News from the run 2c electron spectrometer
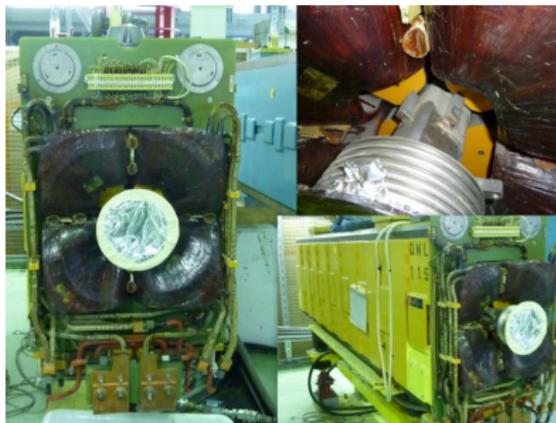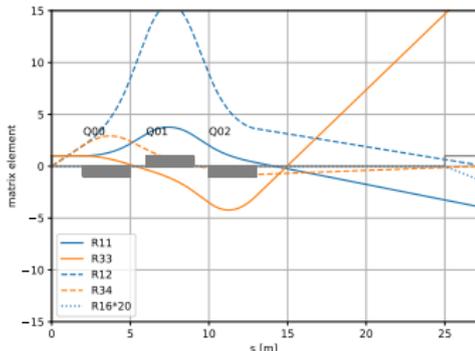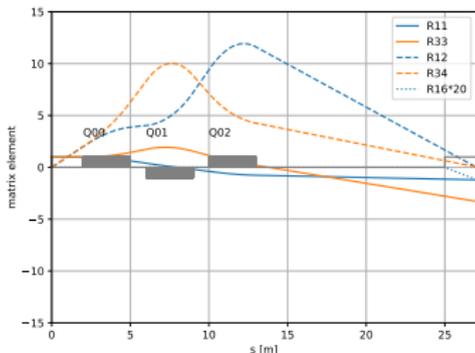
D. A. Cooke

Outline

- Triplet spectrometer with 3 m quadrupoles.
- Performance (emittance etc.)—similar to original baseline doublet design

Also:

- Small run 2b emittance study of the exit ramp.
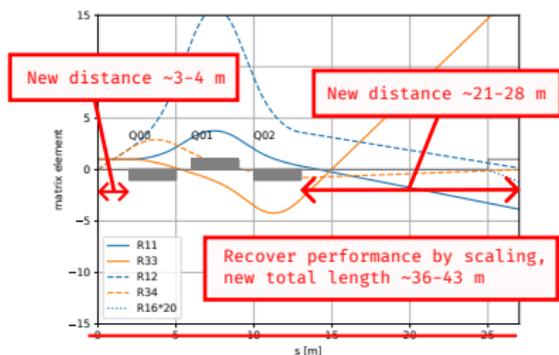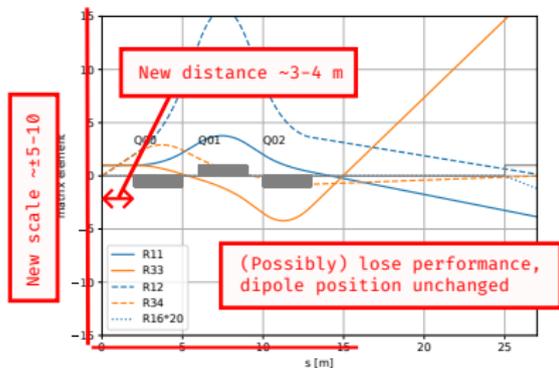
Triplet spectrometer

Previously:

- If we power a slightly over-specification triplet with 3x Heinzinger converter PCU 50-200 (50V-200A) we can achieve equivalent performance to previous design iterations.

- Triplet can be operated in two regimes, with a high magnification mode attained by sacrificing (imaging) energy reach somewhat.

- Magnets could be e.g.: `https://norma-db.web.cern.ch/magdesign/idcard/160/` (dipole), `https://norma-db.web.cern.ch/magdesign/idcard/577/` (quadrupoles—pictured).
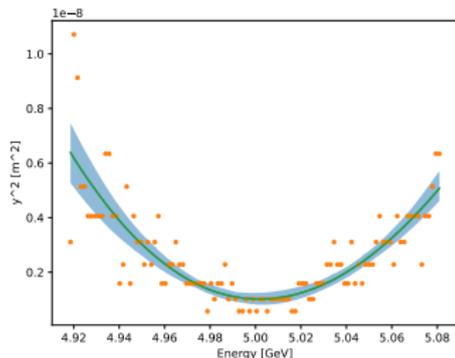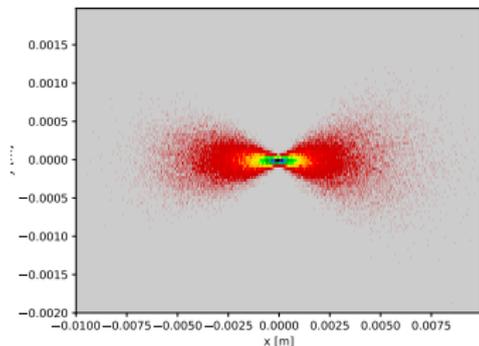
Triplet spectrometer

Now:

- Identical quadrupoles, but some changes to other magnets/positions
- Uncertainty over pre-quad drift distance impacts either performance and/or dimensions
- Dipole aperture increased to accommodate proton halo **at old design dipole position**—what about at +14 m?
- Magnet could be e.g.: `https://norma-db.web.cern.ch/magdesign/idcard/186/` (dipole—pictured).

