Fermilab

U.S. DEPARTMENT OF ENERGY | Office of Science

NORTHERN ILLINOIS CENTER FOR ACCELERATOR AND DETECTOR DEVELOPMENT

NIU

High-Charged Magnetized Beams at FAST-IOTA [MagBeam]

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Collaborators at JLab: S. Benson, J. Gubeli, F. Hannon, S. Wang

* Graduate students

funded proposal to DOE NP

- T1: High-charge magnetized beam:
  - Production of high-charge (**1.6** and 3.2 nC) magnetized beam
  - characterization of magnetization
  - Transport + manipulation over long beamline including use of locally non-symmetric optics
- T2: Understanding halo
  - Explore halo formation in magnetized beam using a long-dynamical range diagnostics (LDRD)
- T3: New merger concept:
  - ~~Tests of merger concept combining RF deflector and magnetic coil proposed by G. Krafft and A. Hutton -- augmenting recent test at Cornell.~~

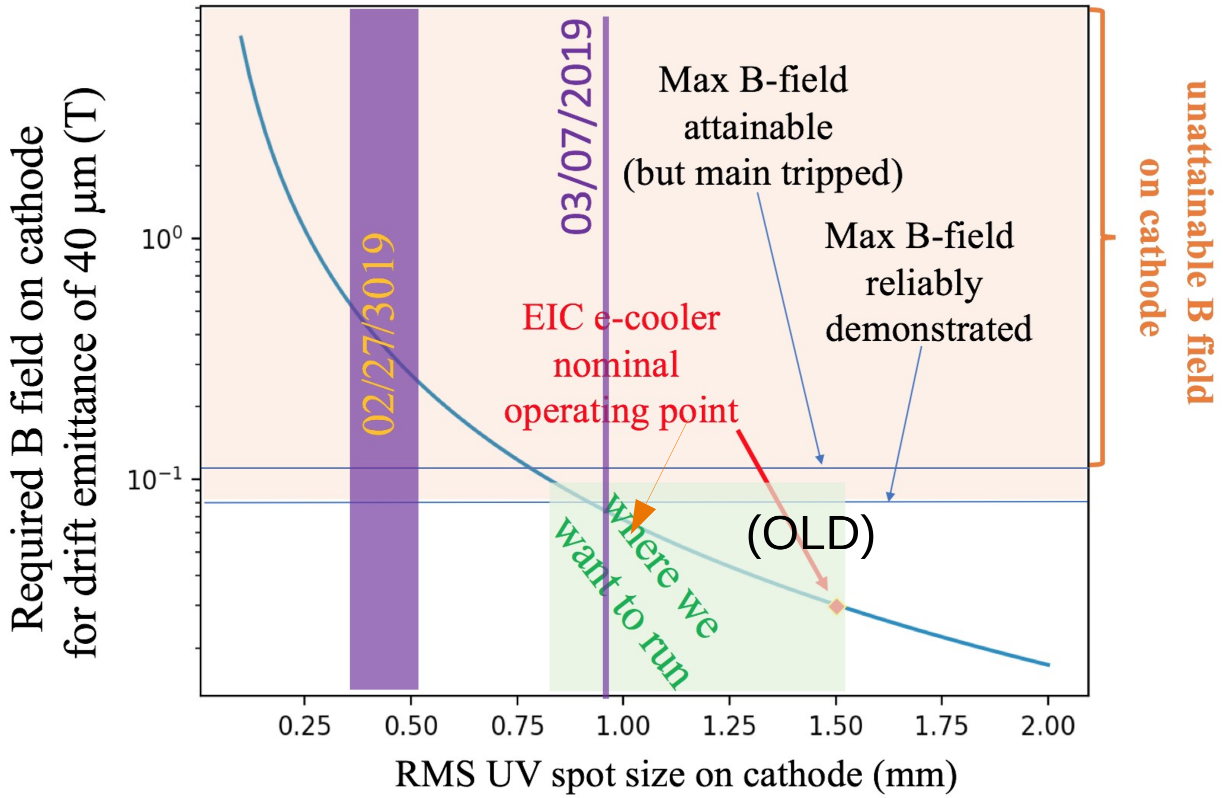
Some encouraging results produced during run I, but poor data quality for publication

Initially planned for run II now moved to run III

Initially planned for run III now moved to another facility (DOE approved)

