IR7 Optics Solution for Ion Collimation?

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Previous meetings, numerous other presentations and reports have presented and discussed a variety of possible solutions to the problem of ion collimation efficiency in the LHC.

Presently, the most promising and robust solution is the installation of "cryogenic collimators" in the dispersion suppressors downstream from the primary collimators in IR7.

It was once suggested that there may be some way to change the optics of IR7 to improve the situation.

This presentation discusses the possibility of a purely optical solution.

In[24]:=
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SetDirectory[NotebookDirectory[]]
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Out[24]=
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G:\Users\j\jowett\Documents\Private\LHC\V6.503\IR7rematch
```

In[25]:=
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Get["IR7rematch1 LCU24Feb2009.m"]
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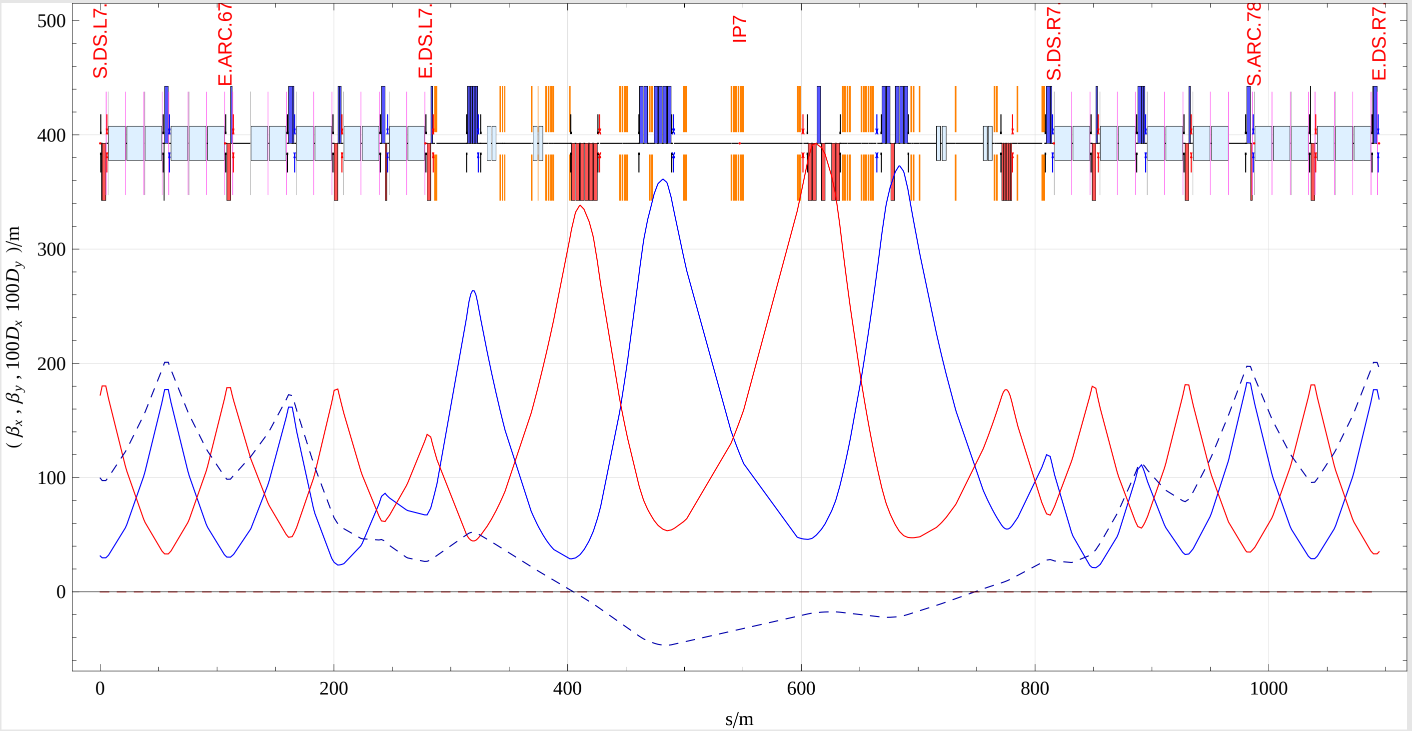
Reminder of IR7 betatron collimation optics



Active Collimators in Phase 1

In the following, we shall look only at the optics downstream from the central (horizontal) primary collimator.

Consider only the initial set of Phase 1 collimators for simplicity of presentation. Extract data from ICOSIM input structures.

In[26]:=
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mfsOpticsDynamicColumnTabulate[LHCB1IR7ActiveCollimators]
```

