# HEP Perspective on FACET-II Long-Term Planning

## Long-Term Planning Meeting

Spencer Gessner, **SLAC**

March 14th, 2023

SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

# How do we think about science at FACET-II?

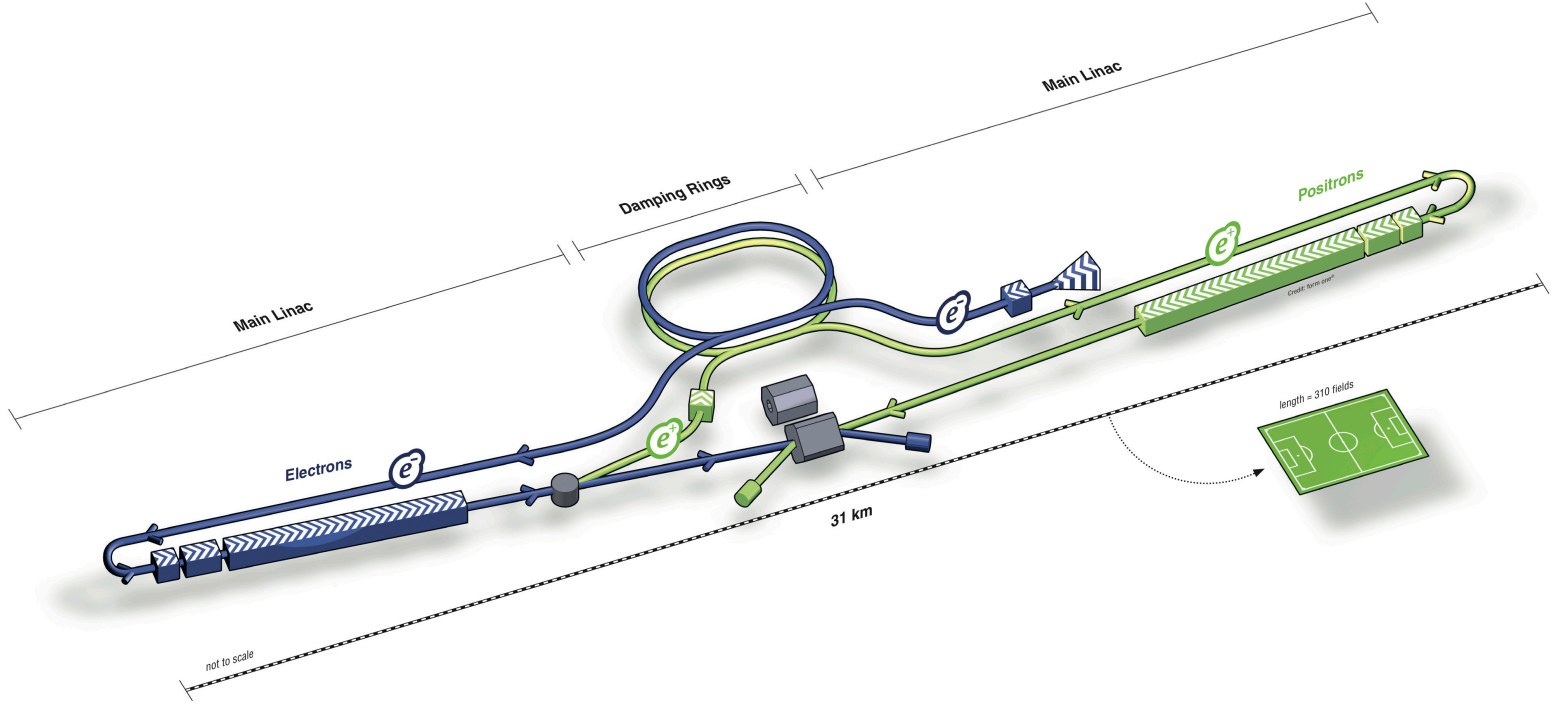
- If we were not constrained by funding, resources, or timelines, how would we pursue the best science at FACET-II?
- If we want to do science quickly, what should our priorities be?
- If we want to pursue Nature-level publications at FACET-II, what should our priorities be?
- If we want to address HEP/P5 concerns, what should our priorities be?

# HEP-Oriented Perspective

1. High-quality PWFA = Energy doubling + high efficiency + low energy spread + emittance preservation
   - What emittance value is acceptable? Is 30 microns too big?
2. Positrons!
   - FACET-II is only place in the world where we can do positron PWFA.
   - Electron-driven, positron-witness PWFA has never been demoed.
   - Obvious need for e+e- collider
3. Laser-electron beam collision for generating gammas
   - Critical for gamma-gamma collider
   - May help to understand QED processes in beamstrahlung
4. Plasma lenses
   - Important for beam delivery system
   - Test Oide limit
5. Low emittance electron beams from plasma
   - Good for HEP if we can get high enough charge

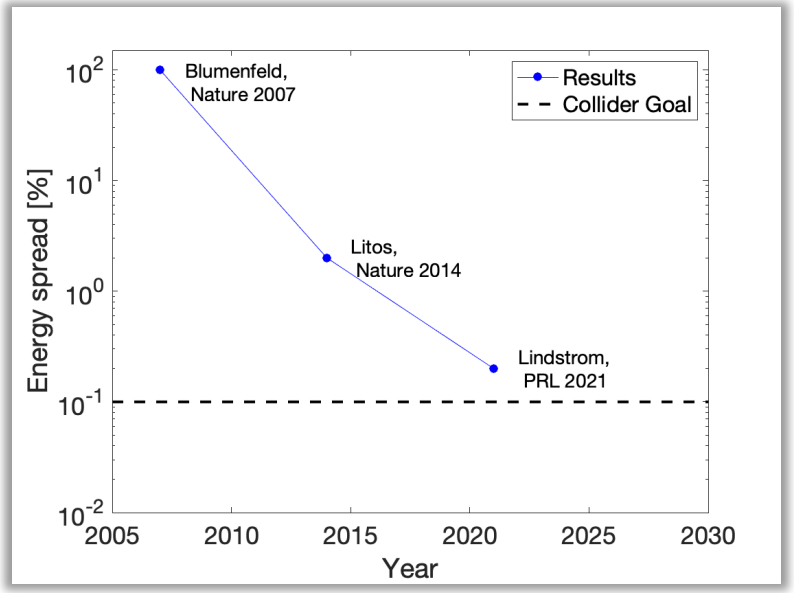
# Slides from Muon Collider Workshop

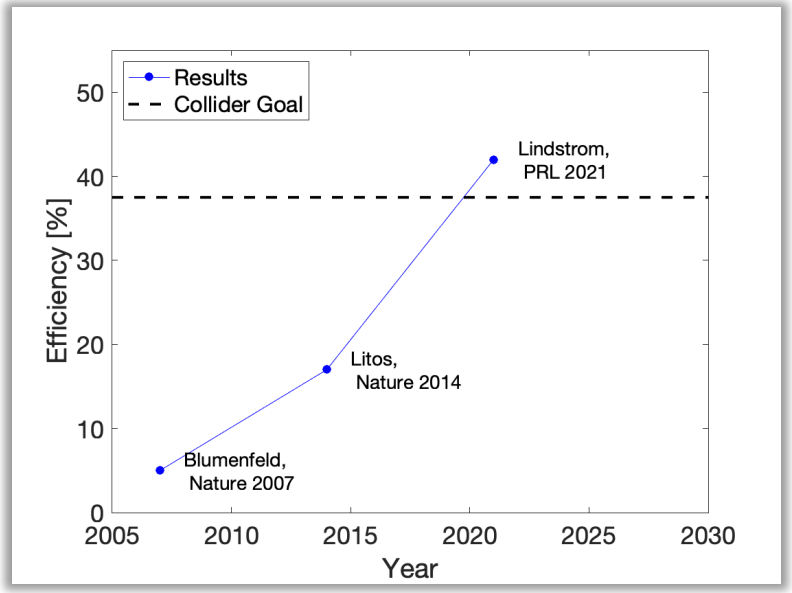
# Linear Collider Goals Drive Wakefield Accelerator Research

