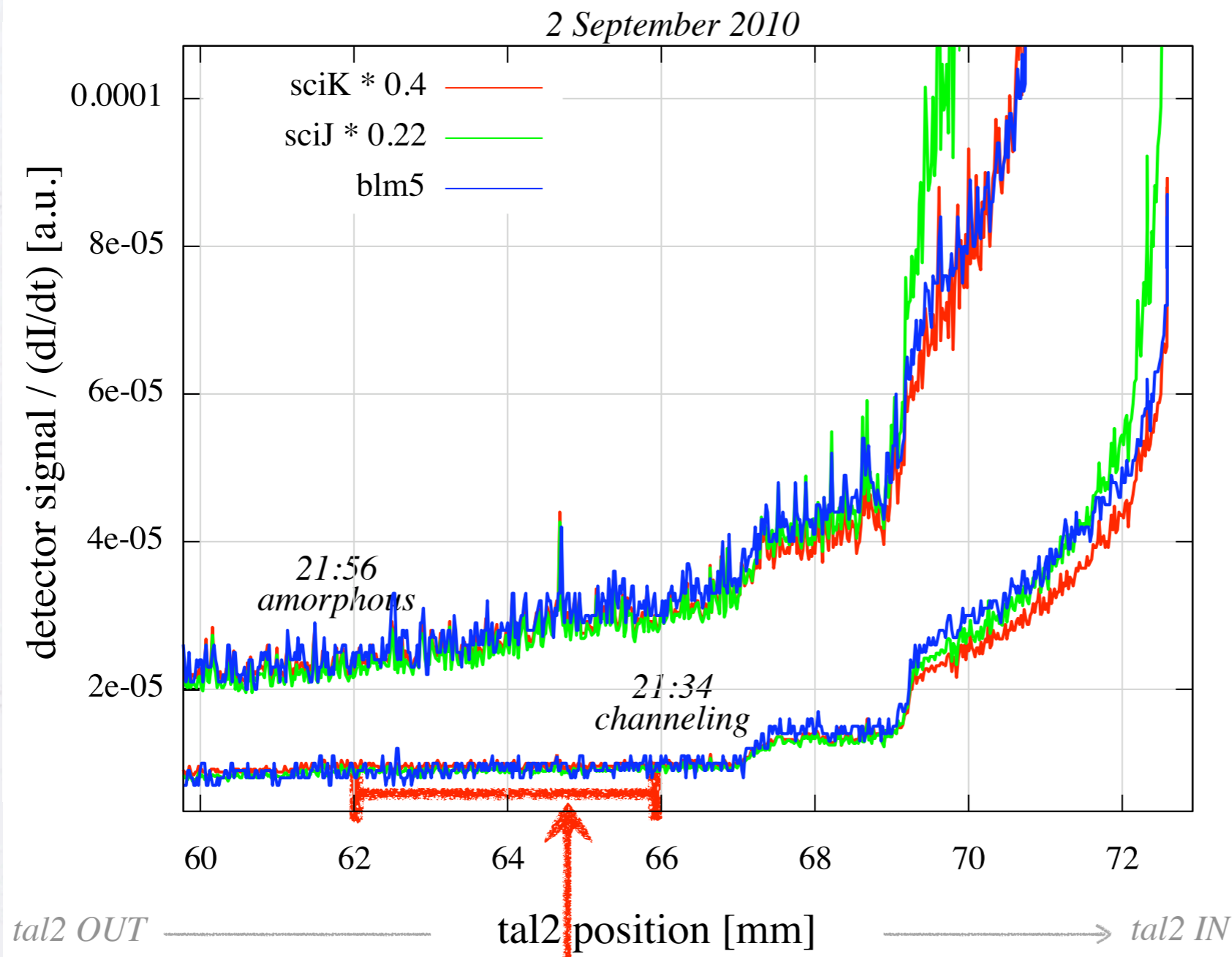
1. Try different normalization procedures for the scans: in particular normalizing to the flux of particles can be more appropriate than using the beam current (like it is now used). → done
2. The phenomena observed could be connected to the pure betatronic blow-up of the beam. Wire scan data should be analyzed to check this possibility. In particular, the tails can be evidenced, by considering the difference between IN scan and OUT scan. → not enough data
3. A comparison between collimator scans and TAL scans can point out the differences between dispersive phenomena and pure betatronic dynamics. → to be done in next runs
4. If the hypothesis about off-momentum particles is correct, it should be visible also as an effect on the bunch. Bunch lifetime should be checked. A comparison of Fast-BCT and BCT signals can give an idea of the number of particles out of the bucket. → in progress (Simone, Daniele)
5. It should be investigated how off momentum particles are generated. Can the known RF noise problem be responsible of this? The filling factor of the bucket should be studied as well. → to be done
6. During data taking, the RF frequency of voltage can be varied, to check if it has an effect on the scan shape. → to be done in next runs
7. A simulation should be implemented (on a longer time scale) to have a comparison with data. → to be done
8. During data taking, the "channeling scan" was always preceding the "amorphous scan". Changing the order of the scan can cross check if the scan shape is determined by crystal orientation. → to be done in next runs