{ ☑ALFX ☐ALFY ☐ANGLE ☐APER_1 ☐APERTYPE ☑BETX ☑BETY ☐CALIB ☐DPX ☐DPY ☐DX ☐DY ☐HKICK ☐K0L ☐K1L ☐K2L ☐K3L ☐KEYWORD ☐KMAX ☐KMIN ☐L ☐LENGTH ☐MATERIAL ☐METHOD ☐MUX ☐MUY ☐N1 ☑NSIG ☐PARENT ☐PHASE ☐PXC ☐PYC ☐RE ☑RE11 ☐RE12 ☐RE13 ☐RE14 ☐RE15 ☑RE16 ☐RE21 ☐RE22 ☐RE23 ☐RE24 ☐RE25 ☐RE26 ☐RE31 ☐RE32 ☐RE33 ☐RE34 ☐RE35 ☐RE36 ☐RE41 ☐RE42 ☐RE43 ☐RE44 ☐RE45 ☐RE46 ☐RE51 ☐RE52 ☐RE53 ☐RE54 ☐RE55 ☐RE56 ☐RE61 ☐RE62 ☐RE63 ☐RE64 ☐RE65 ☐RE66 ☑S ☐VKICK ☐XC ☐YC}

Out[26]=

	α_x	s	β_x	β_y	RE11	RE16	NSIG
TCP.C6L7.B1	2.0406	344.51	149.30	83.458	0.22644	−0.59374	6
TCSG.B4L7.B1	1.4185	540.69	138.33	132.25	1.6359	−1.1576	7
TCLA.C6R7.B1	0.90543	765.76	67.705	153.38	−1.6354	1.4932	10
TCLA.A7R7.B1	−0.8084	785.39	65.437	144.47	−1.5939	1.3703	10

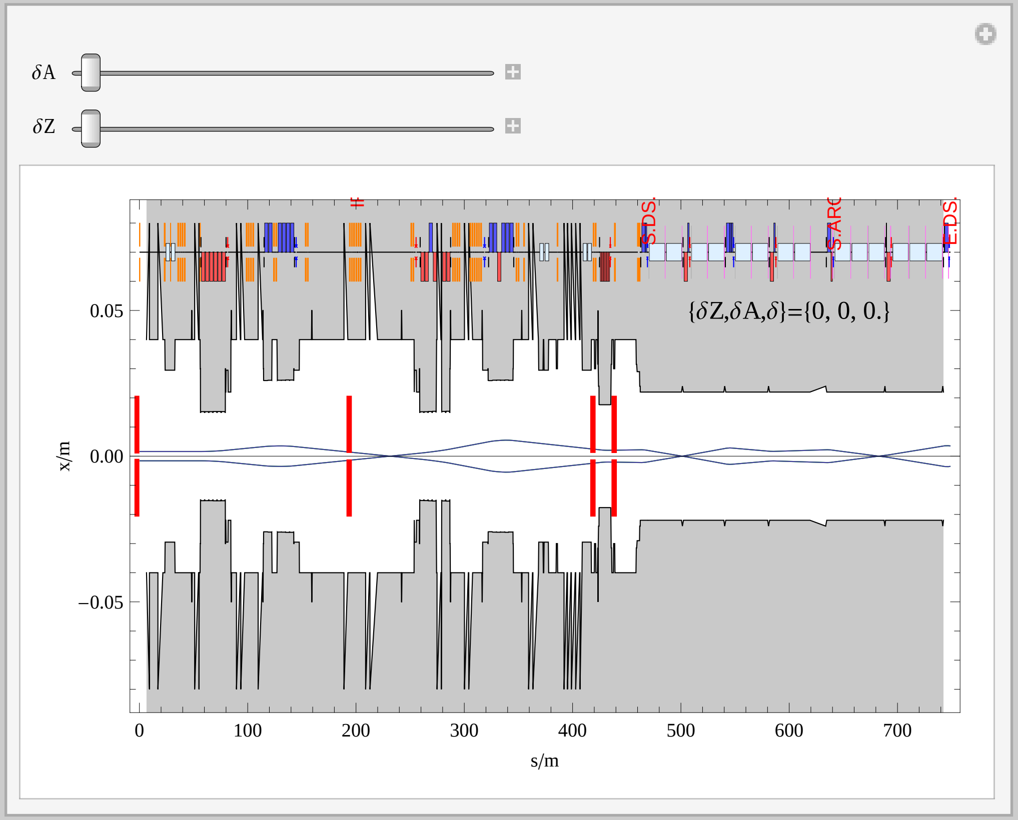
The essential problem of ion beam collimation