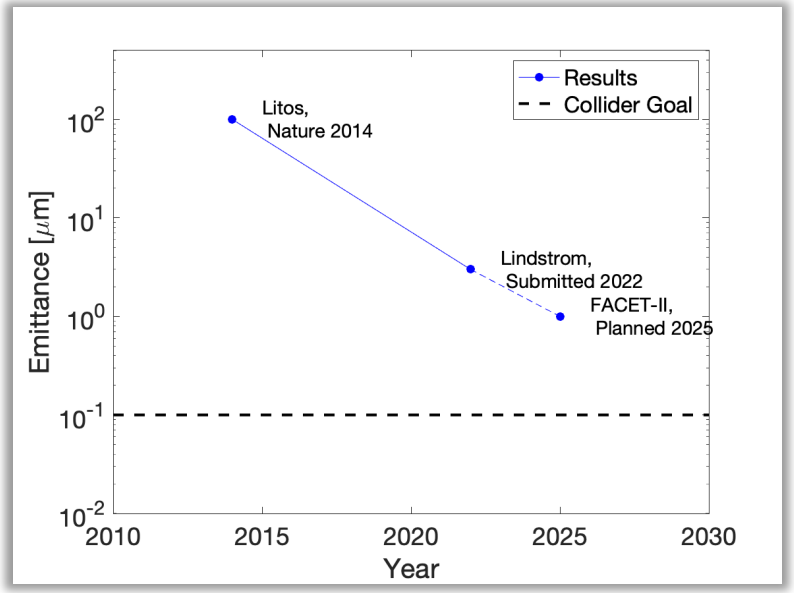



- Multi-TeV Linear Colliders are the ultimate goal of Wakefield Accelerator (WFA) research.
- Research targets include:
  - Ultra-high gradients = Compact colliders
  - Highly-efficient acceleration = Low power consumption
  - Short bunches = Increased luminosity

# Measurable Progress Toward Collider Goals

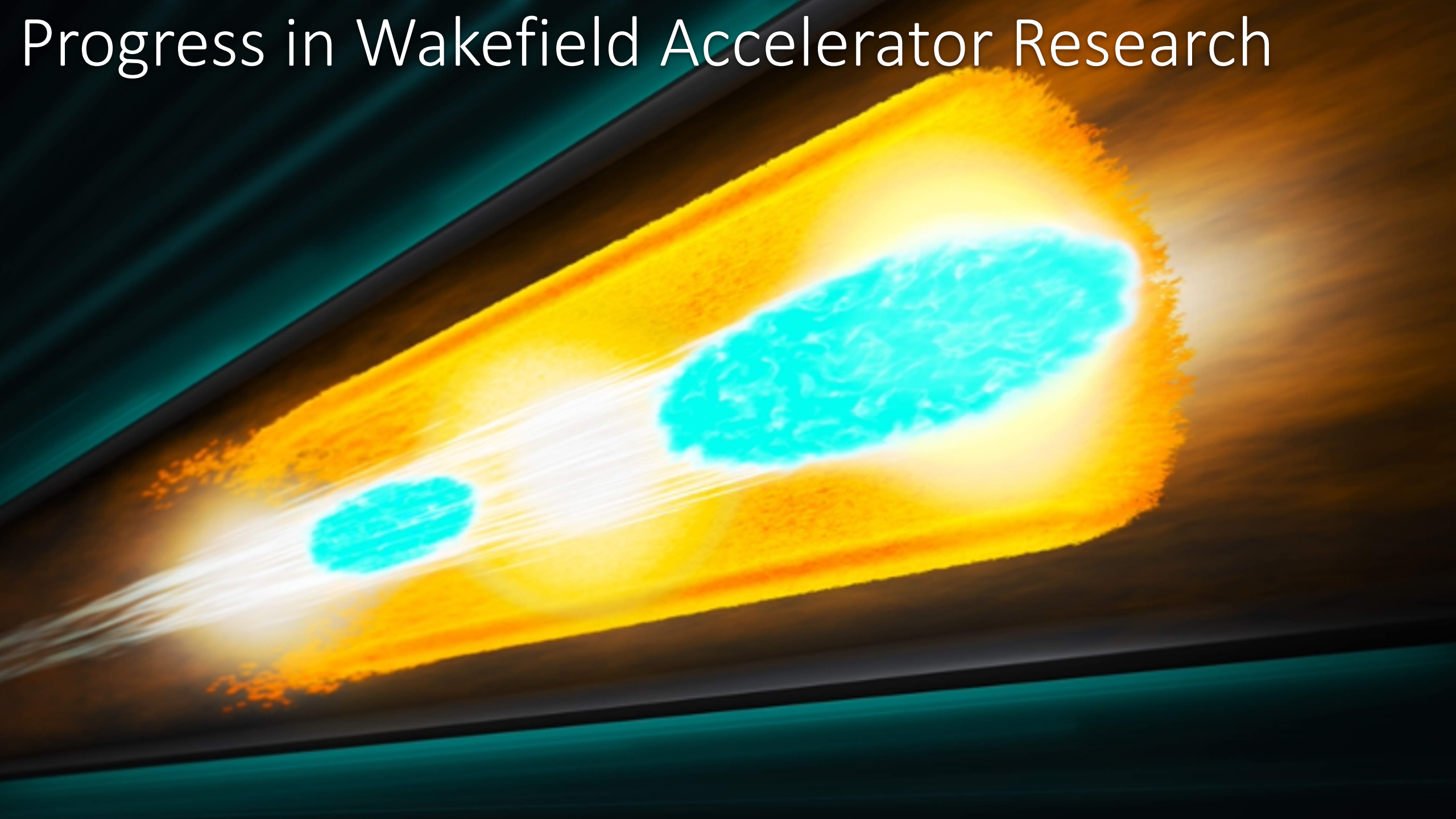



Plasma wakefield accelerators are approaching and *exceeding* the beam quality targets for a Linear Collider.

