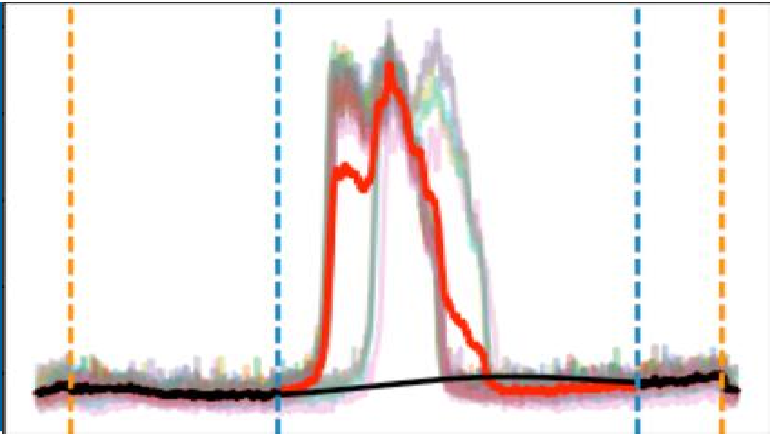
GOAL OF UPGRADES & FIRST STAB AT SPECS (FOR DISCUSSION)



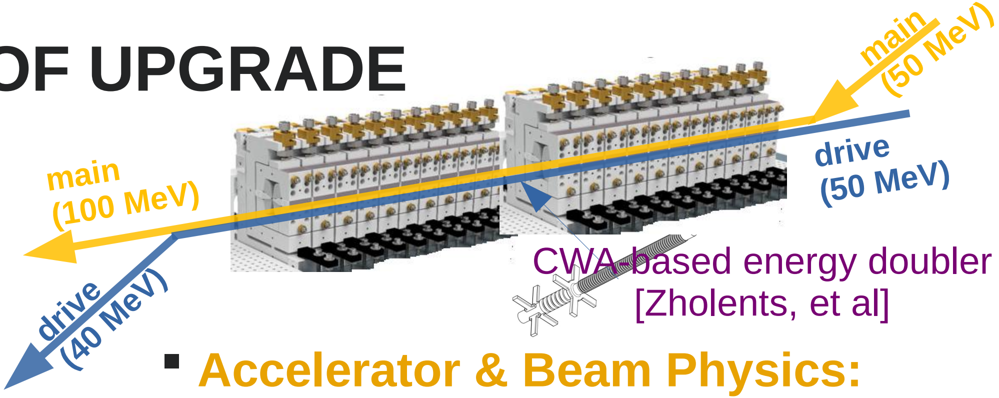
P. PIOT FOR THE AWA TEAM

AWA Upgrades mini-workshop
Virtual, March, 25th 2021

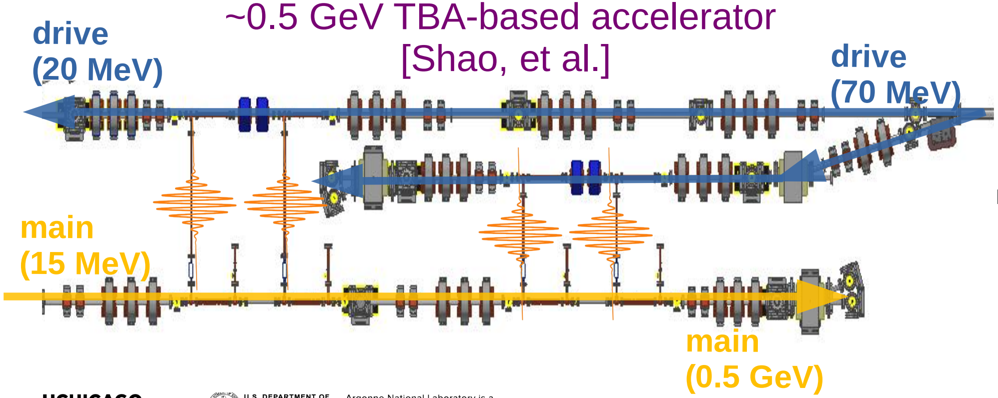
ANTICIPATED BENEFITS OF UPGRADE

Ultimate goals

- **Advanced Accelerator Concepts:**
  - Enabling GV/m scale (sub-THz accelerating structures)
  - Stable focusing/transport
  - Precise synchronization of two independent electron beams



