# SWFA DEMONSTRATORS WITH INTEGRATED TECHNOLOGIES FOR FUTURE LARGE-SCALE MACHINES

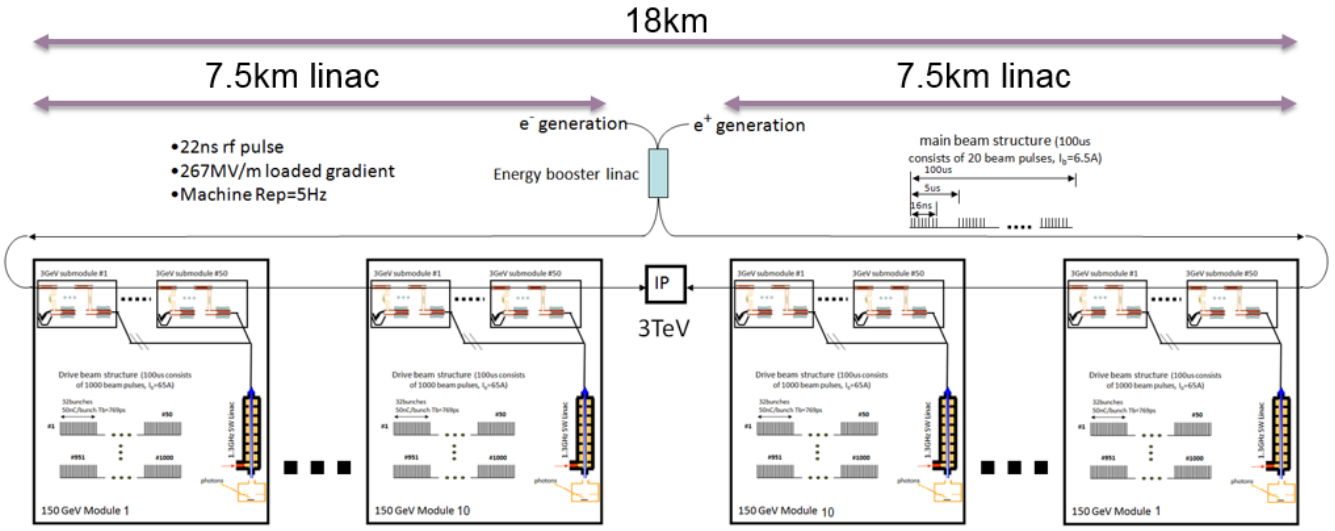
JIAHANG SHAO

Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

AF7 - SUBGROUP RF - MINIWORKSHOP ON CAVITY PERFORMANCE FRONTIER

# BACKGROUND

## TBA: TeV-scale linear collider (AFLC)




W. Gai, et al, *JPP* **78**, 339-345 (2012)

### Key technologies and challenges:

- **High power generation and high gradient acceleration**
- **High efficiency acceleration**
- **Staging**

# BACKGROUND

## TBA: TeV-scale linear collider (AFLC)

- **High power generation and high gradient acceleration**

**400 MW** | **1 GW**

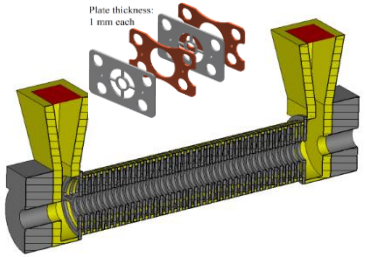
**150 MeV/m** | **267 MeV/m** Main beam acc.