# Progress in Wakefield Accelerator Research



# Research Progress Since Last Snowmass/P5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2013 2014 2017 2018


2018 2019 2022 2023

# Research Progress Since Last Snowmass/P5


2013 2014 2017 2018


2018 2019 2022 2023

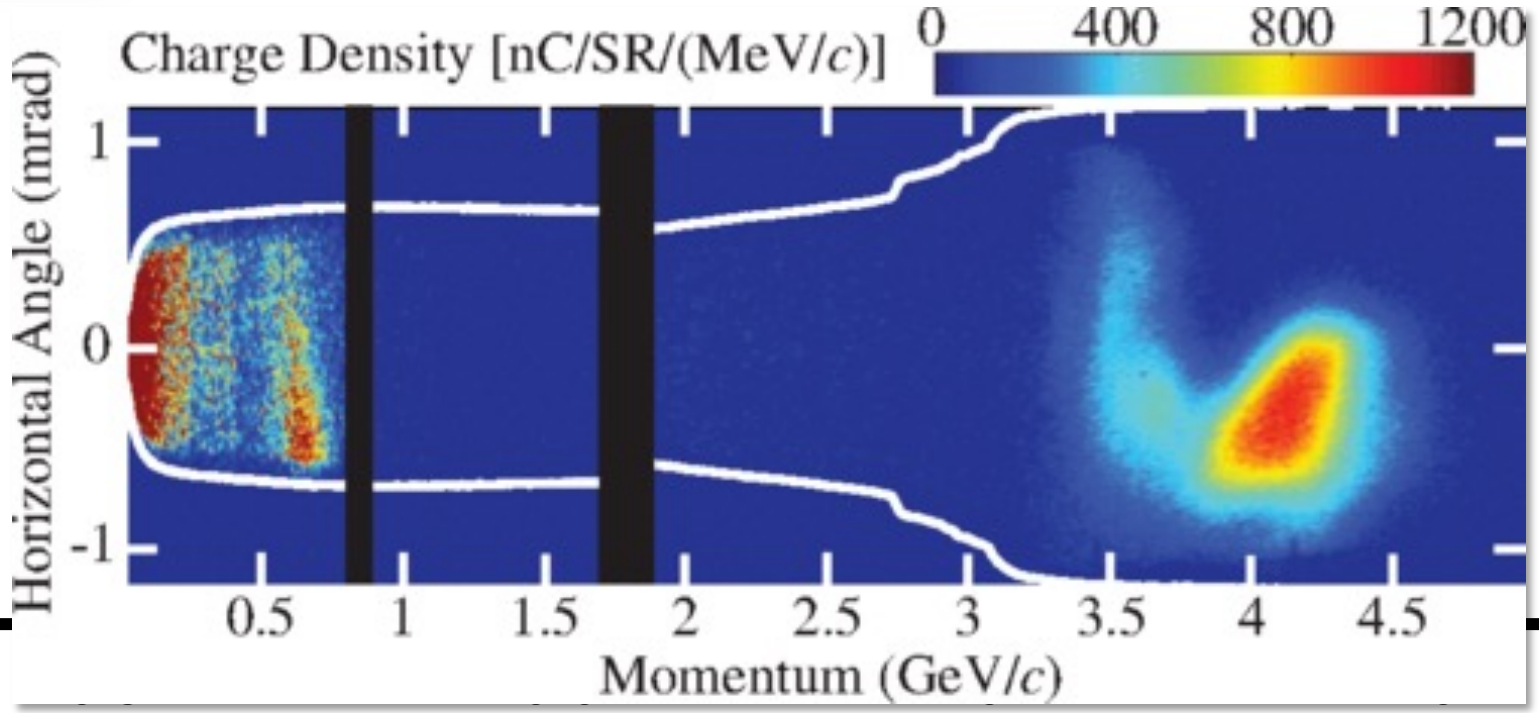
Efficient, Two-Bunch Acceleration in Plasma
M. Litos et al, **Nature**, (2014)

# Research Progress Since Last Snowmass/P5



2013

2018



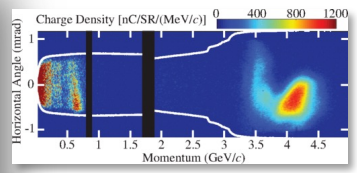

2018

2023

Multi-GeV Laser Wakefield Acceleration
W. Leemans et al, **PRL**, (2014)

# Research Progress Since Last Snowmass/P5



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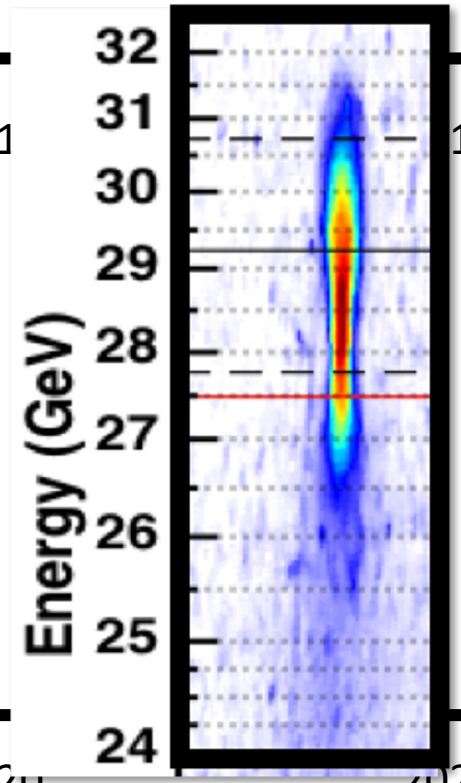
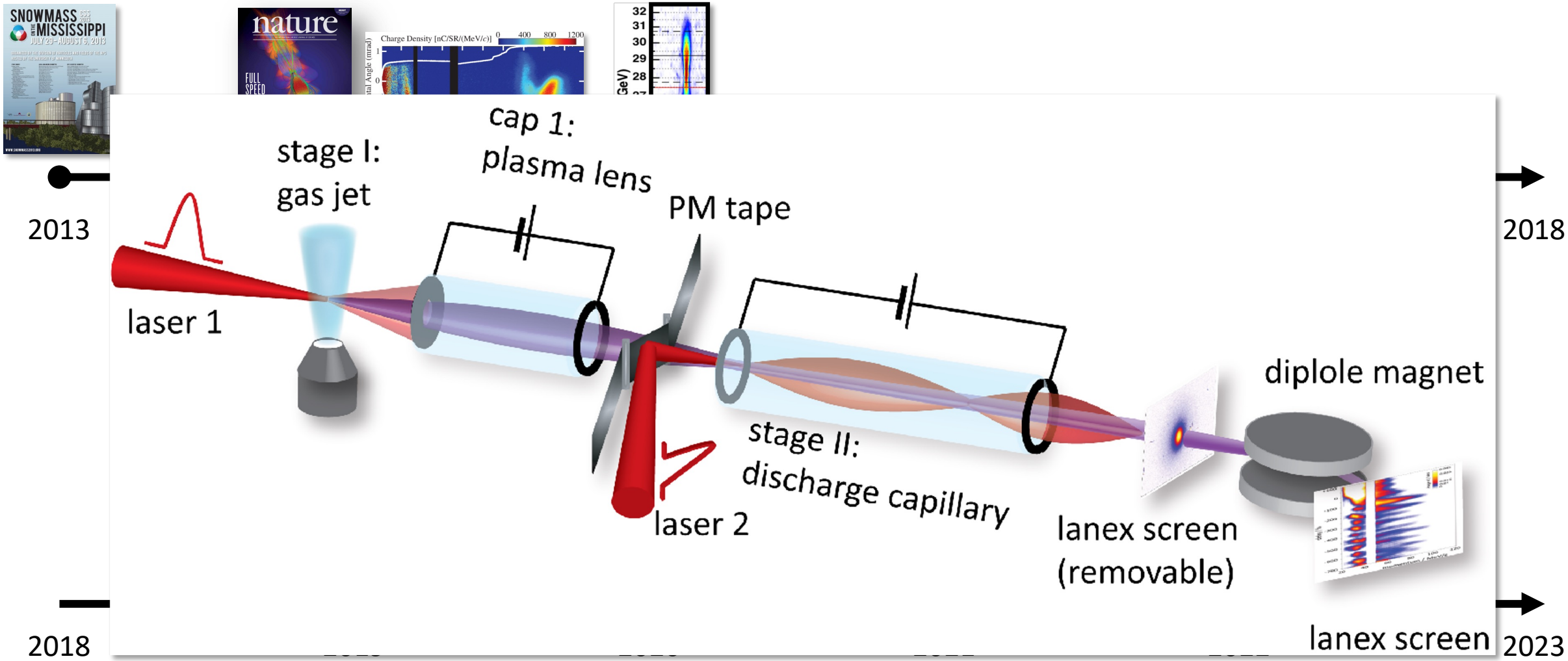



