Possibilities of using LCLS2 as a FACET2 Witness Injector

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FACET Science Workshop

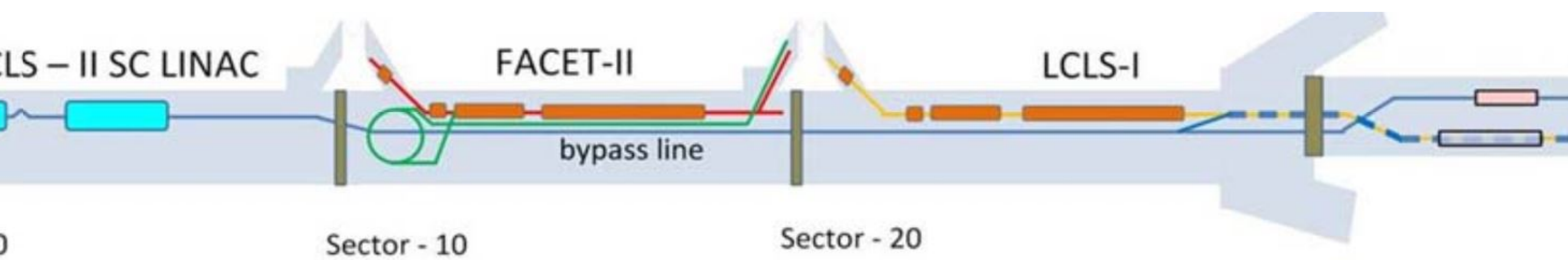
FACET2 and LCLS2

4 GeV LCLS2 beam goes right past the FACET2 user area

A kicker and a duplicate of the chicane used to bring the LCLS2 beam from the LINAC beamline to the bypass line could bring the LCLS2 beam collinear with the FACET2 beam

- Reality may be more complex

Would this be useful as a witness injector?



LCLS2 Beam Properties

Beam Energy: 4GeV nominal
- Possible operation at 4.5 GeV in the near term
- 8GeV energy being considered

Bunch charge: 10-300pC
- Variable depending on X-ray requirements
- Interleaving of different bunch charges not planned, but probably possible

Peak Current: 500-1500A
- 25fs RMS bunch length typical, but 2fs to 150fs operating range
- Interleaving of different bunch lengths not planned but may be possible
- Emittance: 0.15 microns at 10pC to 0.70 microns at 300pC

Beam power: 250KW initial, 1.2MW final

Bunch structure: Arbitrary fill of 1MHz (929KHz) buckets

Comparison with 100-300MeV Witness Injectors.

LCLS2 beam is likely brighter (in normalized units) than a witness injector that FACETII could build for this purpose

- LCLS2 4GeV energy gives a factor of >10 improvement in geometric emittance.
- Compressing to high peak current is difficult at low energy, so LCLS2 beam probably is brighter at high peak current than a 300MeV witness beam.

For experiments where the energy gain from plasma acceleration is small, a 4GeV beam is likely to be easier to transport through the plasma and into diagnostics

LCLS2 beam will be stable and have good diagnostics.

- Important for precision plasma measurements
- Get to piggyback on a $500M accelerator!

Limited tuning available for LCLS2 beam

- Primary running is for X-ray program

LCLS2 beam properties determined by X-ray program, may make scheduling difficult

To what extent can the LCLS2 beam be adjusted shot by shot?

Pulse Stealing Operation

- LCLS2 control and data acquisition systems are already designed to allow pulse stealing for diagnostics lines and to keep dump line paths verified.
  - Directing 30Hz pulses to FACET should have no effect on LCLS2 experiments.
- Components needed
  - 30Hz and "dogleg" line to move the beam axis
  - FACET / LCLS2 combining optics
  - Beam synchronization