**250 MV/m** BD test

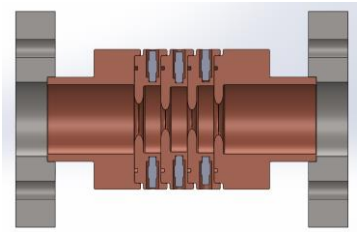
**Metallic disk loaded**
**400 MW**

M. Peng, et al, *in preparation*

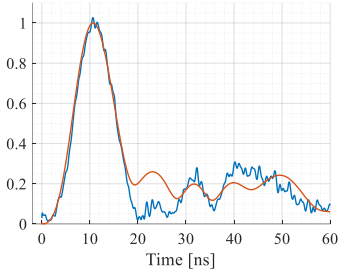
**Metamaterial**
**380 MW**



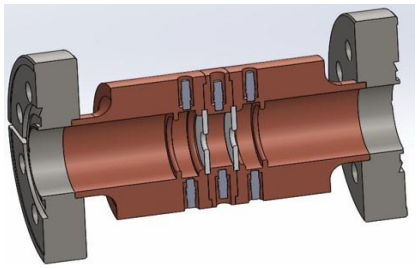

X. Lu, et al, *APL* **116**, 264102 (2016)



M. Peng, et al, *in preparation*



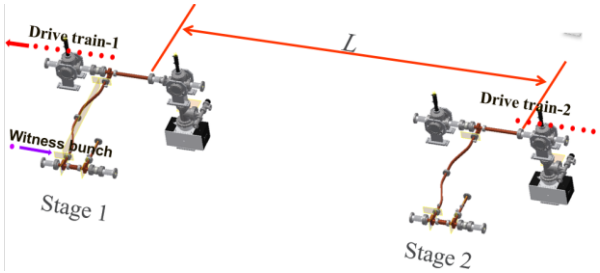

- **High efficiency acceleration**

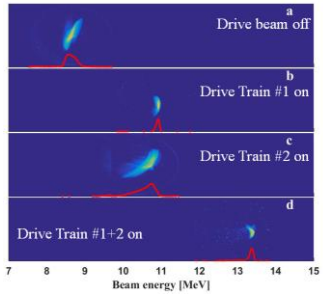


B. Freemire et al. *in preparation*

- **Staging**

**Multi-stage** | **Multi-structure** | **High fidelity**

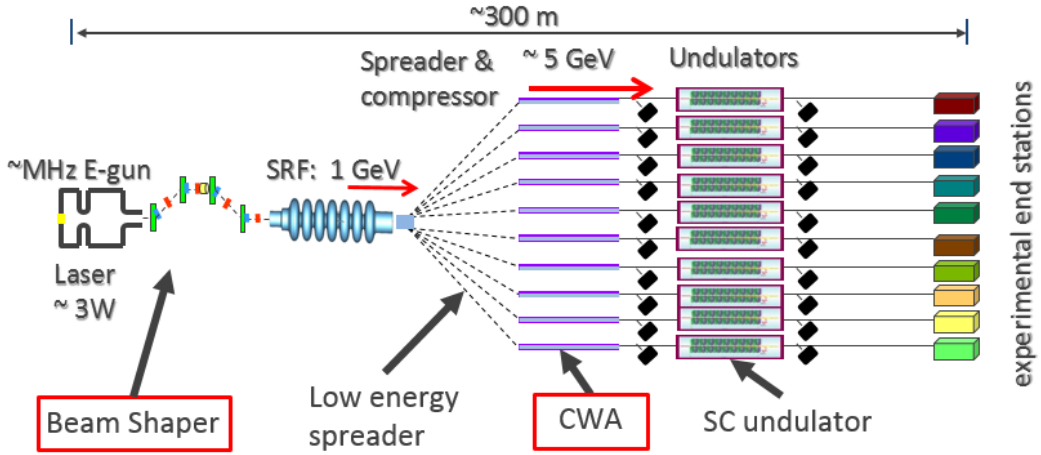