Unfortunately the interactive version crashes my ancient laptop, so I can only show static frames.

Unlike protons, Pb ions undergo hadronic and electromagnetic fragmentation processes in collimator material, losing neutrons and protons and emerging with different magnetic rigidities.

Since there is little multiple scattering in the collimators before this happens, the ions do not make it out to secondary collimators as protons do.

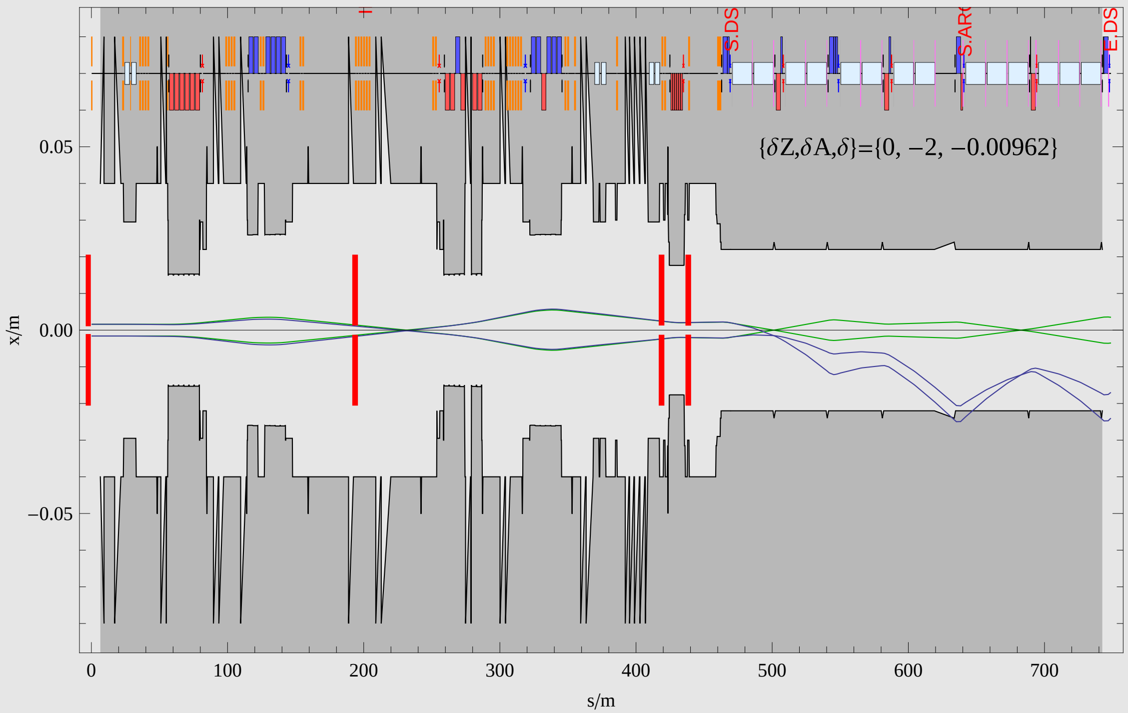
First show representative rays from main beam and unaltered Pb^{208} ions just grazing the primary collimator.



Example of Pb^{206} created by 2-neutron EMD

One example of many fragments (actually the most troublesome one).

Different magnetic rigidity leads to loss in dispersion suppressor.



N.B. the first problem to be solved is single-pass. Multi-turn effects would have to be looked at later (probably in ICOSIM).

We can see how the cryo-collimators do the job straightforwardly.

