Beam-breakup instability studies

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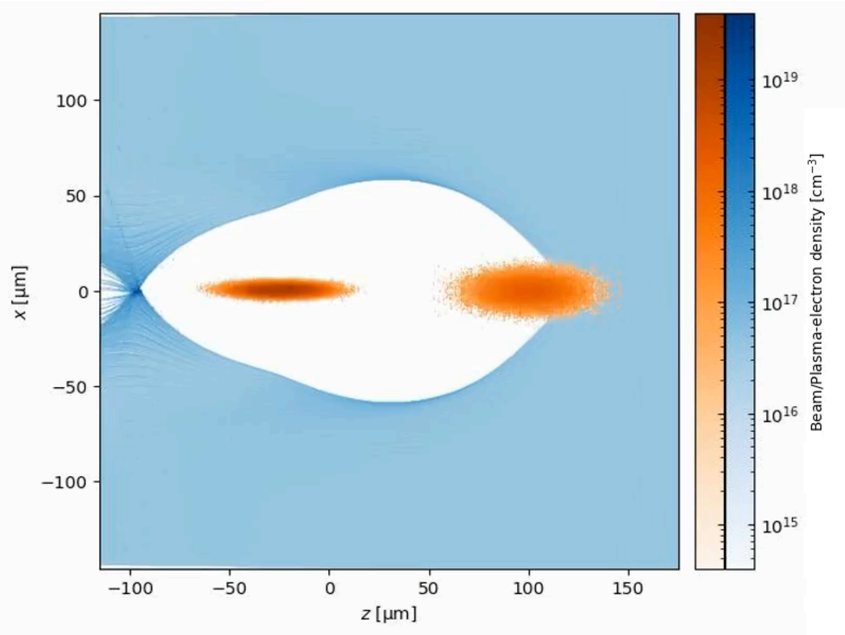
Transverse instabilities: **Beam-breakup instability**

Hosing (drive bunch):

* Can be mitigated
  - Large bunch size — *Martinez de la Ossa et al., PRL 121, 064803 (2018)*
  - Induced energy chirp — *Mehrling et al., PRL 118, 174801 (2017)*

Beam-breakup (trailing bunch):

* Small bunches with no energy spread (ideally) desired
  - Operation in the quasilinear regime — R. Lehe et al., PRL 119 244801 (2017)
  - Suppression of beam-breakup instability with Ion Motion *Mehrling et al.,* PRL 121 264802 (2018)



Beam-breakup instability and efficiency

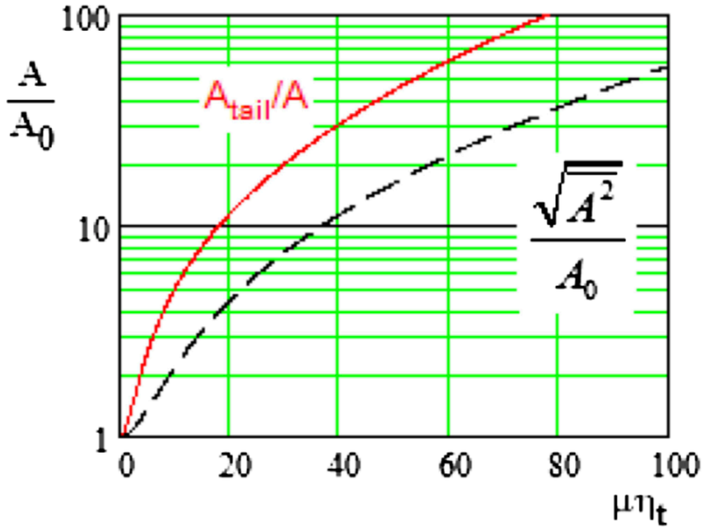
Relationship between instability and efficiency proposed “limits” the achievable efficiency.