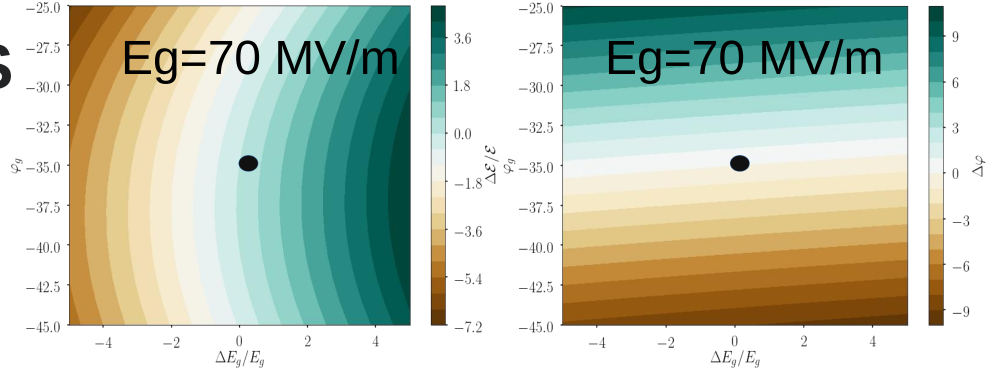
- **Accelerator & Beam Physics:**
  - Bright e- sources (high gradient)
  - Advanced beam shaping
- **Enabling new opportunities:**
  - Laser-beam interaction
  - New diagnostics R&D, ML/AI
- **Higher experiment throughput**
  - Better streamlining (e.g. scripts,…)
  - Automatic tuning/correction algo.

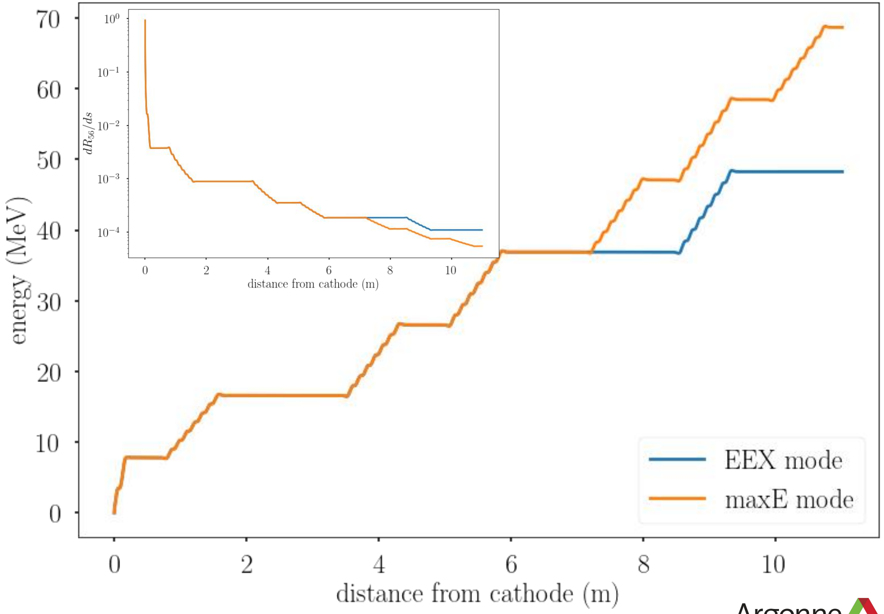


LONGITUDINAL DYNAMICS

Drive-Beam Accelerator (70 MeV)

- The photoinjector configuration is conventional
- The longitudinal beam dynamics is ”rigid” downstream of the gun (R56~0)
- The gun-laser phase is operated for the best emittance and correspond to a compression factor $\frac{\Delta\varphi_0}{\Delta\varphi_g} \sim 1$
  - Jitter in laser $\Delta\varphi_g$ translates into to jitter in beam arrival time $\Delta\varphi_0$
  - Gun amplitude jitter mostly produces energy jitter $\Delta\mathcal{E}$