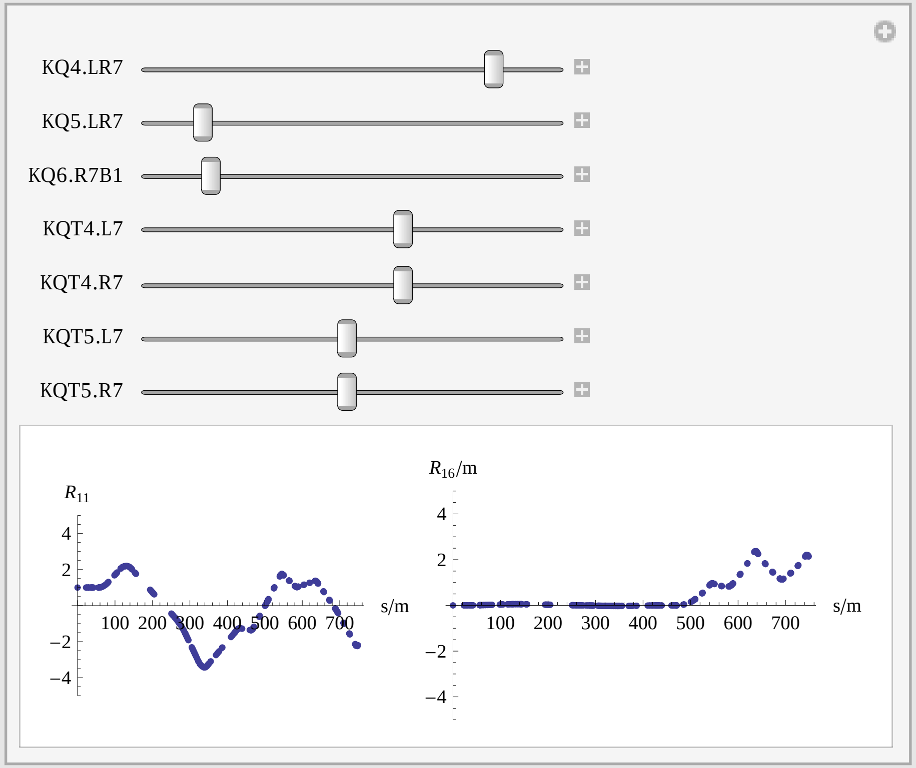
Approach to illustrating flexibility of optics

Following is a new approach to "***semi-analytic matching***" in Madtomma environment, I will skip technical details here.

- Build list of 6 by 6 transfer matrices of all elements downstream of horizontal TCP in normal optics (matrices can be taken from MAD if desired, or built directly from the element sequence information, differences not important at LHC energy).
- Replace transfer matrices of all quadrupoles up to beginning of dispersion suppressor with thick-lens *symbolic versions, depending on the quadrupole strength* (taking account of several quadrupoles being on common power supplies, etc.).
- Use the *Mathematica* function **FoldList** with matrix Dot product to construct the matrices at all elements for any values of the 7 independent power supplies.
- In this application we can often make do with 3 by 3 chromatic matrices.
- Plots of transfer matrix elements, on- and off-rigidity trajectories, etc., with interactive knobs (limiting strengths to available values at collision energy) for quadrupole strengths are possible.
- No attempt to match to rest of machine (this turns out not to be unnecessary).