C. Jing, et al, *NIMA* **898**, 72 (2018)

# BACKGROUND

## CWA: XFEL




A. Zholents, et al, *Proceedings of IPAC2018*

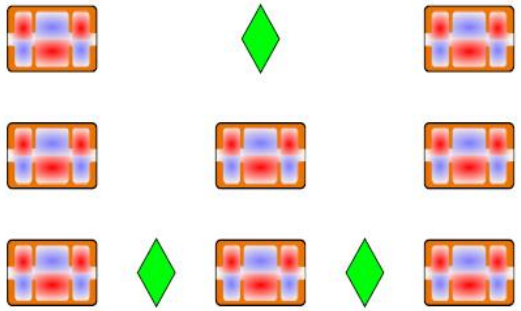
**Key technologies and challenges:**

- **High charge drive beam shaping**
- **High frequency corrugated waveguide structure**
- **Beam break-up control**
- **SC undulators**

# BACKGROUND

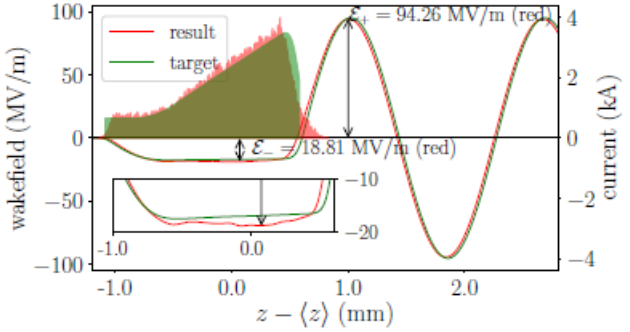
## CWA: XFEL

- **High charge drive beam shaping**



TDC shaping

G. Ha, et al, *PRAB* **23**, 072803 (2020)

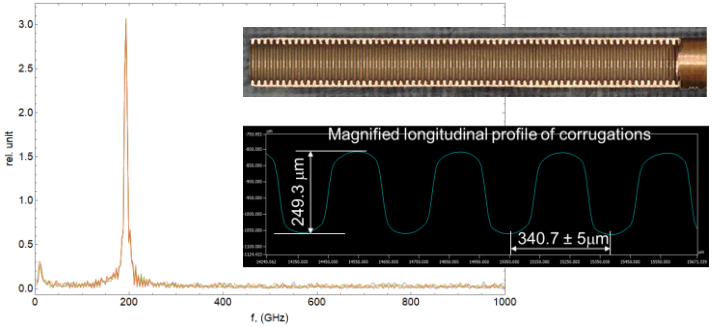



Laser shaping

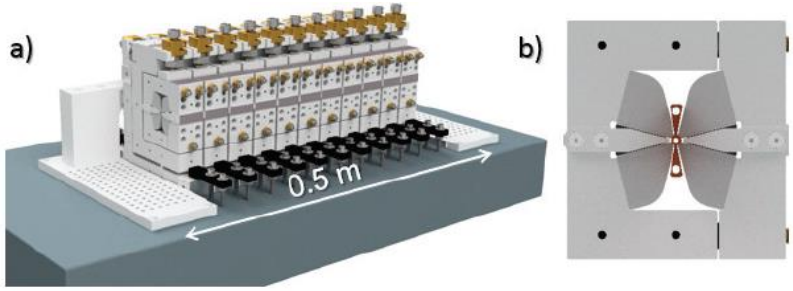
W. Tan, et al., *arXiv* 2101.07414 (2021)