Emittance fitting results

Triplet capable of reaching $\sim 1 \times 10^{-10}$ m rad scale geometric emittances (but needs higher beam charge for the same precision):

Input (5 GeV):

- beam size at plasma exit [m]: 1.7e-06
- beam divergence [rad]: 5.88e-05
- waist loc [m]: 0.000
- emittance [m.rad]: 1e-10

Output

- beam size at plasma exit [m]: (1.90+/-0.06)e-06
- beam divergence [rad]: (5.40+/-0.16)e-05
- waist loc [m]: 0.0001+/-0.0012
- emittance [m.rad]: (1.027+/-0.026)e-10

(Uncertainties from fit, only one simulation run).

Emittance fitting results

Triplet—low magnification is *incapable* of reaching $\sim 1 \times 10^{-10}$ m rad scale geometric emittances. Size measurements fall below pixel limit:
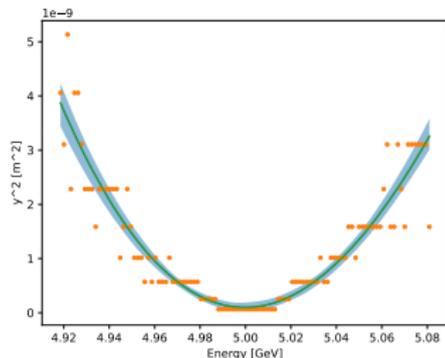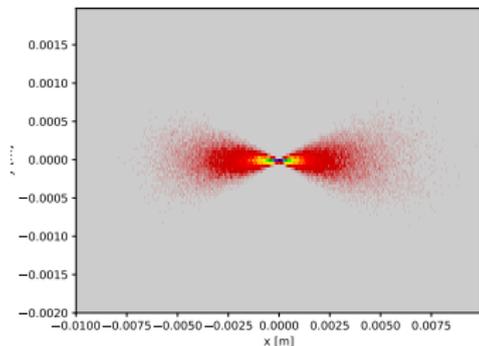
Input (5 GeV):

- beam size at plasma exit [m]: 1.7e-06
- beam divergence [rad]: 5.88e-05
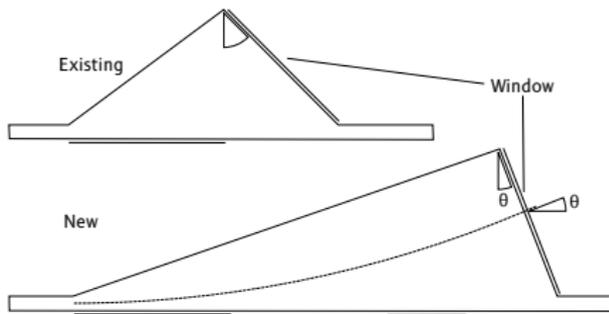- waist loc [m]: 0.000
- emittance [m.rad]: 1e-10

Output

- beam size at plasma exit [m]: (5.9+/-1.2)e-07
- beam divergence [rad]: (4.60+/-0.12)e-05
- waist loc [m]: 0.0005+/-0.0011
- emittance [m.rad]: (2.7+/-0.5)e-11

(Uncertainties from fit, only one simulation run).

Energy range

- Baseline design is that vacuum window not foreseen to change.
- In order to accommodate possible optical synchrotron radiation (OSR) diagnostic window, modified vacuum window with space for CF40/CF63 flange could also be produced.
- CF40 outer diameter of 70 mm **reduces upper energy edge to 11.5 GeV at maximum field (0.945 T)**
- CF63 outer diameter of 114 mm **reduces upper energy edge to 9.0 GeV at maximum field (0.945 T)**
- Only CF40 is compatible with specifications using PXMBXHBCWP dipole model. Except: *'Observation: In the specifications the maximum current is 540A but no magnetic measurement values are available with this current.'* is attached to this magnet.
- Modifying the screen in this way allows vacuum chamber design to be finalised soon and has no big impact on spectrometer performance (it just requires that we have two different scintillating screen sizes available).
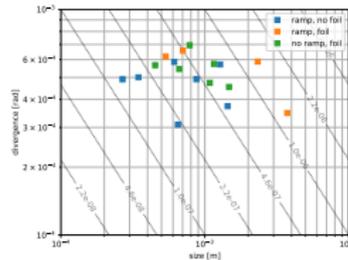
Design summary