2018 2019 2020 2021 2022 2023

Two-bunch acceleration to 9 GeV
M. Litos et al, **PPCF**, (2015)

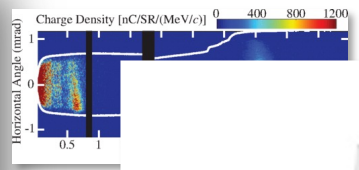
# Research Progress Since Last Snowmass/P5

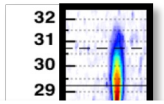



Staging of Laser Wakefield Accelerators
S. Steinke et al, **Nature**, (2016)

# Research Progress Since Last Snowmass/P5



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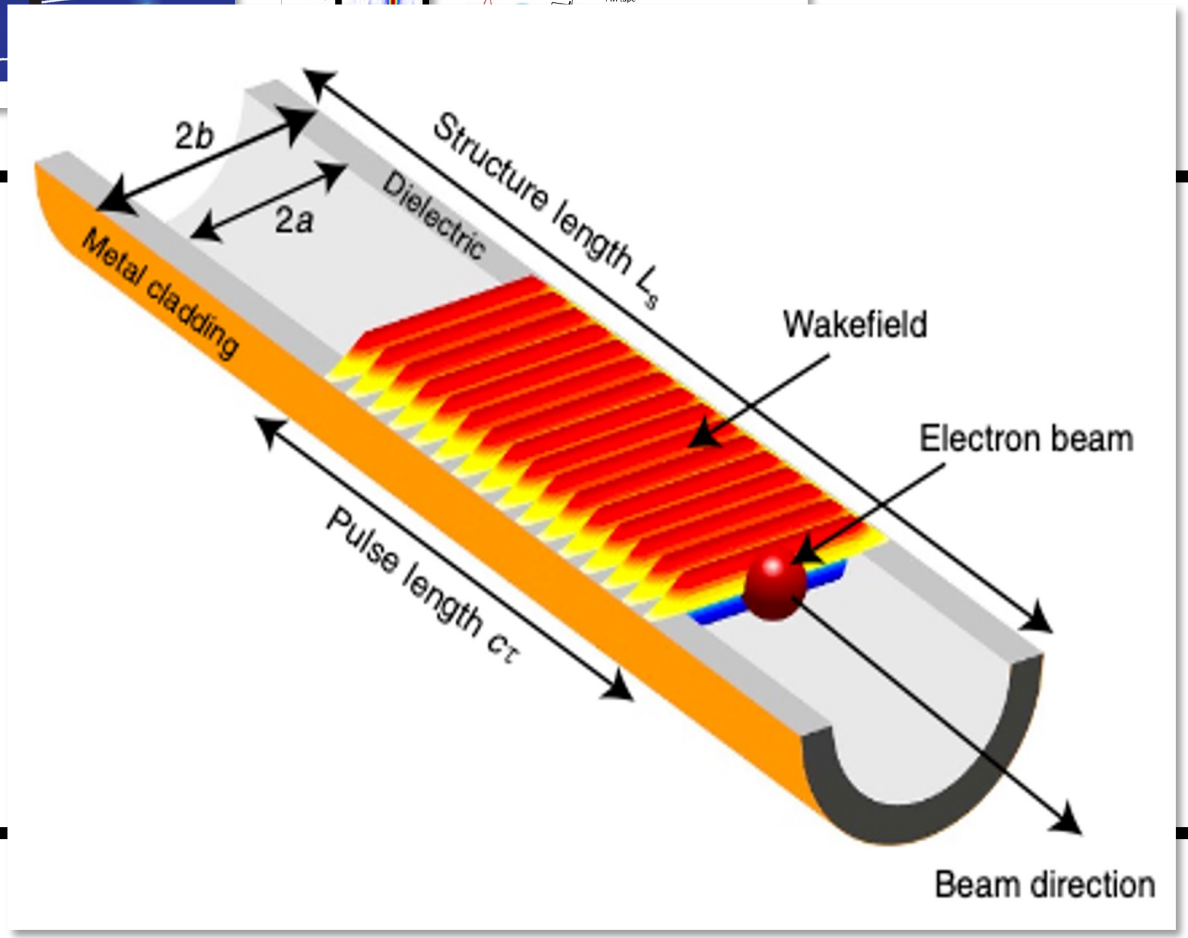
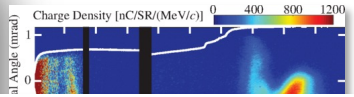


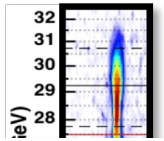

2018 2019 2022 2023

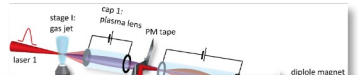
1.3 GV/m Dielectric Wakefield Acceleration
B. O'Shea et al, **Nat. Comm**, (2016)