— Efficiency versus instability in plasma accelerators PRAB 20, 121301 (2017)

$$\eta_t \approx \frac{{\eta_P}^2}{4(1-\eta_P)}$$

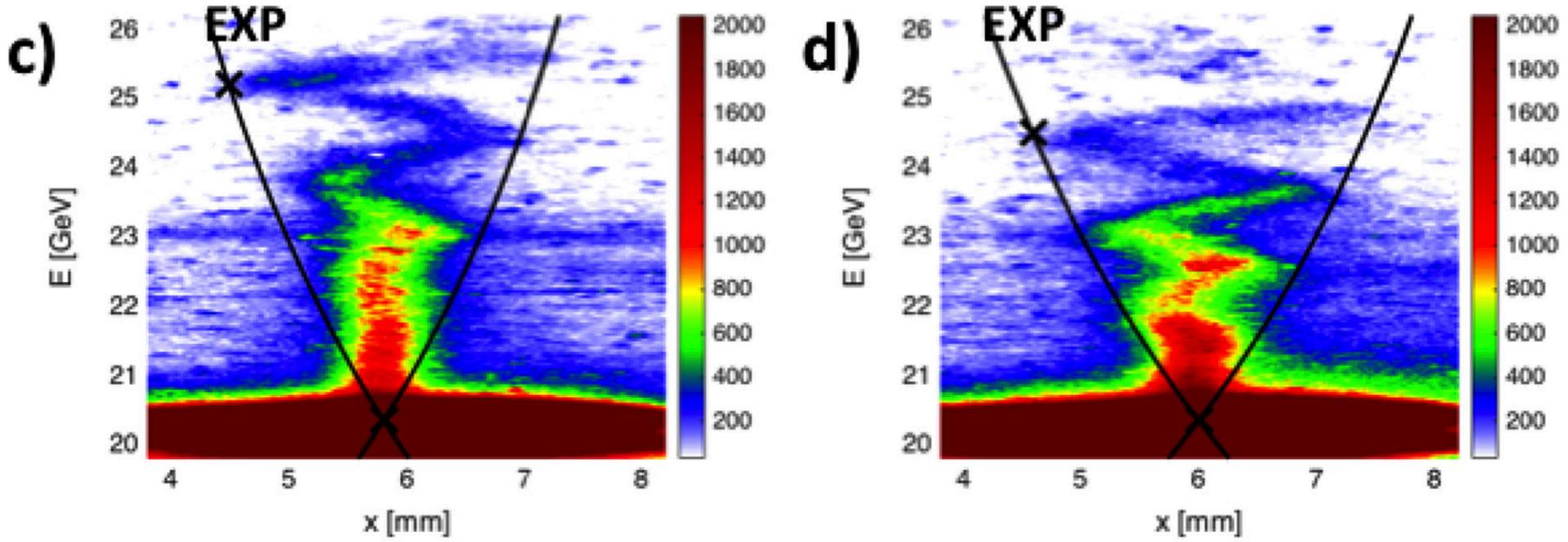
Transverse wakefields blow up at high efficiencies.

This leads to an exponential increase in amplitude of the trailing bunch



Source: Lebedev et al., PRAB 20, 121301 (2017).