- **High frequency corrugated waveguide**

Courtesy of A. Zholents

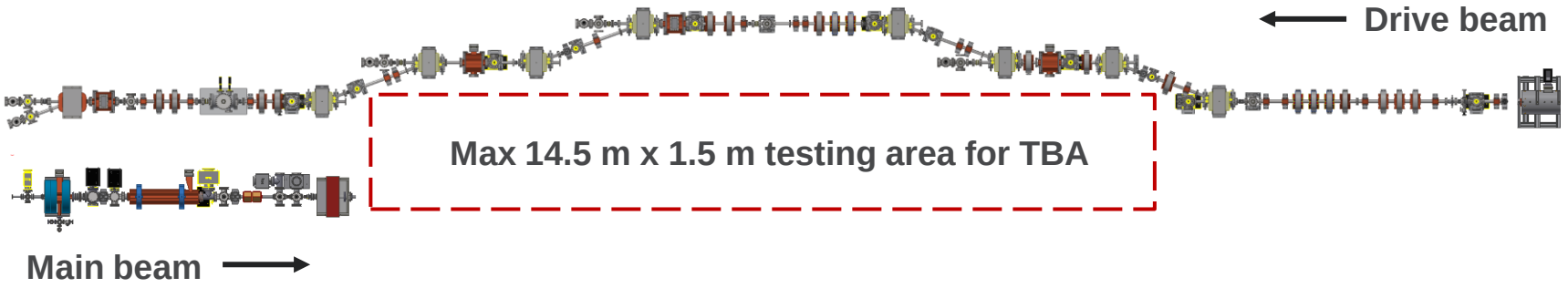



- **Beam break-up control**




A. Zholents, et al, *Proceedings of IPAC2018*

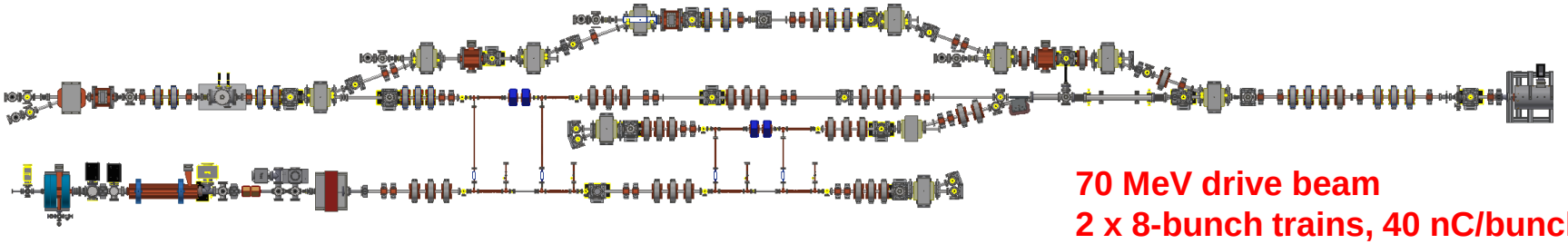
# ARGONNE WAKEFIELD ACCELERATOR FACILITY (AWA)




- **Two independence beamlines**
  70 MeV drive beam, 15 MeV main beam
- **World's highest charge drive beam**
  100 nC single bunch, 600 nC bunch train
- **Beam shaping**
  World's only operating EEX/DEEX, CSR-free shaping methods in development
- **Flexible beamline configuration**
  Multiple testing zones available