# Research Progress Since Last Snowmass/P5






2013

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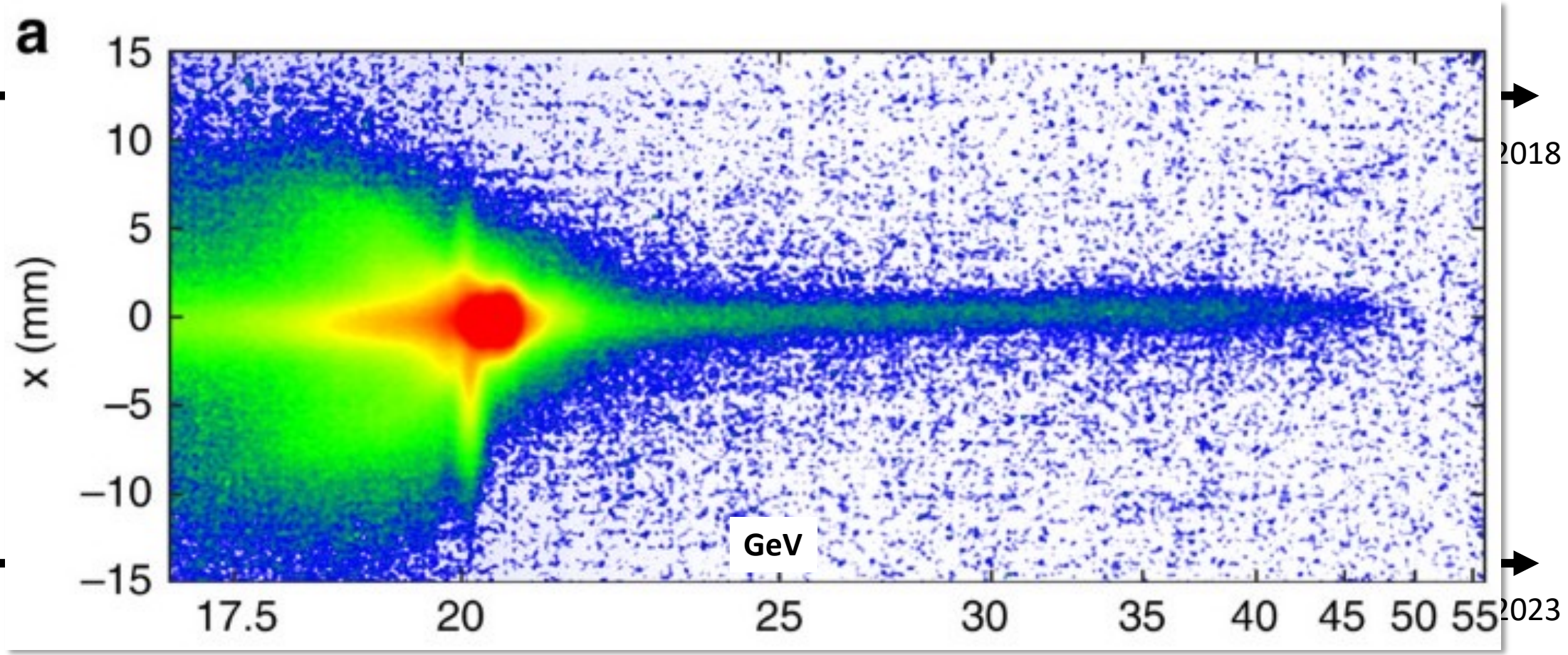


2018

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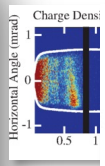
150 GV/m Plasma Wakefield Acceleration
S. Corde et al, **Nat. Comm**, (2016)

# Research Progress Since Last Snowmass/P5



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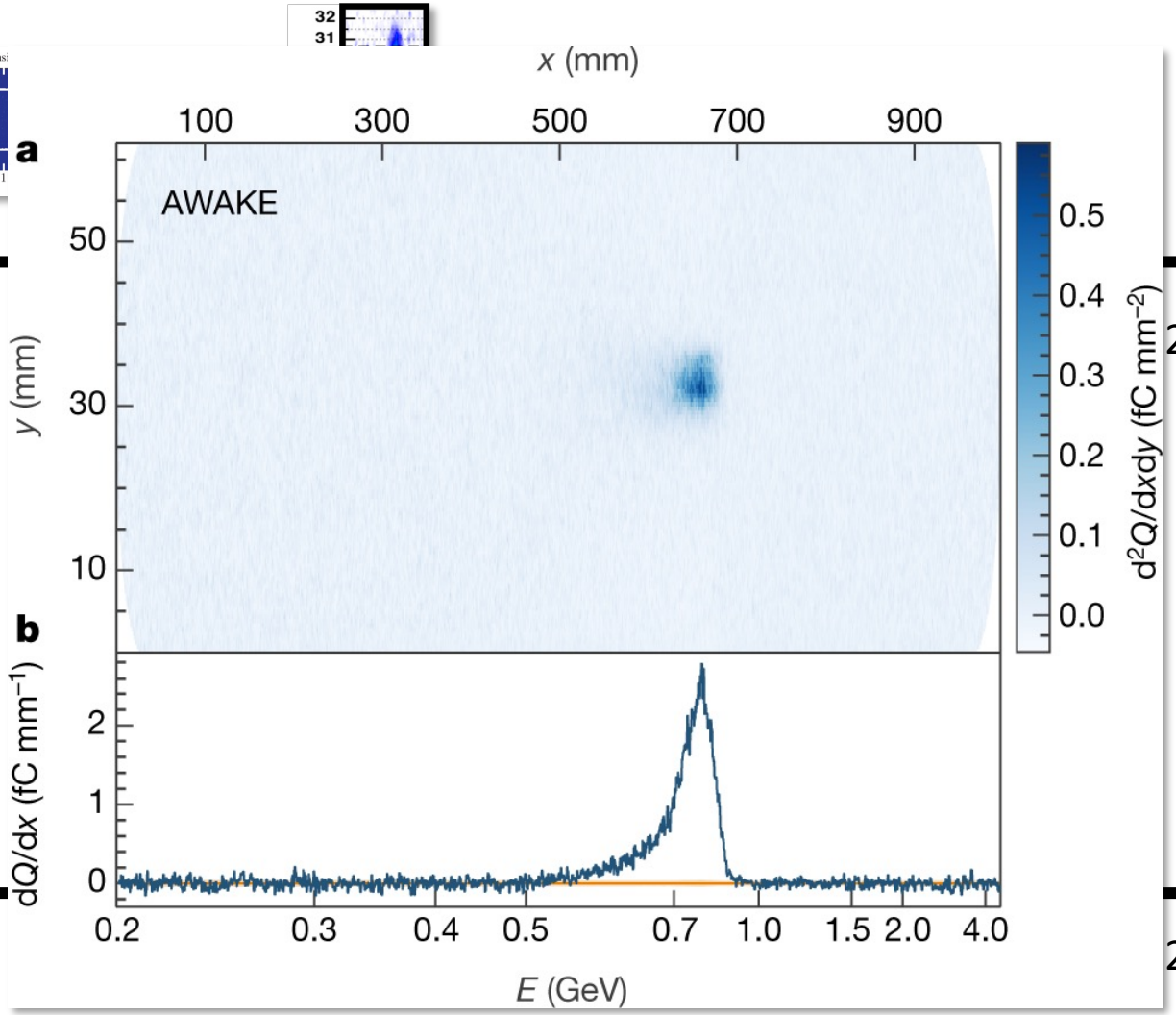
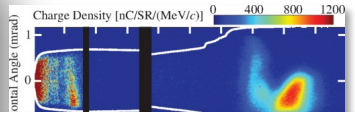
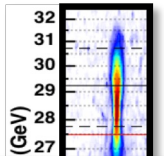


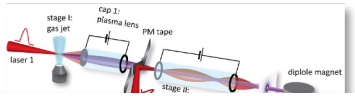

Proton beam-driven PWFA
AWAKE Collab., **Nature**, (2018)

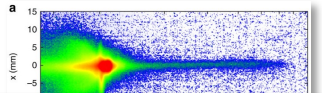
# Research Progress Since Last Snowmass/P5