Kicker Magnet and Dogleg

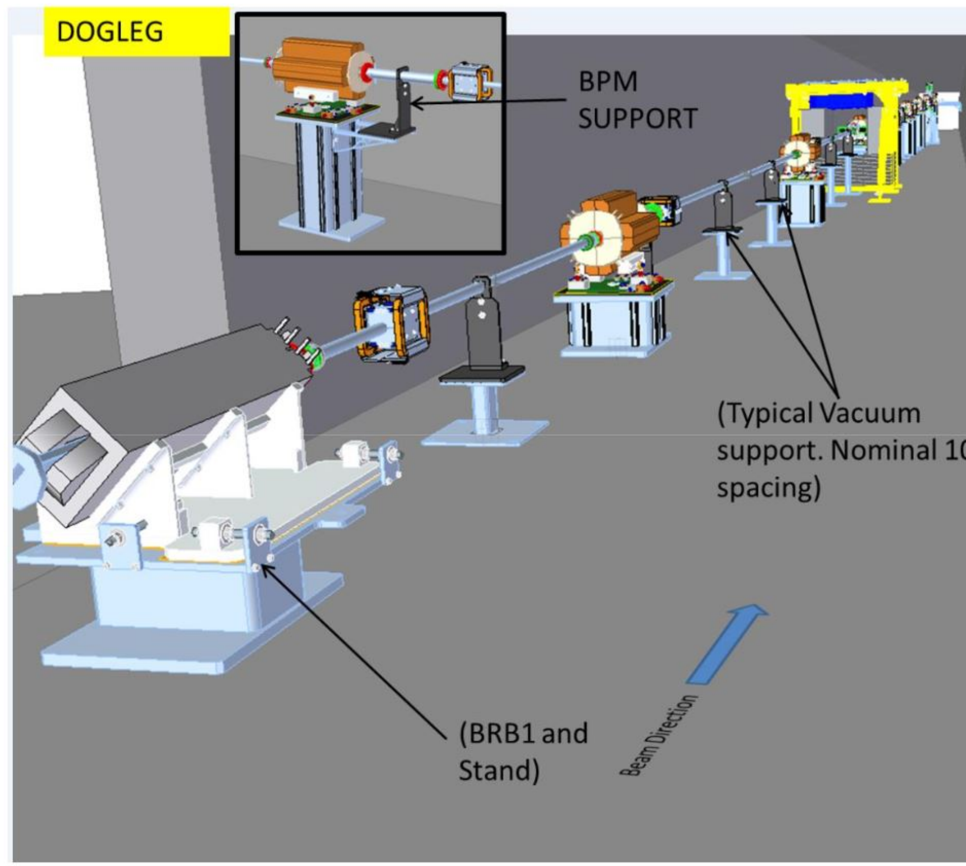
LCLS2 has a 100Hz kicker at the 100MeV point, and a 1MHz kicker at 4GeV. Both meet the stability and settling time requirement

- The first is probably not strong enough, the second is much higher average power than is needed.
- Clearly possible, but needs study

LCLS2 dogleg is large, but design exists.

No technical problem but needs cost estimate

nent	Quantity	Engineering Name	Status
Magnet	2	1.0D38.37	existing magnet
Magnet	8	R56	new design
pole Magnet	1	1.97Q20	existing magnet
pole Magnet	9	1.97Q10	existing magnet
pole Magnet	2	2Q4W	existing magnet
Corrector $(x + y)$	17	Type-4	existing design
Collimator	1	-	new
e BPM	10	-	existing design
canner	1	-	existing design



FACETII / LCLS2 Combining Optics

TII has e+ / e- compression chicane in front of experimental area for 10GeV beam

2 beam offset in vertical and horizontal

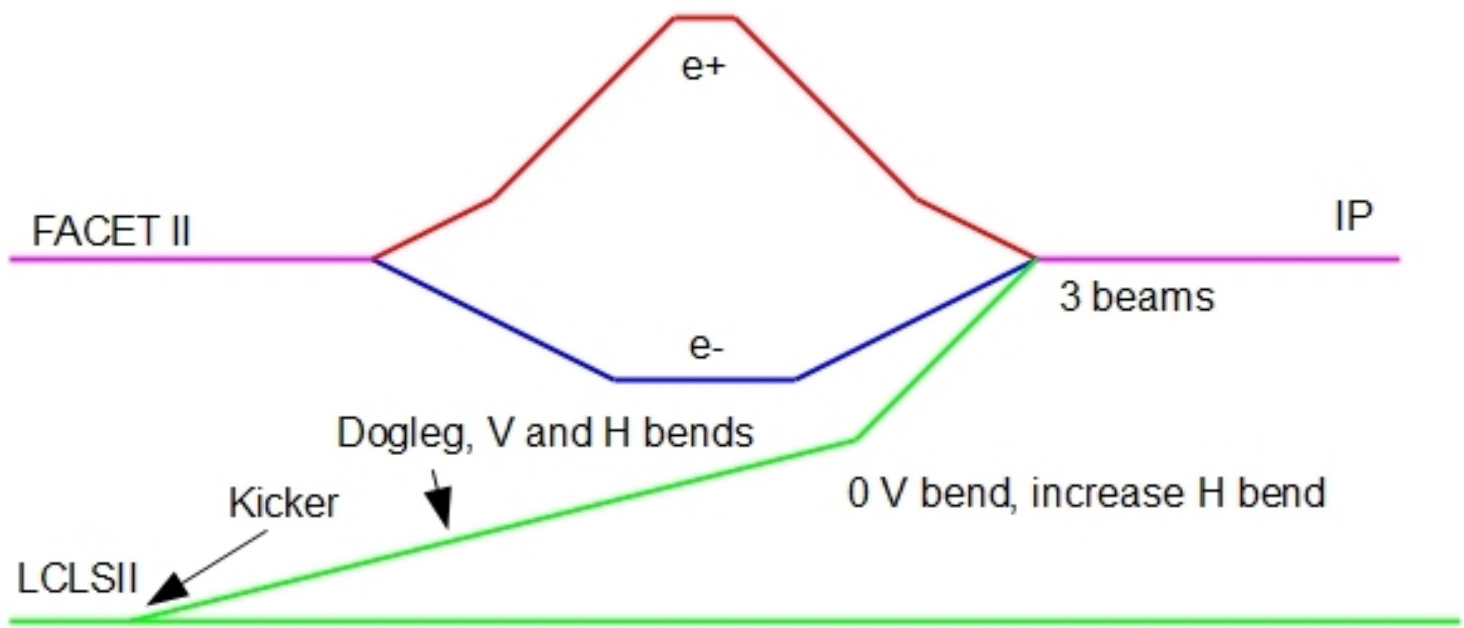
bring LCLS2 beam to same vertical level, then set input angle to combine final ben