# PROPOSED DEMONSTRATORS (NEAR-TERM)

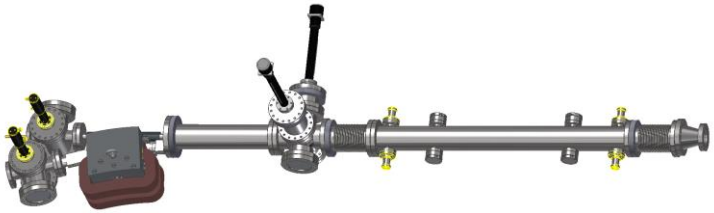
## TBA: 500 MeV demonstrator

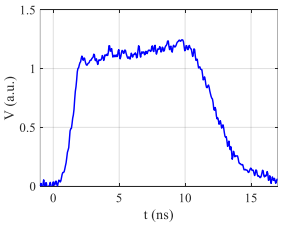


**15 MeV main beam**
**Low charge single bunch**
**Accelerated to ~500 MeV**

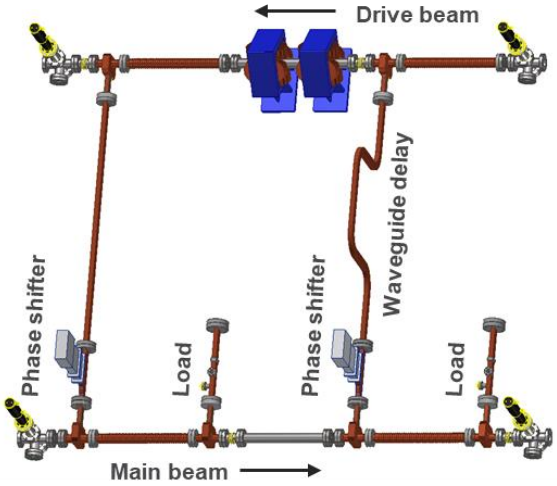
**70 MeV drive beam**
**2 x 8-bunch trains, 40 nC/bunch**
**Decelerated to ~20 MeV**

- **Drive beam distribution**





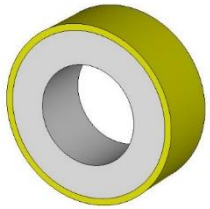

- **Stage acceleration**



# PROPOSED DEMONSTRATORS (NEAR-TERM)

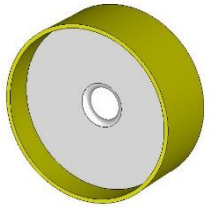
## TBA: 500 MeV demonstrator

- **Dielectric loaded structure**



| | f GHz | $\varepsilon_r$ | a mm | r/Q kΩ/m | $\beta_g$ | L m | $P_{flat}$ GW | $W_{loss,2}$ MeV | $W_{gain,4}$ MeV | G MV/m |
|---|---|---|---|---|---|---|---|---|---|---|
| PETS | 26.0 | 3.75 | 3.1 | 11.6 | 0.33 | 0.46 | 1.27 | 52.0 | / | / |
| ACC | | 3.75 | 1.2 | 26.1 | 0.27 | 0.43 | / | / | 417 | 242 |

- **Dielectric disk structure**



| 2π/3 | f GHz | $\varepsilon_r$ | a mm | r/Q kΩ/m | $\beta_g$ | L m | $P_{flat}$ GW | $W_{loss,2}$ MeV | $W_{gain,4}$ MeV | G MV/m |
|---|---|---|---|---|---|---|---|---|---|---|
| PETS | 26.0 | 38 | 3.2 | 13.3 | 0.31 | 0.42 | 1.37 | 54.2 | / | / |
| ACC | | 9.8 | 1.2 | 28.1 | 0.30 | 0.49 | / | / | 502 | 256 |

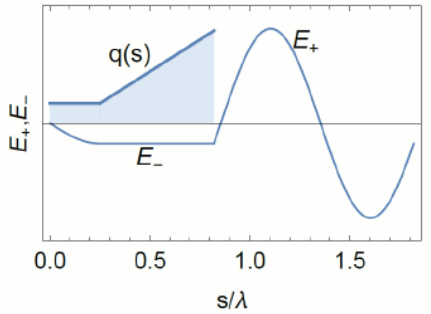
- **Other candidates under investigation**