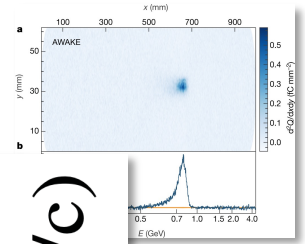




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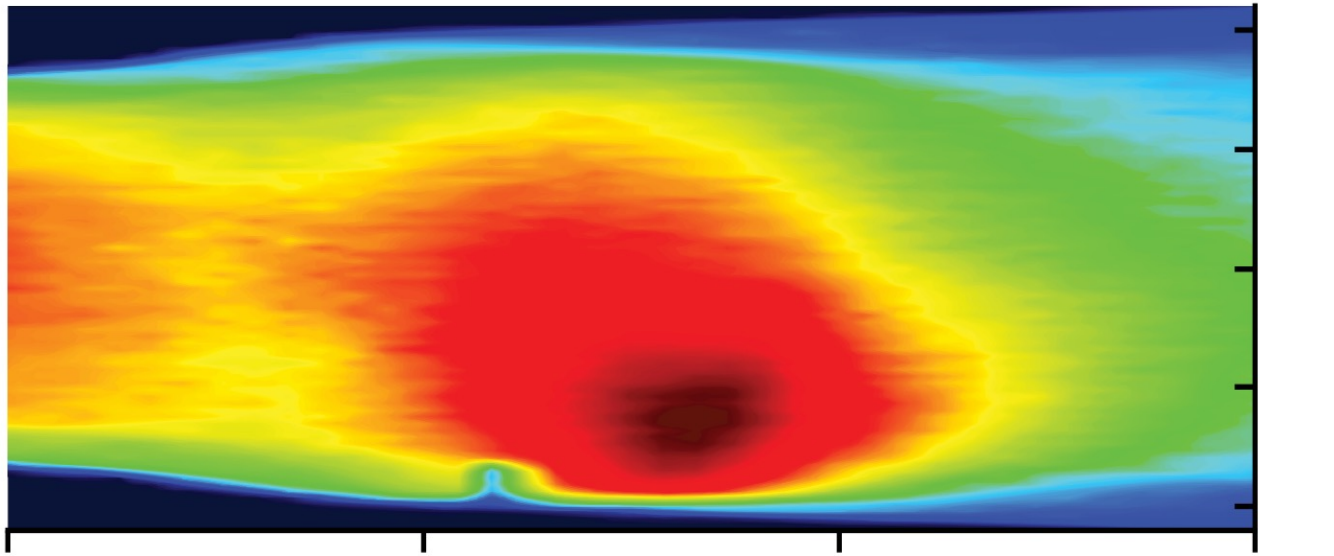
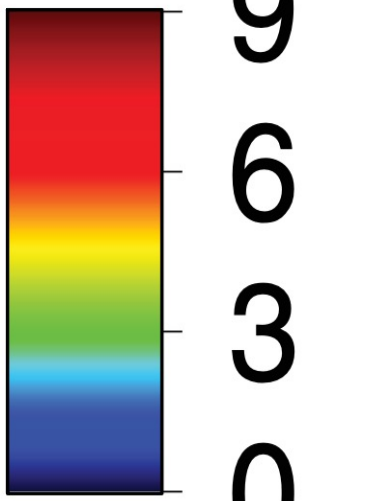








pC/mrad/(GeV/c)

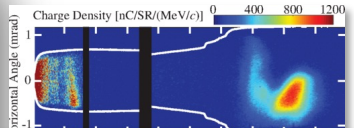
2018 2019 21 2022 2023

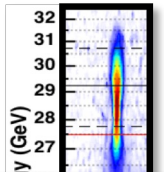
Momentum (GeV/c)

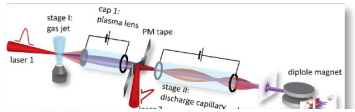
8 GeV Laser Wakefield Acceleration
A. Gonsalves et al, **PRL**, (2019)

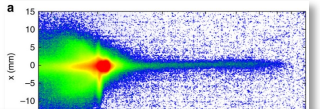
# Research Progress Since Last Snowmass/P5

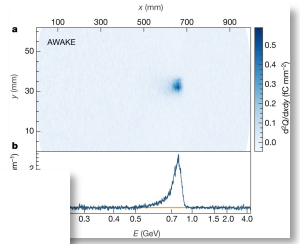




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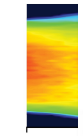


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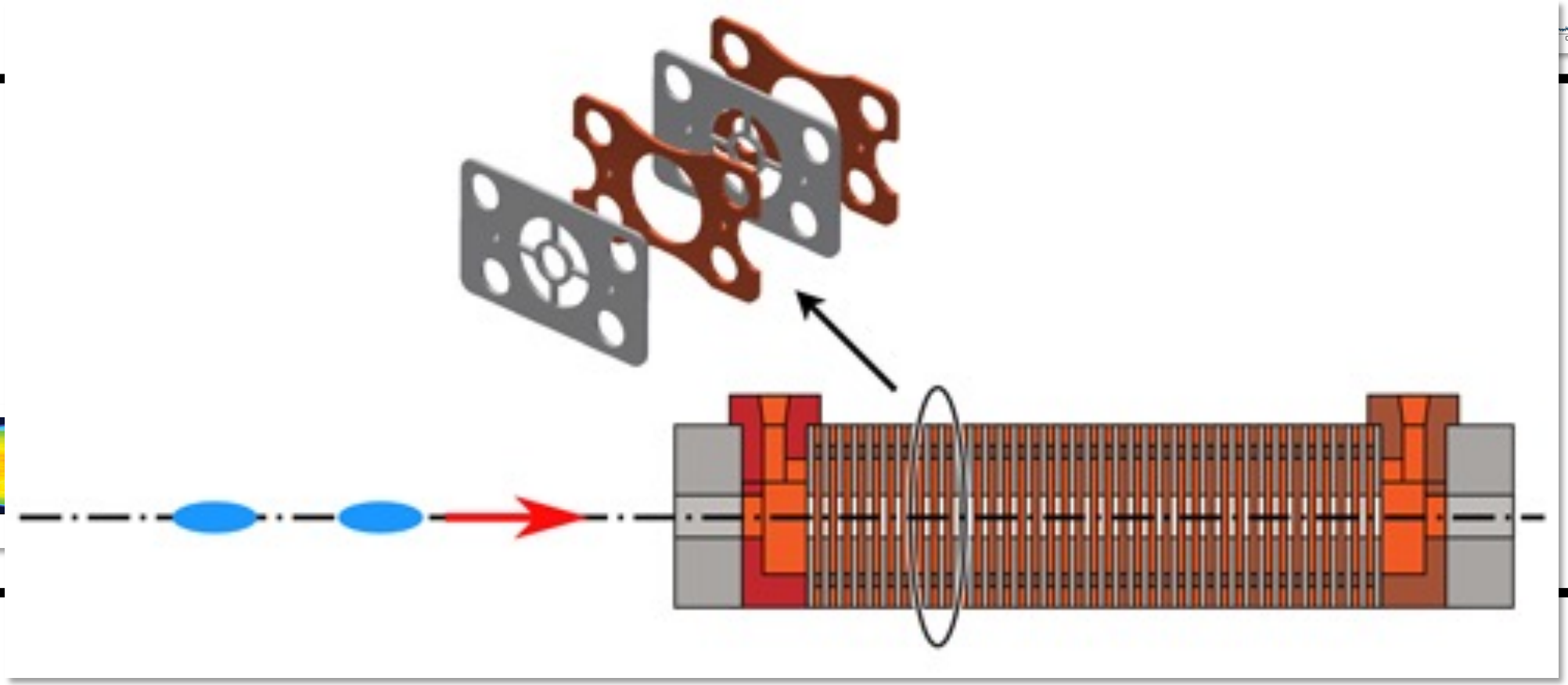
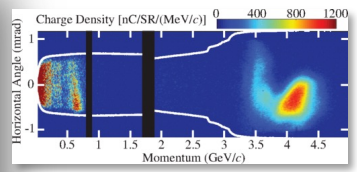
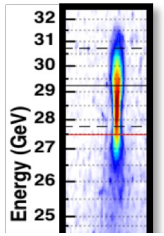