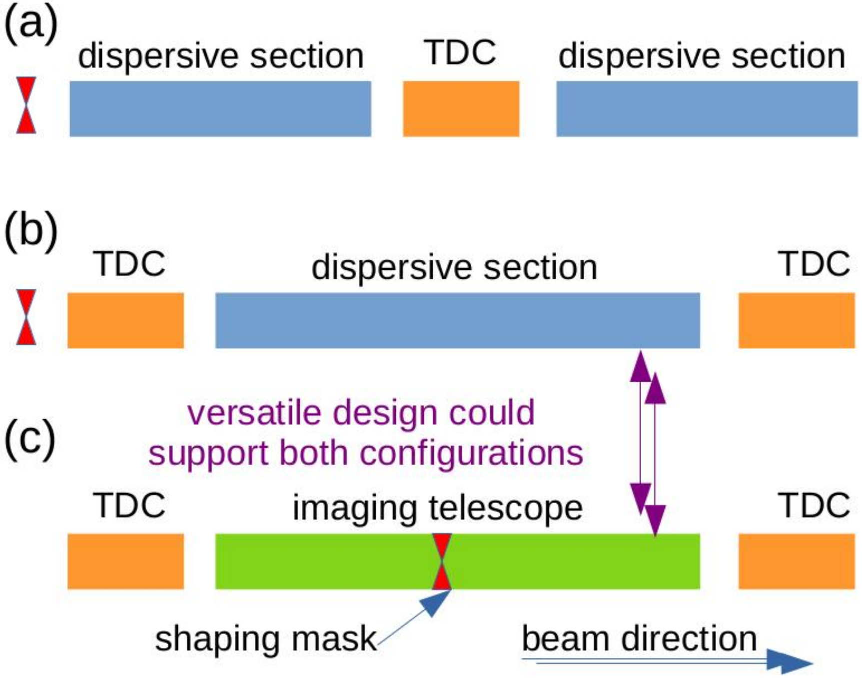




SPECIAL BEAMLINES (NOW AND PLANNED)

Accelerator & Beam Physics

- AWA beamline incorporate 4 transverse-deflecting cavities (**TDC**)
  - Diagnostic purpose
  - Phase-space exchanger/shaper
- EEX beamlines:
  - Single $(x, x') \leftrightarrow (\zeta, \delta)$
  - Double $(x, x') \leftrightarrow (\zeta, \delta) \leftrightarrow (x, x')$
- Shapers (under consideration):
  - Double-TDC shaper [Ha, 2020]
  - Chirper (w/ LANL) [Yampolsky, 2020]



LONGITUDINAL DYNAMICS

Requirements from TDC-based beamlines (general considerations)

- Synchronization with 1.3-GHz deflecting cavities (at zero Xing $\varphi_\perp = 0$)
  - Control over the $\langle x' z \rangle$ correlation i.e. $\kappa \equiv \frac{dx'}{d\zeta} \simeq \frac{ekV_\perp}{\mathcal{E}}$
  - Assume RMS phase jitter $\Delta\varphi_\perp \simeq k\sigma_z \ll 1$ so that $\Delta\varphi_\perp \sim 0.5$deg
  - Deflecting strength requirement $\Delta\kappa/\kappa \leq 0.01$ (coupling term dominated by cavity thick length effect) so

$$\frac{\Delta\mathcal{E}}{\mathcal{E}} \leq 5 \times 10^{-3} \quad \text{and} \quad \frac{\Delta V_\perp}{V_\perp} \leq 5 \times 10^{-3}$$

- TDCs are sometime used downstream of dispersive beamlines so that energy jitter causes of change in time of flight (and timing error in the TDC) imposing

$$\frac{\Delta\mathcal{E}}{\mathcal{E}} \leq \frac{\Delta\varphi_\perp}{kR_{56}} \quad \text{i.e.} \quad \frac{\Delta\mathcal{E}}{\mathcal{E}} \leq 5 \times 10^{-3} \quad \text{(for our standard EEX)}$$

LONGITUDINAL DYNAMICS

Requirement on timing

- Phase jitter are principally introduce by the laser so $\Delta\varphi_g \sim 0.5$ deg
- Some beamlines require the chirp h to be set (and stable) to a precise value – typically $h = -1/R_{56}$:
  - EEX beamlines
  - Bunch compressor (e.g. as part of AWA-II or combined with TDC-shaper)
- One can estimate the error on the chirp to be

$$\frac{\Delta h}{h} = \left|\frac{\Delta V}{V}\right| + \left|\frac{\Delta \mathcal{E}}{\mathcal{E}}\right| + |\Delta\bar{\varphi} \times \tan\bar{\varphi}|$$

An effective phase for the full linac

- Requiring $\frac{\Delta h}{h} \leq 0.01$ implies

$$\frac{\Delta V}{V} \leq 5 \times 10^{-3}$$

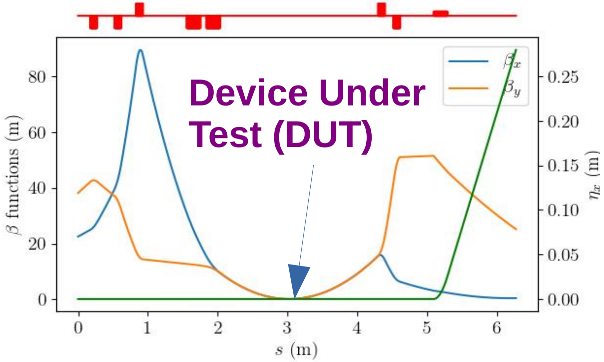
$$\frac{\Delta \mathcal{E}}{\mathcal{E}} \leq 5 \times 10^{-3}$$