Relevance of FAST injector to EIC e- cooling

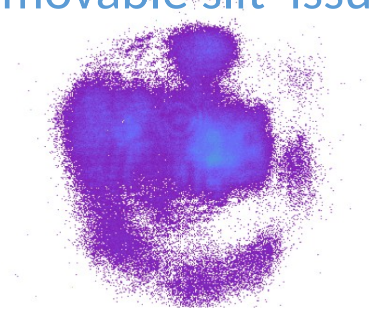
- Similar beam parameters except for a higher peak current

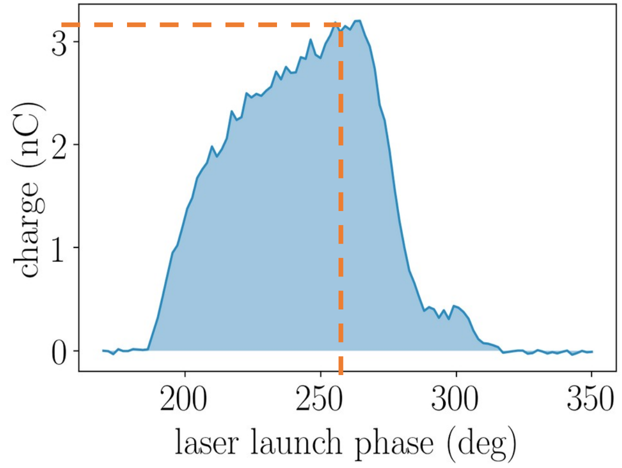


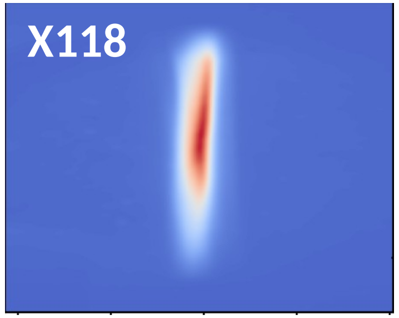
Parameter	Unit	JLEIC	FAST
Beam Energy	MeV	[20,55]	45
Beam Charge	nC	3.2 /1.6	>3.2
cath. spot size	mm	1.1	1
B field on cath.	T	0.05	< 0.09
cyclotron emitt.	μm	≤ 19	< 5
drift emitt.	μm	36	37
δp/p (uncor.)	-	3.10^{-4}	$< 4.10^{-4}$
δp/p (pk-to-pk.)	-	$<6.10^{-4}$	$\mathcal{O}(10^{-4})$
bunch length σ_z	cm	2	0.2

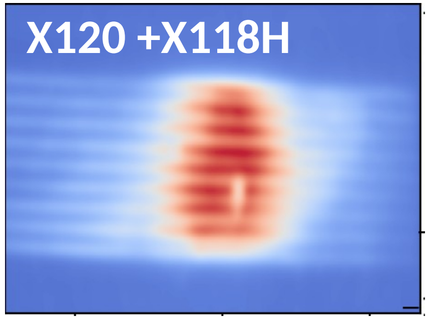
Outcomes and limitations of Run I

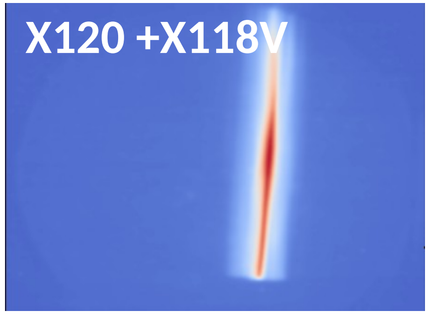
- Significantly improved bunch charge:
  - Emission was space-charge-limited
  - Increasing spot size resulted in bunch charge up to 6 nC
- Produced and transported a magnetized beam up to the low energy dump:
  - Characterized magnetization and other beam parameters
- Produced a flat beam:
  - Measured associated emittance (which corresponds to the incoming magnetized beam eigen emittances)
- Limitations:
  - Emittance measurement of eigenemittance could not be performed precisely due to movable slit issues
  - We could not trust the ICT
  - Laser inhomogeneity











Outcomes and Summer Improvements

- Issue with single-slit scan was fixed (Daren, Jinhao) and analysis (Aaron) shows is could be used for emittance measurement
- Improved analysis of data is encouraging