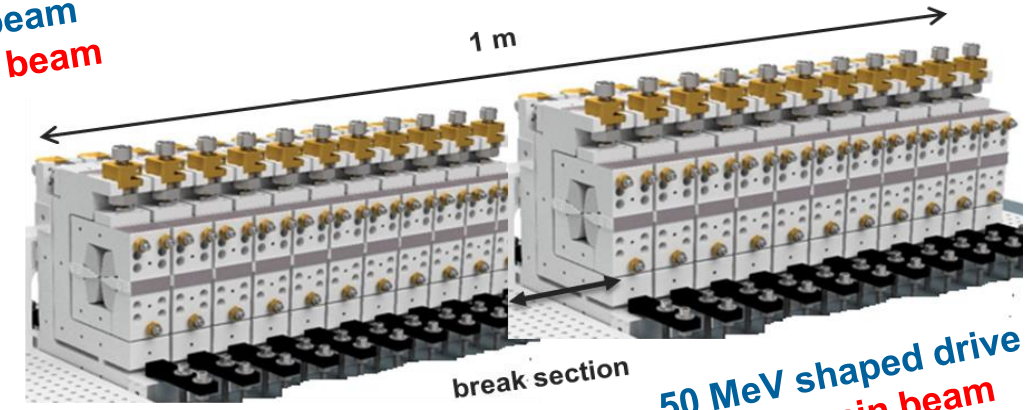
- 40 nC drive beam: $\varepsilon_n = 80$ μm
- 0.1-3 nC main beam: $\varepsilon_n = 10$ μm

# PROPOSED DEMONSTRATORS (NEAR-TERM)

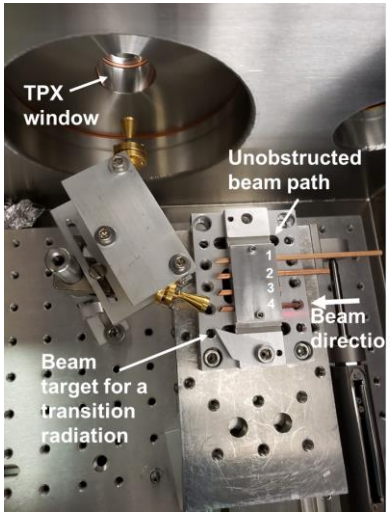
## CWA: Energy doubler

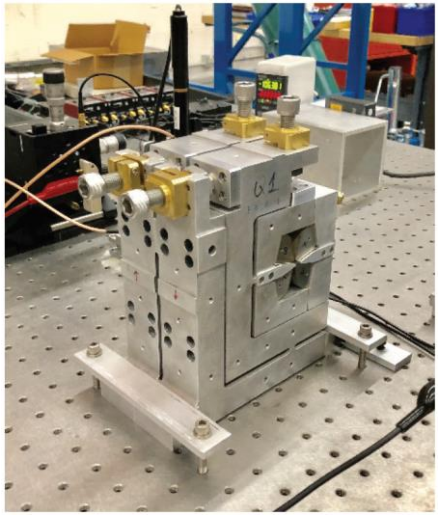
40 MeV drive beam
100 MeV main beam




50 MeV shaped drive beam
50 MeV main beam



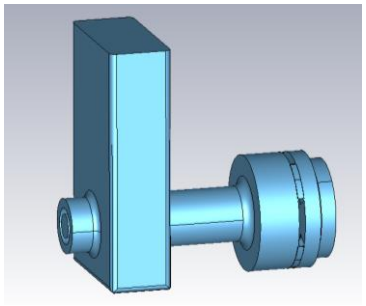



Courtesy of A. Zholents

# PROPOSED DEMONSTRATORS (MID-TERM)

## TBA

- **3 GeV multi-bunch demonstrator**
  4 stages, 6 PETS/stage
  24 accelerating structure
  13 GHz main beam with multi-bunch train generated from X-band gun