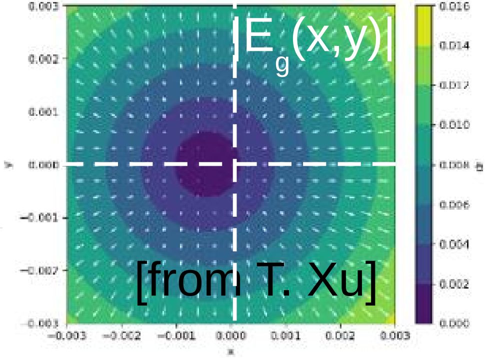
$\Delta\bar{\varphi} \sim 0.5$ deg accommodates $|\bar{\varphi}| \leq 20^\circ$

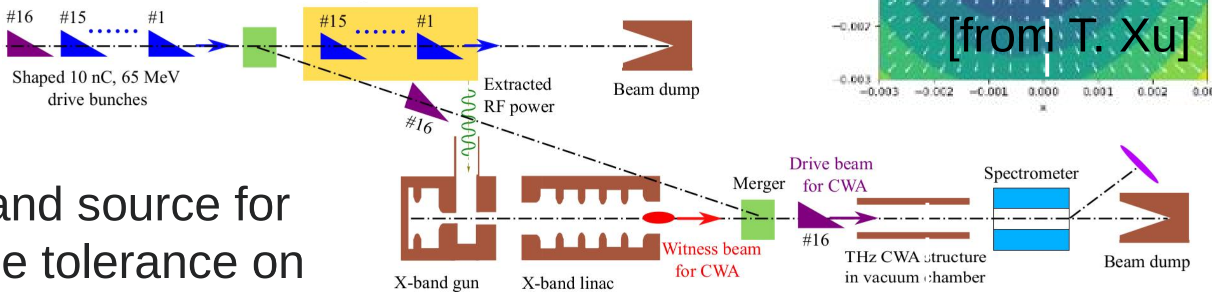
OTHERS CONSIDERATIONS (TO LIST)

Requirement from transverse dynamics & other

- Final focus
  - Energy jitter impact final spot in DUT (not quantified but estimate based on chromatic functions show that previous energy jitter requirement is OK)
- Transverse kick
  - Asymmetric power couplers in gun and linac introduce a time-dependent kick (not quantified)
- So far focused on 1.3 GHz, we have a proposal to use an independent X-band source for sub-THz CWA (phase tolerance on 1.3 GHz would be tighter by factor 9!)







[from NIU/IIT proposal using Euclid X-band gun]

SUMMARY & ON-GOING WORK

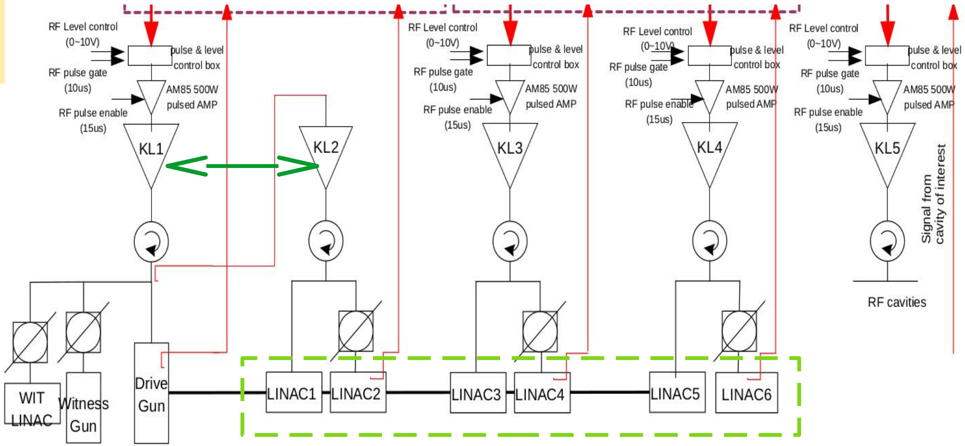
Trying to generate a PDR à la APS

- Develop some simple model to estimate ”macroscopic” requirements on phase/ amplitude jitters the estimated phase and amplitude tolerances are

$$\frac{\Delta V}{V} \leq 5 \times 10^{-3}$$

$$\Delta\bar{\varphi} \sim 0.5 \text{ deg}$$

- Will use TWICE (python version of LiTrack [by W.H. Tan]) to perform a statistical analysis and provide phase and amplitude tolerances on individual components for RF configuration



$V \; \bar{\varphi}$

- **Any else we should do to specify system?**