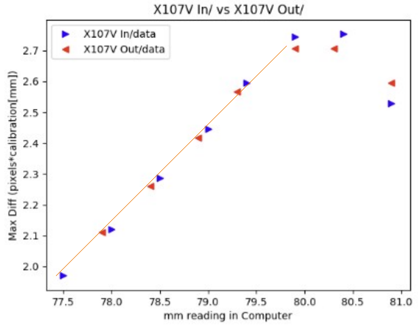
RFTB Eigen-Emittances

Paramters	units	
ε_+	μm	32.5±2.9
ε_-	μm	2.2±1.9
ε_u (calc.)	μm	8.2±.4
$\mathcal{L}$ (calc.)	μm	15.2±1.5

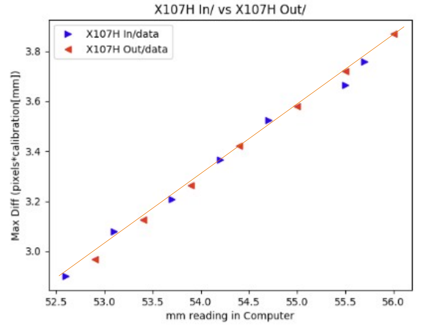
Cathode Magnetization

Paramters	units	
Magnetization	μm	13.9±6

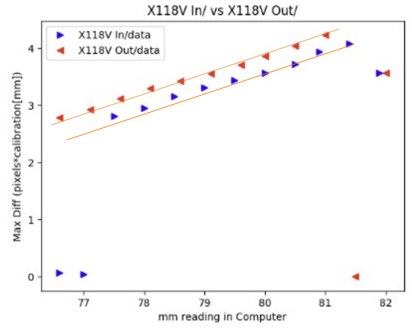
$$\begin{cases} \varepsilon_{n,+} = 2\gamma\mathcal{L} \\ \varepsilon_{n,-} = \dfrac{(\varepsilon_{n,u})^2}{2\gamma\mathcal{L}} \end{cases}$$