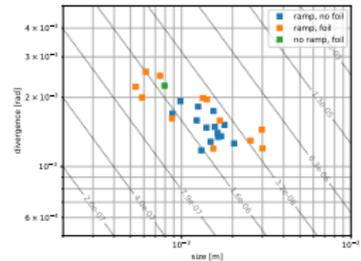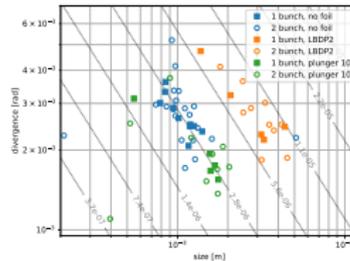- Layout/performance unclear without further constraints on magnet positions.

- Need to fix the constraints (as we saw in Eduardo's talk yesterday): everything depends on everything else, so it's an integration problem, since there are regions where the performance can be retained.

- Lower field dipole limits possible window size for optical synchrotron radiation window unless magnet observations are to be believed.

Run 2b emittance

- Small study of plasma exit ramp—effect on beam parameters of accelerated electrons.
- Can approximately 'turn off' the ramp, using the final in-plasma plunger, but this introduces scattering from the plunger.
- Take three measurements: final plunger in, laser beam dump in, no foils, and compare the three sets.
- If ramp spoils the emittance, final plunger should give smaller result than laser dump. But both are spoiled by the foil, so the 'no foil' tests this effect.
- Scattering in the foil is also simulated in GEANT4.
- Analysis complete for $2 \times 10^{14}\,\mathrm{cm^{-3}}$, no-step only. Low charge capture might hamper fitting.

Run 2b emittance: comparative results

- Results shown plotted as angular width against waist size, with contours of constant emittance.

- Three complete set at:
    - $(2 \times 10^{14} \text{ cm}^{-3}, 400 \text{ MeV})$ (shown at collaboration meeting 2025(a), uniform)
    - $(2 \times 10^{14} \text{ cm}^{-3}, 850 \text{ MeV})$ (with 4% density step)
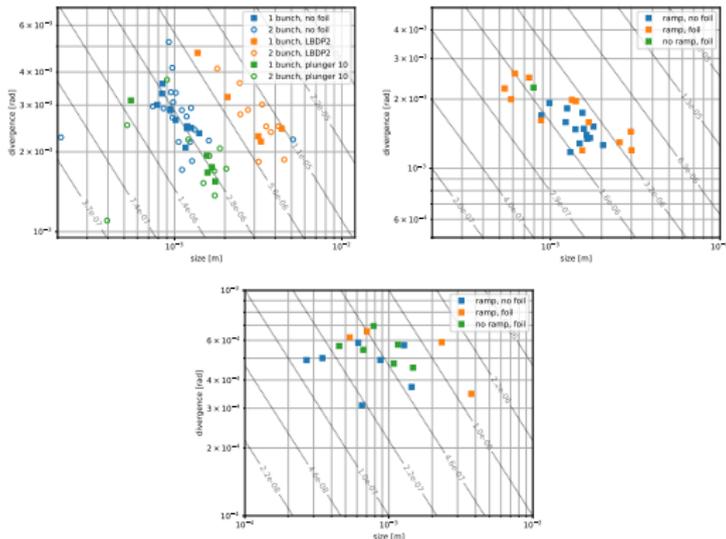   - $(7 \times 10^{14} \text{ cm}^{-3}, 1500 \text{ MeV})$ (with 2% density step)

Clockwise from top left: 400 MeV, 850 MeV, 1500 MeV.

Run 2b emittance: comparative results

- Foil scattering reproduced well in GEANT4 simulation.
- Effect of ramp (and also foil) small at higher energies.
- Ramp effect not visible, owing to low statistics or instrumental resolution (I don't have an estimate for it).

Set	ϵ_{in}	ϵ_{foil}
$(2 \times 10^{14}\,\mathrm{cm}^{-3}, 400\,\mathrm{MeV})$	3	7.0
$(2 \times 10^{14}\,\mathrm{cm}^{-3}, 850\,\mathrm{MeV})$	2	2.2
$(7 \times 10^{14}\,\mathrm{cm}^{-3}, 1500\,\mathrm{MeV})$	0.6	0.65

Emittance (mm mrad) increase from passage through 300 μm aluminium foil (using the approximate starting values for the beam parameters from measurement) as predicted by GEANT4 simulation.

Clockwise from top left: 400 MeV, 850 MeV, 1500 MeV.

Ramp emittance summary

- Promising for run2c, in the sense that the effect appears to scale favourably with energy.
- No new data is coming, so in simulation we trust (see John's bonus slides from yesterday), but perhaps we don't need to worry about this effect.