Real data is hard to interpret

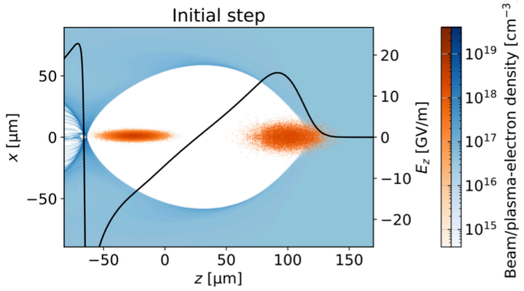


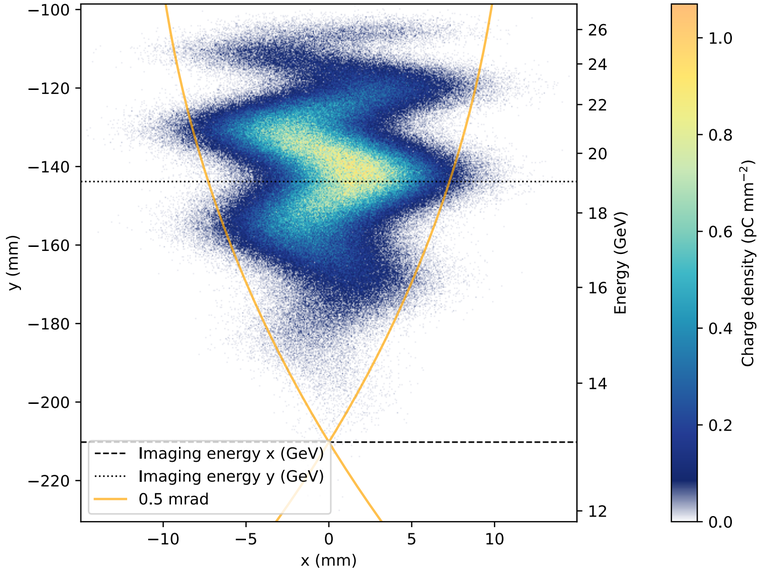
Source: Adli et al., Nucl. Instrum. Methods Phys. Res. Sect. A 829, (2016)

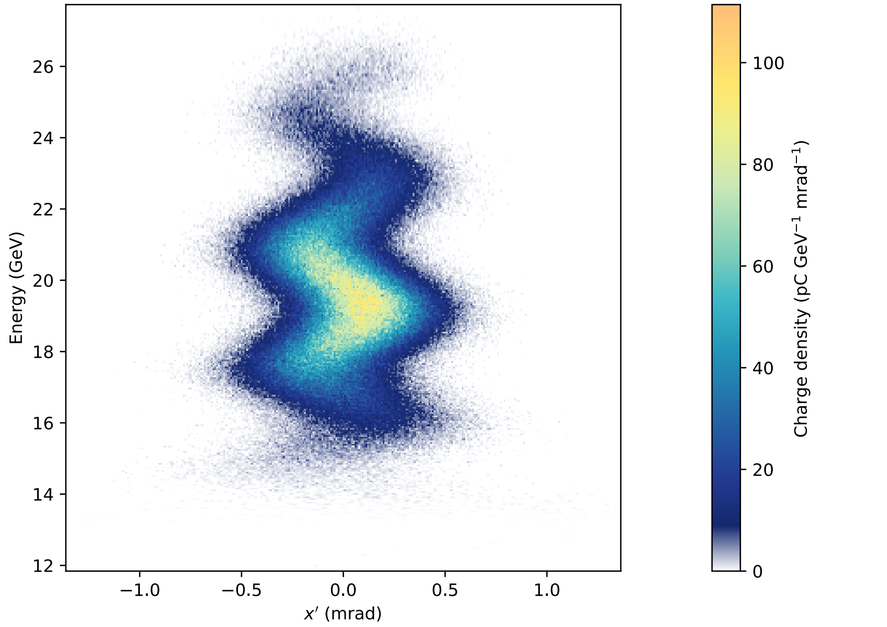
Converting spectrometer image to x'-E distribution

* We have:
  * $x_{\text{screen}} = m_{11}(E)x_0 + m_{12}(E)x_0'$
  * $m_{12}(E)$ scales more strongly than $m_{11}(E)$ with bunch energy
  * $x_0' = \dfrac{x_{\text{screen}}}{m_{12}(E)}$ (Valid away from imaging energy)
  * $\sigma_{x',\text{error}} = \dfrac{\sigma_x m_{11}(E)}{m_{12}(E)}$
  * $$\frac{d^2Q}{dx'dE} = \frac{d^2Q}{dxdy} \cdot \frac{dx}{dx'} \cdot \frac{dy}{dE} = \frac{d^2Q}{dxdy} \cdot m_{12}(E) \cdot \frac{dy}{dE}$$