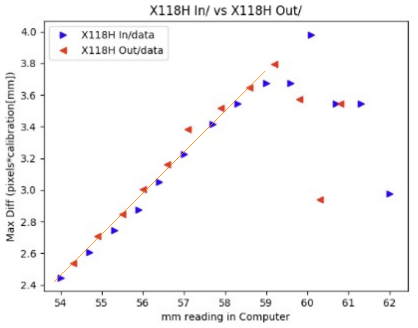
(a) Vertical X107 Slits



(b) Horizontal X107 slits



(c) Vertical X118 Slits



(d) Horizontal X118 Slits

Shearing Magnetization

Paramters	units	Data Set 1	Data Set 2
Magnetization	μm	31.8±4.9	37.8±3.3

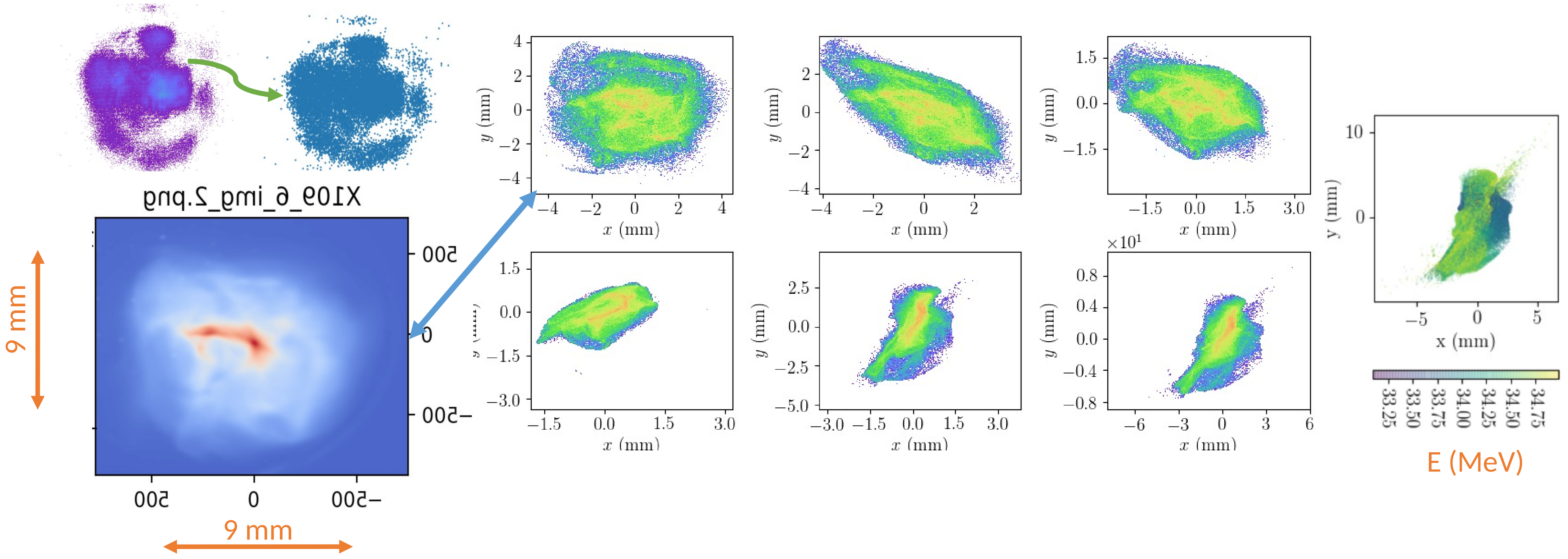
Cathode Magnetization

Paramters	units	Data Set 1	Data Set 2
Magnetization	μm	26.3±8.7	23.8±10.2

(analysis from Aaron Fetterman)

Simulation using realistic experimental conditions reproduce some of the experimental feature (A. Fetterman et al. NAPAC19)

- Optimization done for idealized laser distribution
- Impact of non-ideal distribution is explored via simulation

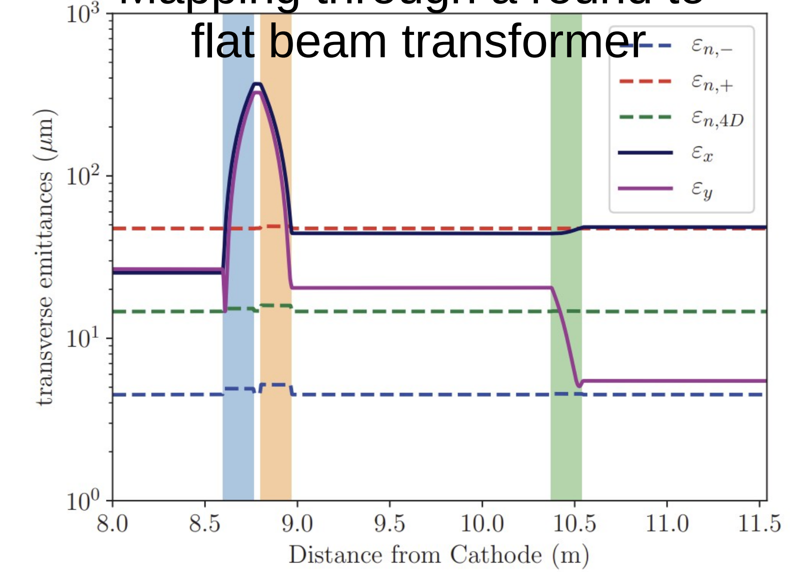


Proposal (phase I: 4 shifts)

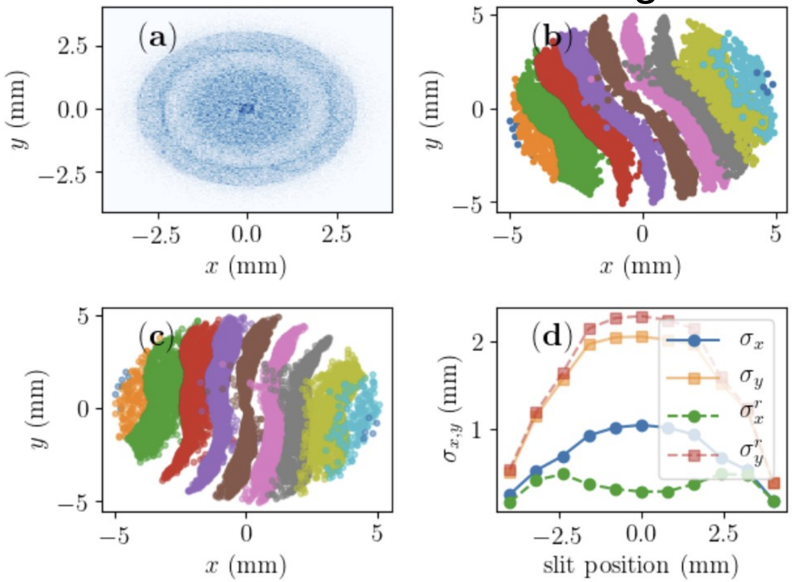
- Shift 1: essentially reproduce settings of run 1 (FEB/MAR):
  - Vary solenoid and monitor vacuum (processing)
  - Test all diagnostics and especially all the scanning single slits diagnostics
- Shifts 2-4 (contiguous): 1.6 and 3.2-nC magnetized beam characterization
  - Measure magnetization, eigen emittances,
  - Perform parametric studies for a few cases: several laser-spot radii. Ratio of Bmain and Bbuck
  - Take data to compare the two eigen-emittance measurement methods