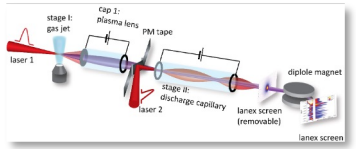
High-Power Metamaterial Structure
X. Lu et al, **PRL**, (2019)

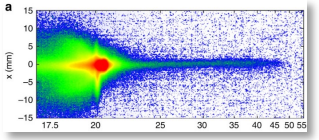
# Research Progress Since Last Snowmass/P5

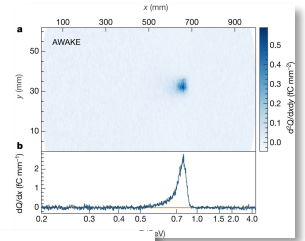


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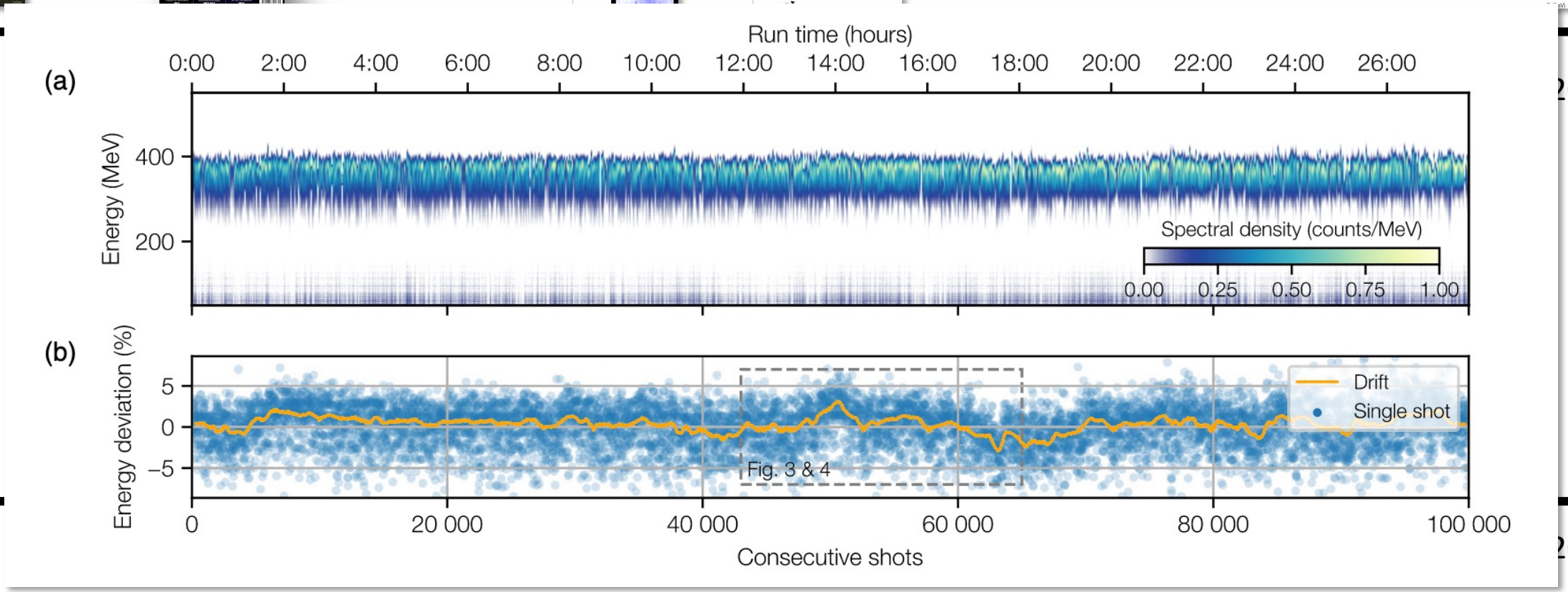
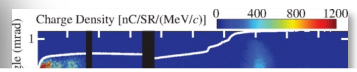
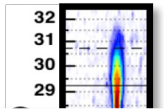


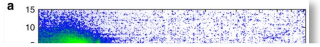

Stable Operation of a Laser Plasma Accelerator
A. Maier et al, **PRX**, (2020)

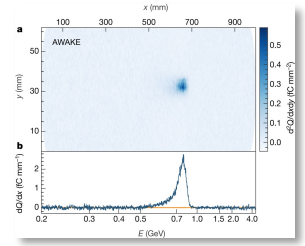
# Research Progress Since Last Snowmass/P5





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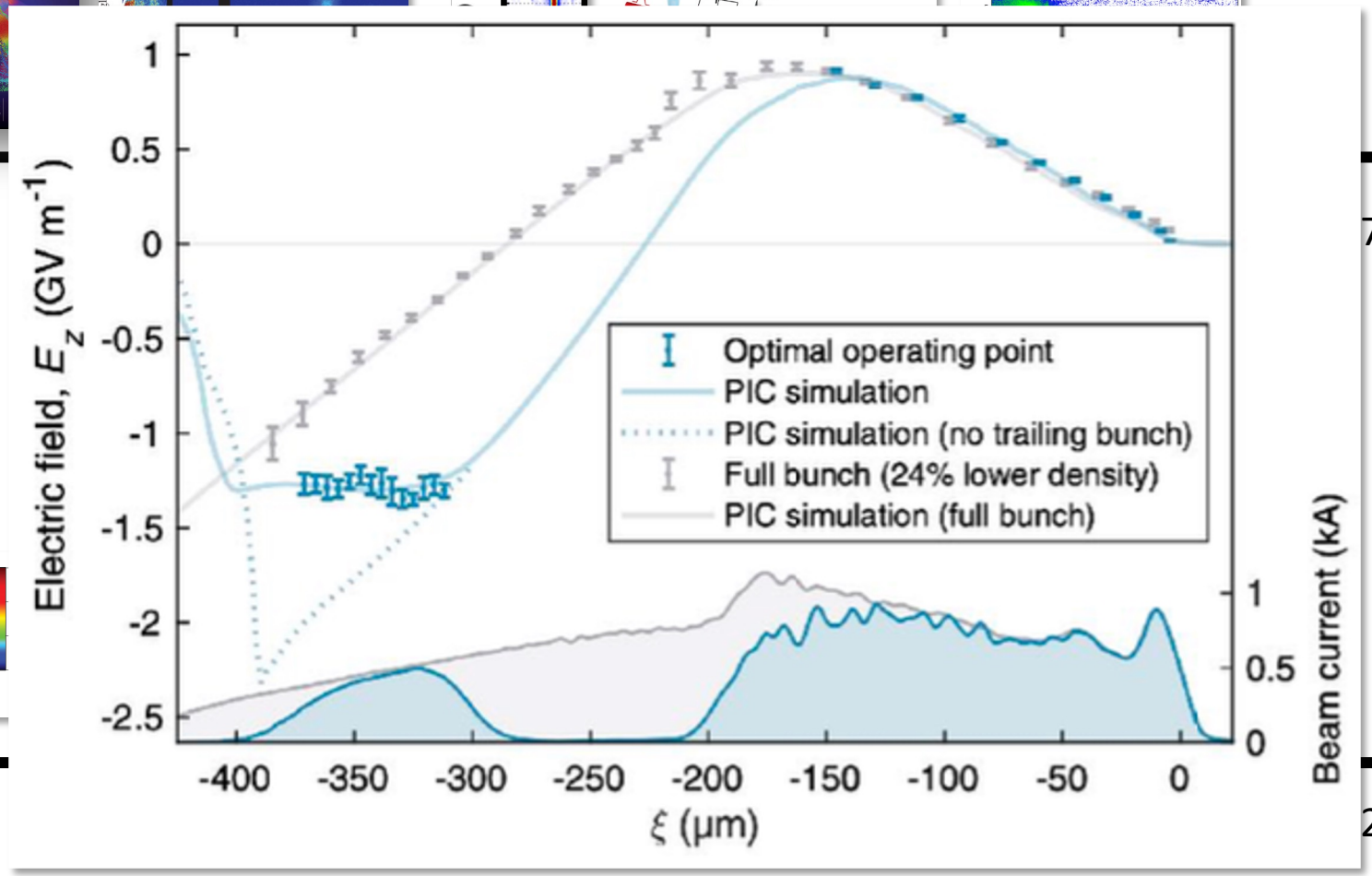