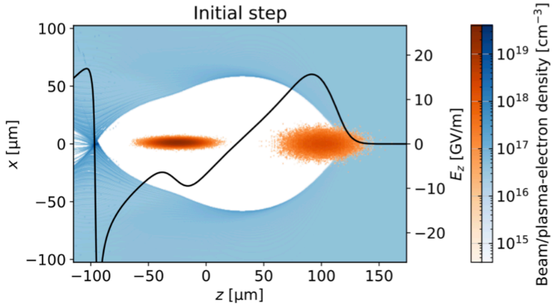
Low-charge (underloaded)

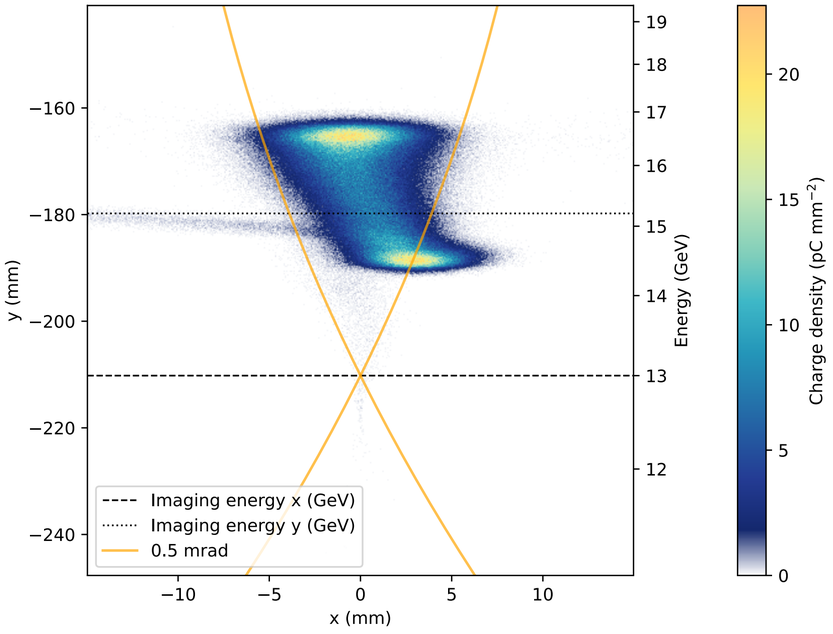


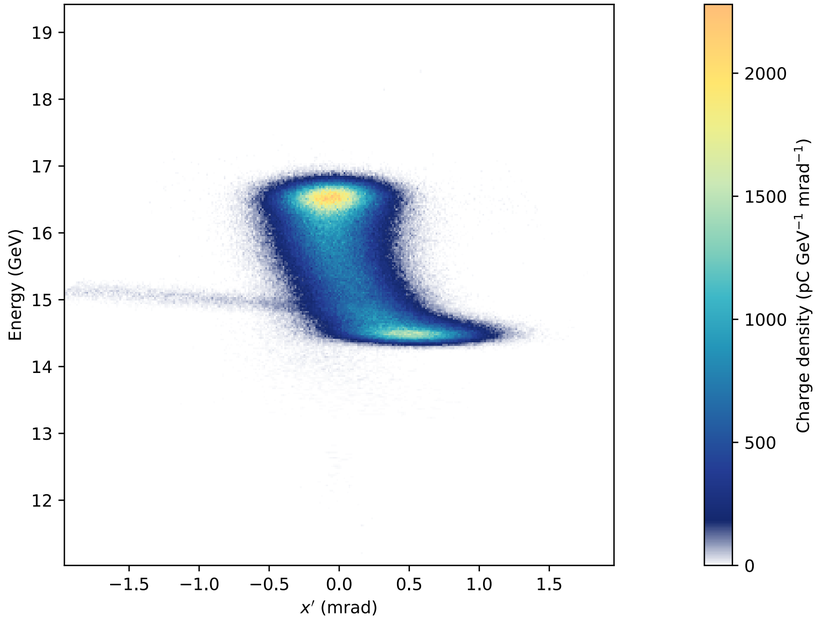




High-charge (overloaded)