equires fixed LCLS2 energy

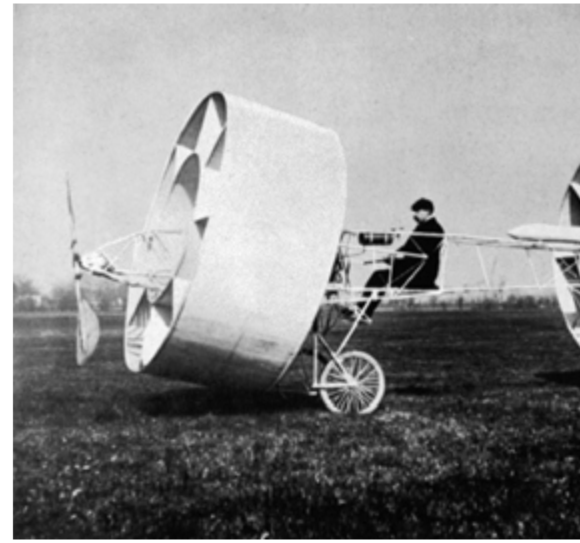
Modification to LCLS2 dogleg

asy to draw cartoon, but needs real beam optics study

use separate combining chicane – fewer constraints, but need to evaluate effect o
TII beams.



Optics – Lots of questions



The layout on the previous page is just a cartoon!

- Its not clear this even works for 1st order optics!

Is it possible to match the 4GeV beam size through the 10GeV final magnets?

The new dogleg will have dispersion.

- **This might be good!** The LCLS2 beam still has an energy chirp at this point – might be possible to compress further
- But can it be set to the required amount for full compression?

CSR beam breakup could be a serious issue in the final strong bend magnet

Many alternate optics can be considered

Needs real study!

Beam Synchronization

Master source for LCLS2 designed synchronize LCLS1

- All LCLS1 pulses land on a valid bucket for LCLS2
- Common "resync" frequency of 71.428 MHz

Can synchronize FACET2 as well.

- FACET2 ring is 14.57MHz go-around, or 204 X "resync".

Transporting 476MHz reference to FACET is straightforward with a stabilized fiber (commercial link) if not already in the plan.

Relative beam jitter will be limited by the jitter of FACET2, probably ~100fs RMS. Dominated by high power RF systems.

- This limit applies to any coupling of FACET to an independent electron source

LCLS2 pulse by pulse changes.

- LCLS2 accelerator uses superconducting cavities.
  - Can only change fields very slowly – not for bunch by bunch.
- “Fast” knobs?
  - Can use an independent gun laser – low rate, so not very difficult
  - Laser intensity: can make modest fast charge changes, and
  - Laser timing: will affect final compression
- Off frequency superconducting structure
  - For modes rate (~100<KHz) can tune one LCLS2 structure in L2 off by 100KHz. Normal bunches see nominal field, but bunches in offset bunches see different field > different compression. (this trick may be useful for LCLS2 for serving multiple users anyway).
- Needs study to determine how much flexibility there is in LCLS2 beams delivered to FACET2.

Worth Pursuing?

LCLS2 beam could be a very good probe: very low geometric emittance, low energy spread, at a convenient energy for plasma diagnostics.

A high stability and well diagnosed probe beam is important for understanding plasma physics:

- We've known for a while that plasma accelerators can generate very high gradients
- Need to show that they can operate with enough stability to be useful
- If both the pump and probe beams are unstable, its very difficult to map out the plasma effects

There is probably a way to make the optics work, but it will take some accelerator physics effort to find out.

Not clear how the construction cost compares with a separate 300MeV injector.

- Operating costs are low because it uses parasitic LCLS2 beam.