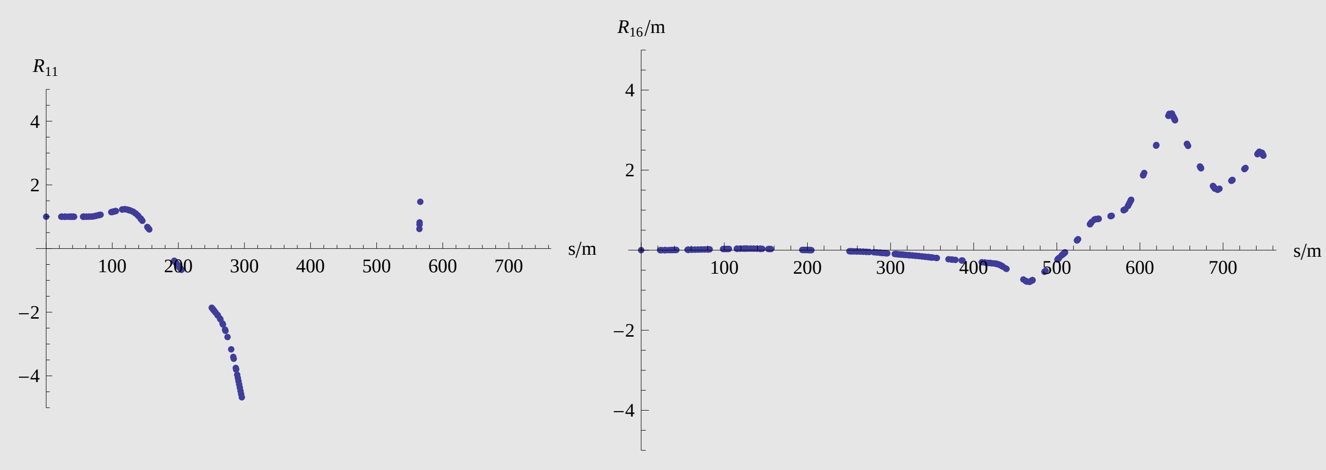
Transfer matrix elements

Simplest plot showing the essential matrix elements for this problem, first with the settings of the normal collimation optics. The sliders allow us to change the quadrupole strengths over the available ranges at collision energy:



Even in the most extreme case (dramatically violating many conditions on optics and aperture), it is impossible to get any significant increase(beyond about 0.3 m) of R_{16} in the region of the secondary collimators