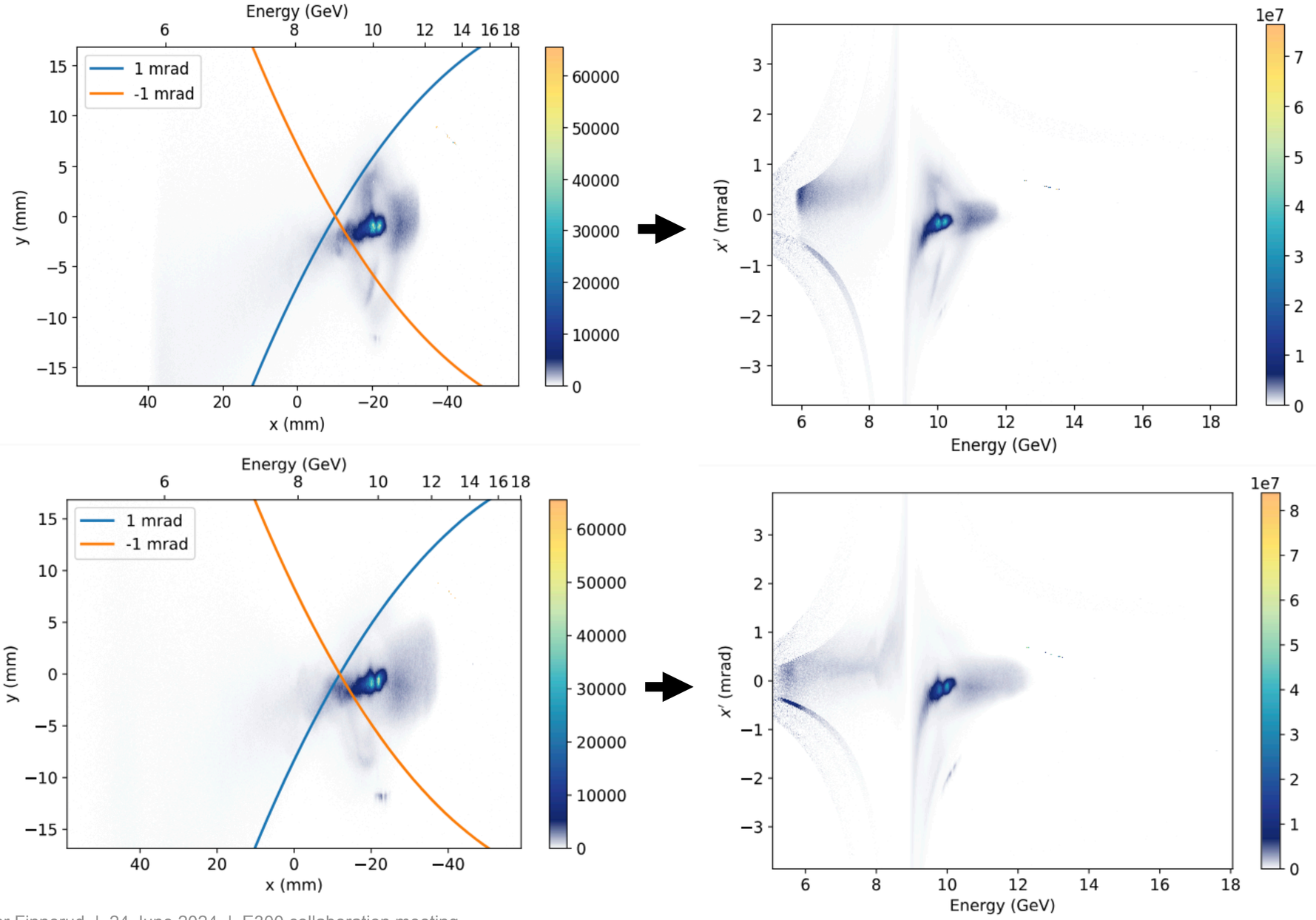






Imaging 9 GeV in transverse plane and 12 GeV in dispersive plane

Implemented new feature in spectrometer config to image different energies in x and y