Beam termination in low-energy absorber

Mapping through a round to flat beam transformer



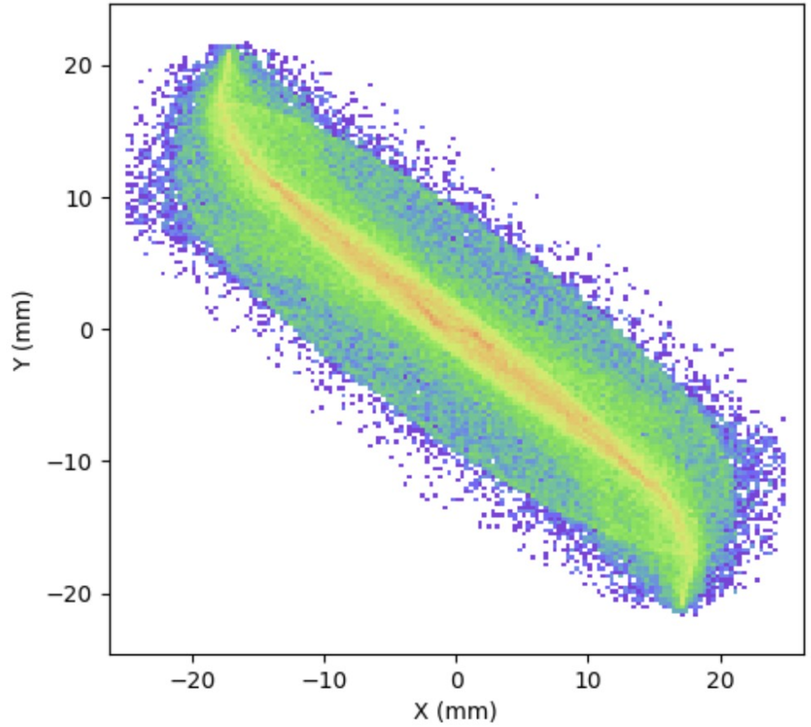
Direct measurement on mag. beam



Proposal (phase II: 2 shifts)

- Shift 5-6: beam transport to downstream cryomodule (assuming all data of phase I have been collected)
  - Transport through cryomodule (ideally with cryomodule eventually off)
  - Generation of a “skew” flat beam with Q441-3
  - Measure beam magnetization downstream of cryomodule and injector values.
  - If times allows study propagation of magnetized beams in a non-locally but globally symmetric beamline

Flat beam generated using Q441-3 quads and observed in the 450 area



!!! Beam termination: not sure on its way to HE dump (is it acceptable with up to 10 bunches (total Q~50 nC over macropulse?)

Personnel + TODO list

- **Shift personnel:**
  - Shift 1: local people (NIU include A. Fetterman and P. Piot)
  - Shift 2, 3, and 4: Jlab personnel will join (list to be finalized once we have possible dates)
  - Shift 5, 6: locals only (TBC) will likely include NIU's C. Marshall, A. Fetterman and P. Piot.
- **Hardware:**
  - Check CCD focus at slit locations [Aaron]
  - Deploy/test RCDS algorithm for fast on-line flat beams optimization [Philippe]
  - Ability to change the laser spot size between 2 to 4 mm (full radius) if not what is possible?
  - Are the ICTs OK?
- **Data acquisition/analysis**
  - Tools are mostly ready and will enable some preliminary on-line analysis to guide experiment