Out[29]=



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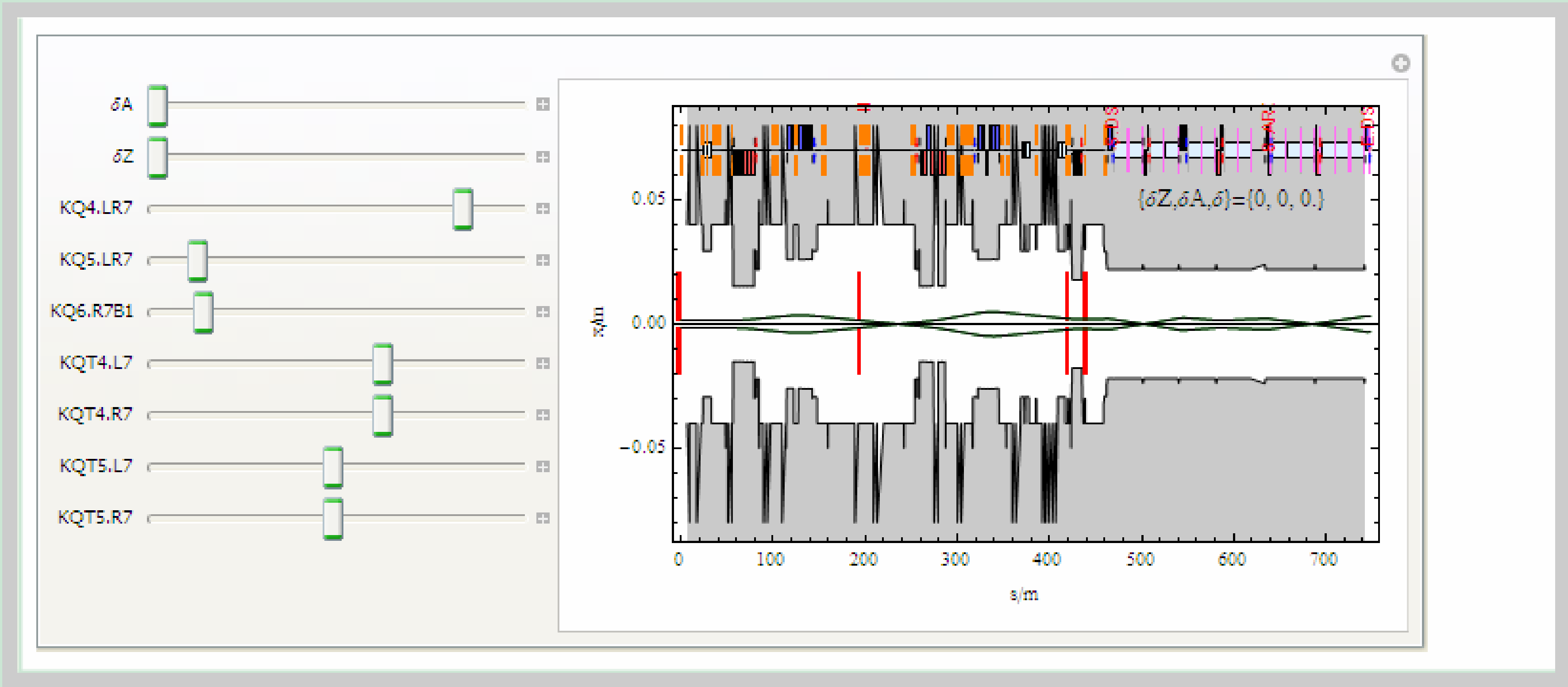
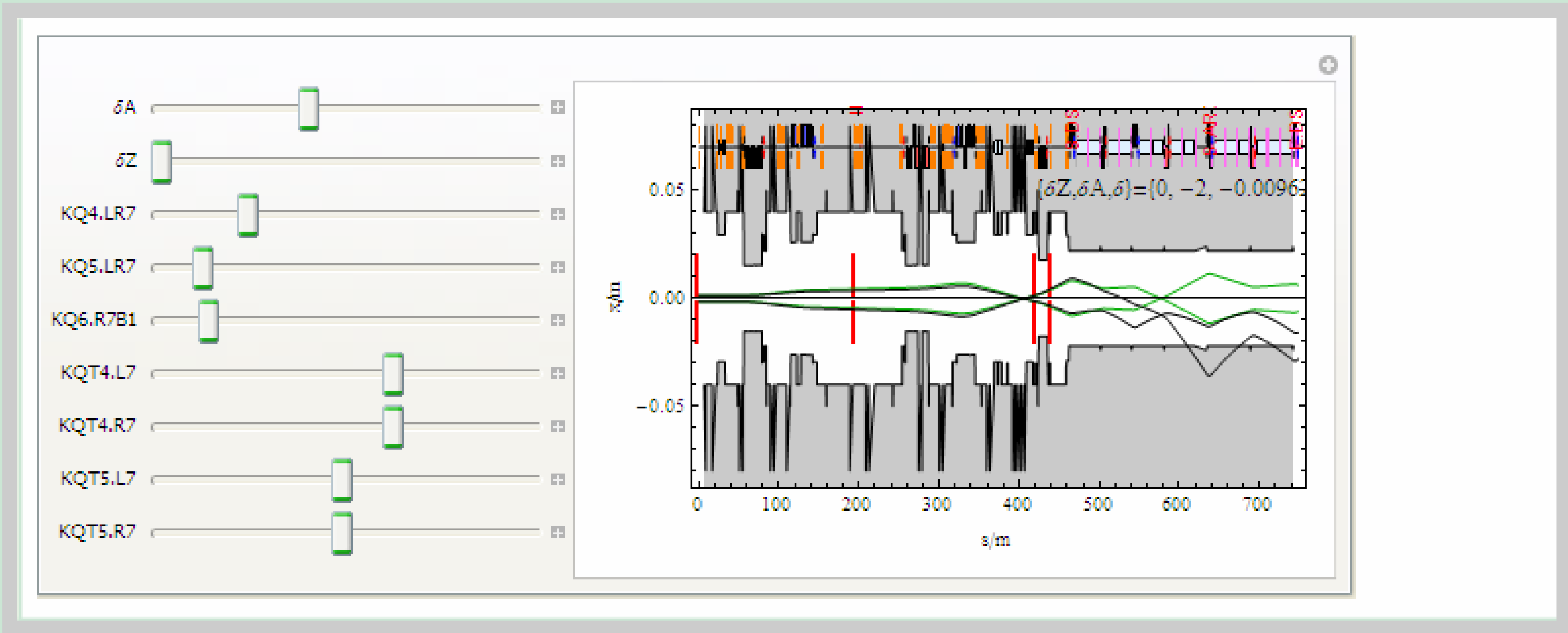
Representative rays for the collimation process

Show more of what is going on in the collimation process. A full dynamic interface is possible, again showing representative rays of main beam and most massive isotopes scattered from collimator.



^{206}Pb with a drastic change of KQ4.LR7 strength

Probably far beyond anything that can be matched into LHC optics.



No help for single-pass problem. Would need sufficient differentiation of main beam and ^{206}Pb trajectories in the region of the secondary collimators.

All other variations of the quadrupole strengths lead to similar conclusions.

Conclusions

As expected, a purely optical solution to the problem of ion collimation in IR7 does not exist.

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