the halo reduction factor is calculated ONLY for the tertiary halo, between 1 mm and 5 mm before the TAC shadow

# DETECTORS COMPARISON

which detectors to use for calculating the halo reduction factor?



in the region of  
interest, the 3  
detectors are  
proportional one  
to another

no discrepancy between scintillator and BLM data

# TAL2 scans summary

- the main result of the tal2 scan is the **halo reduction factor**, i.e. the ratio between the population of the tertiary halo(meaning escaping to the W absorber) in amorphous and in channeling
- the detectors data are normalized with respect to the flux of primary particles lost (BCT derivative).

Crystal	Time		Emittance m rad	Flux		apertures		halo reduction factor	
	Channeling	Amorphous		Channeling p/s	Amorphous p/s	Crystal sx	TAC sx	SCI K	BLM5
3	2 Sept 21:18 → 21:29	2 Sept 22:13 → 22:23	1.9E-08	8.65e6÷16.15e6	7.60e6÷9.15e6	5.7	7.2	3.77÷3.97	3.70÷5.20
3	3 Sept 00:40 → 01:01	3 Sept 01:50 → 01:56	1.7E-08	7.45e6÷7.67e6	5.64e6÷6.24e6	6.7	8.3	1.34÷1.44	1.38÷1.54
3	3 Sept 00:03 → 00:14	3 Sept 01:50 → 01:56	1.7E-08	7.46e6÷7.92e6	5.64e6÷6.24e6	6.7	8.3	1.80÷2.10	2.08÷2.26
3	21 Oct 16:48 → 16:56	21 Oct 17:33 → 17:42	2.5E-08	7.02e6÷7.04e6	4.65e6÷6.10e6	4.1	5.5	3.10÷3.90	n.a

no discrepancy between scintillator and BLM data

- the amorphous losses are always larger than the channeling ones
- halo reduction factors between 1.4 and 5.2** have been obtained for different system configurations

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# CONCLUSIONS

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of collimator and scraper scans for proton beams



- \* **Collimator and scraper scans** are an integrated measurement of the scattered halo.
- \* Collimator scans allow to measure the channeling parameters: **channeling kick, angular width, and multi-turn channeling efficiency.**
- \* **Efficiency measurements on crystal 3 in 2010 confirms efficiency values about 70%.**
- \* Scraper scans sample the tertiary halo and are used to calculate the **tertiary halo reduction factor**, i.e. the ratio between the population of the tertiary halo (meaning escaping to the W absorber) in amorphous and in channeling.
- \* Detailed analysis showed intrinsic difficulties in the data interpretation due to the high dispersion value at the TAL2 location: this generates a complicated superposition of on-momentum and off-momentum particles.
- \* A large off momentum tail has been observed. Further investigations (including a dedicated simulation) will be done in the next months.
- \* **Halo reduction factors between 1.4 and 5.2 have been found.**