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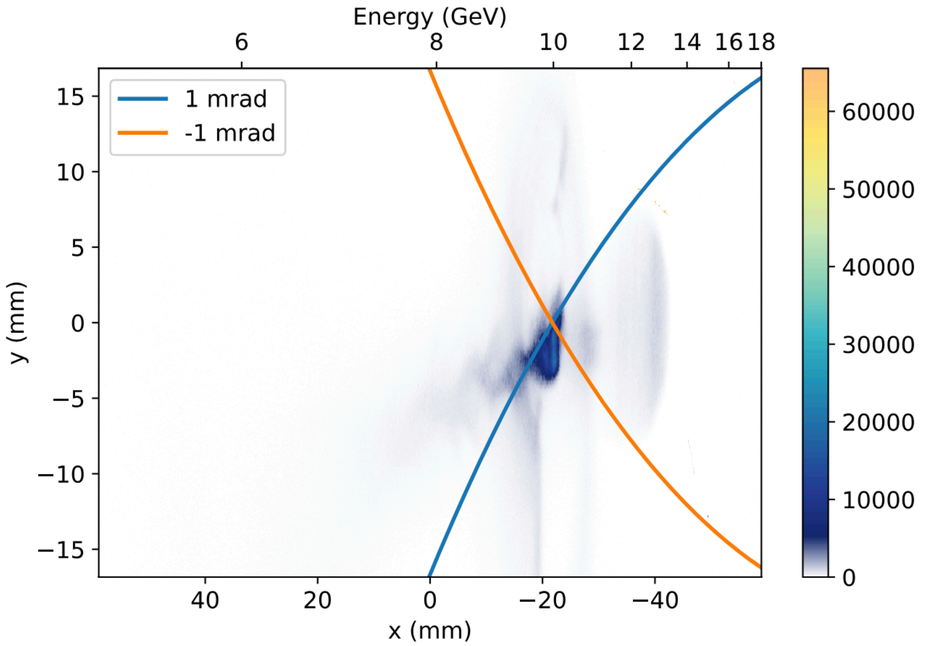

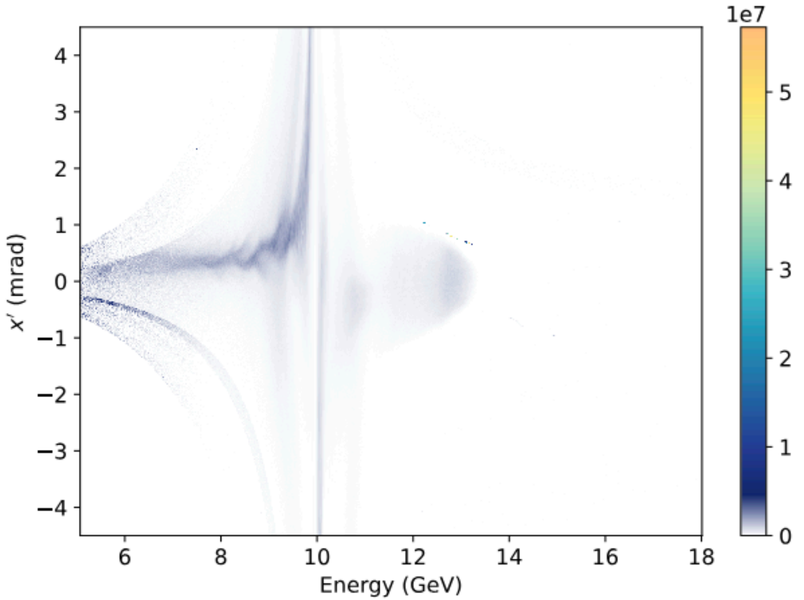

Summary and Outlook

- Method is working. Ready to be used as online monitor during shifts.
- Look for interesting shots in the data with transverse oscillations.
- Data sets including energy calibrations at different spectrometer setups.
- Calibrate angle and position offset.
- Charge calibrations in order to estimate efficiency.
- Compare configurations with different amount of witness charge
  - This lets us probe strength of instability as a function of efficiency.