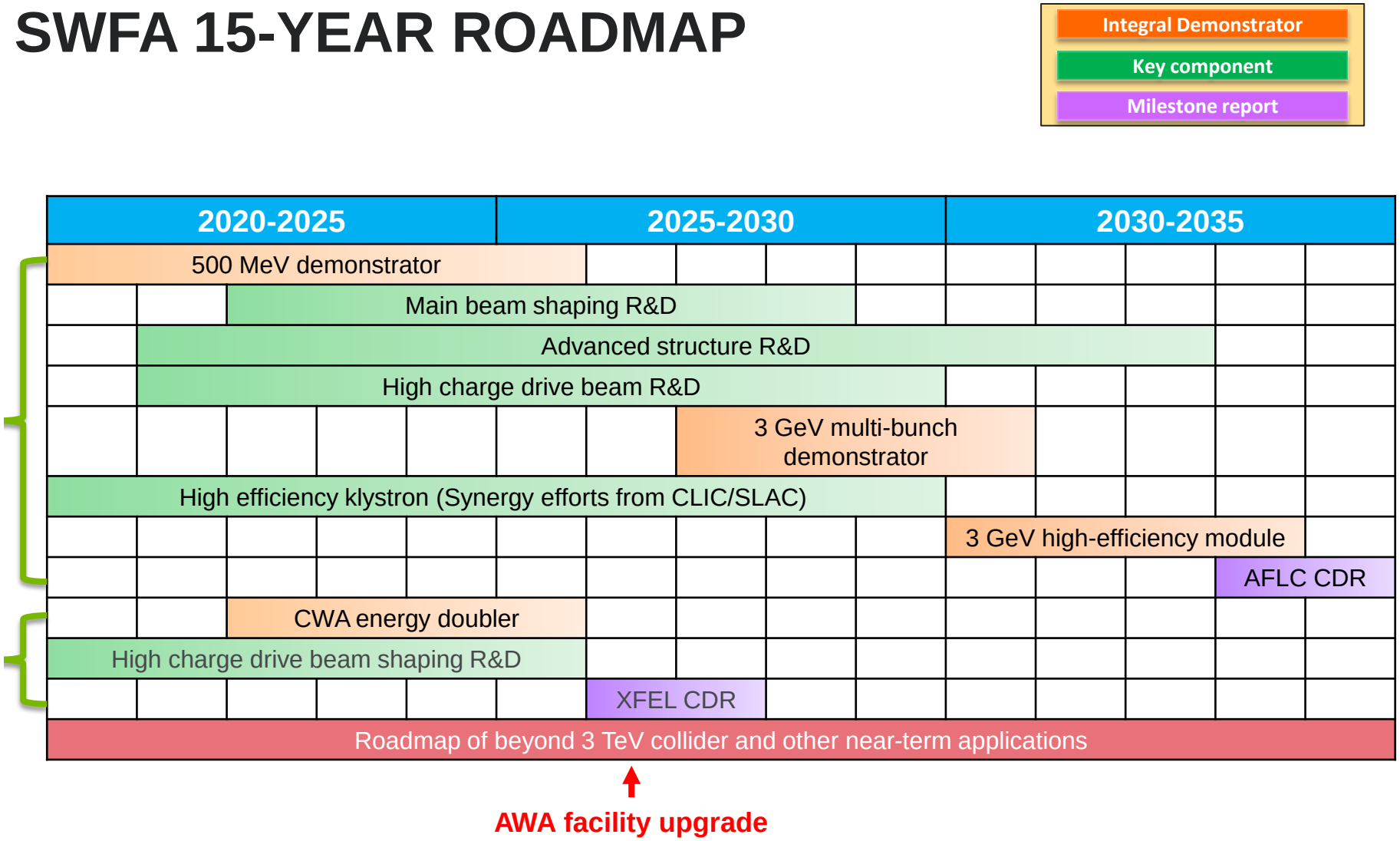


- **3 GeV high-efficiency module (fully functional module for AFLC)**
  Main beam shaping
  Beam loading compensation
  High efficiency klystrons

## CWA

- **Explore CWA concepts for future TeV-scale collider**

# SWFA 15-YEAR ROADMAP



# SUMMARY

- **Solid progress has been made on key technologies in TBA and CWA**
- **Near-term demonstrators in the AWA facility are proposed to test integrated technologies for future linear collider and XFEL**
- **Mid-term demonstrators aim for higher-level integration towards fully functional modules in future large scale machines**
- **Collaboration in the SWFA community, knowledge from broader high gradient studies, support from funding agencies are critical for demonstrators realization and success**