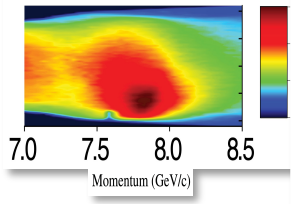


2018

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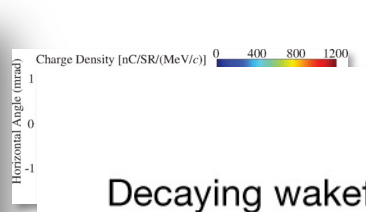
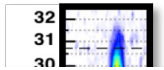
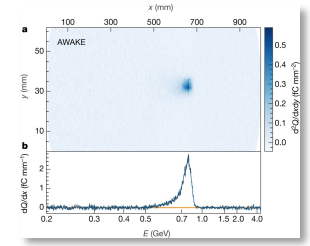
0.2% Energy-Spread with 42% efficiency PWFA
C. Lindstrom et al, **PRL**, (2021)

# Research Progress Since Last Snowmass/P5



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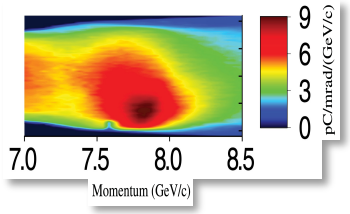
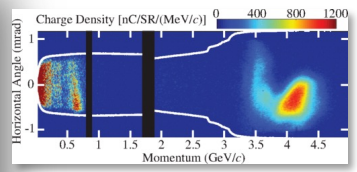


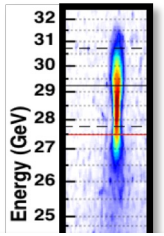

2018 2019 022 2023

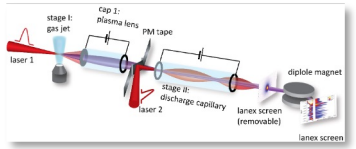
High repetition-rate PWFA
R. D'Arcy et al, **Nature**, (2022)

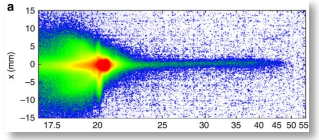
# Research Progress Since Last Snowmass/P5

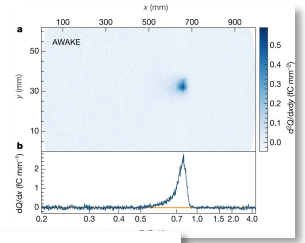


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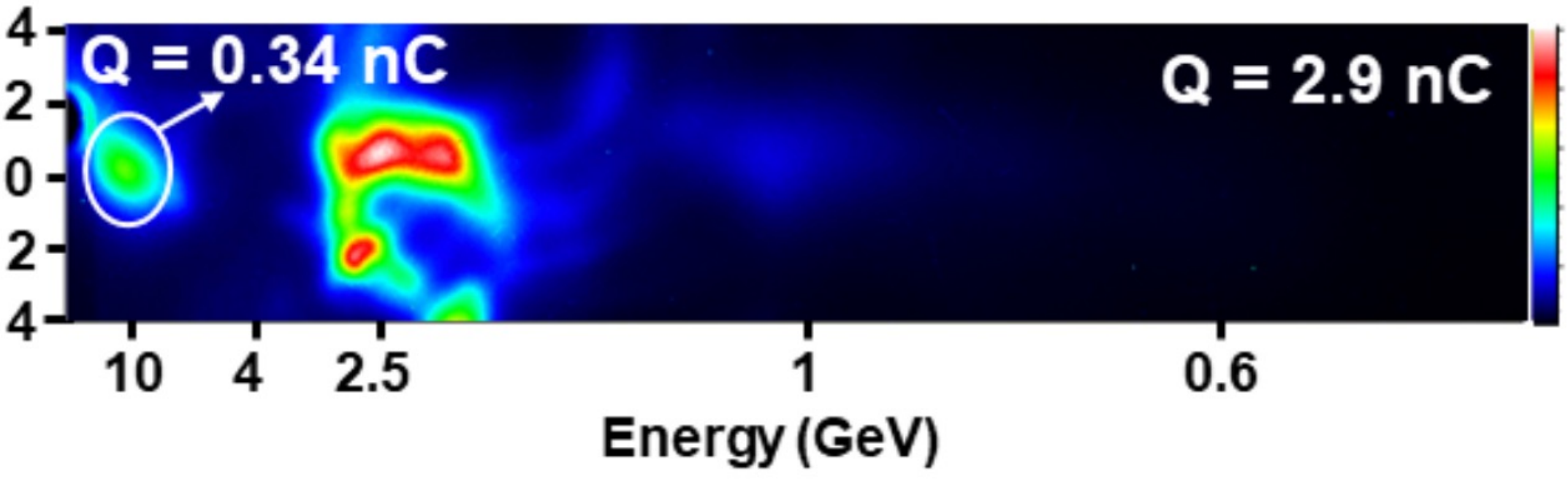



20 023

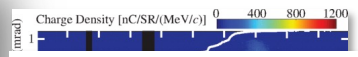
10 GeV Laser Plasma Accelerator
C. Aniculaesei et al, **arXiv 2207.11492**, (2022)

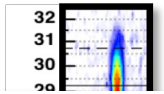
# Research Progress Since Last Snowmass/P5

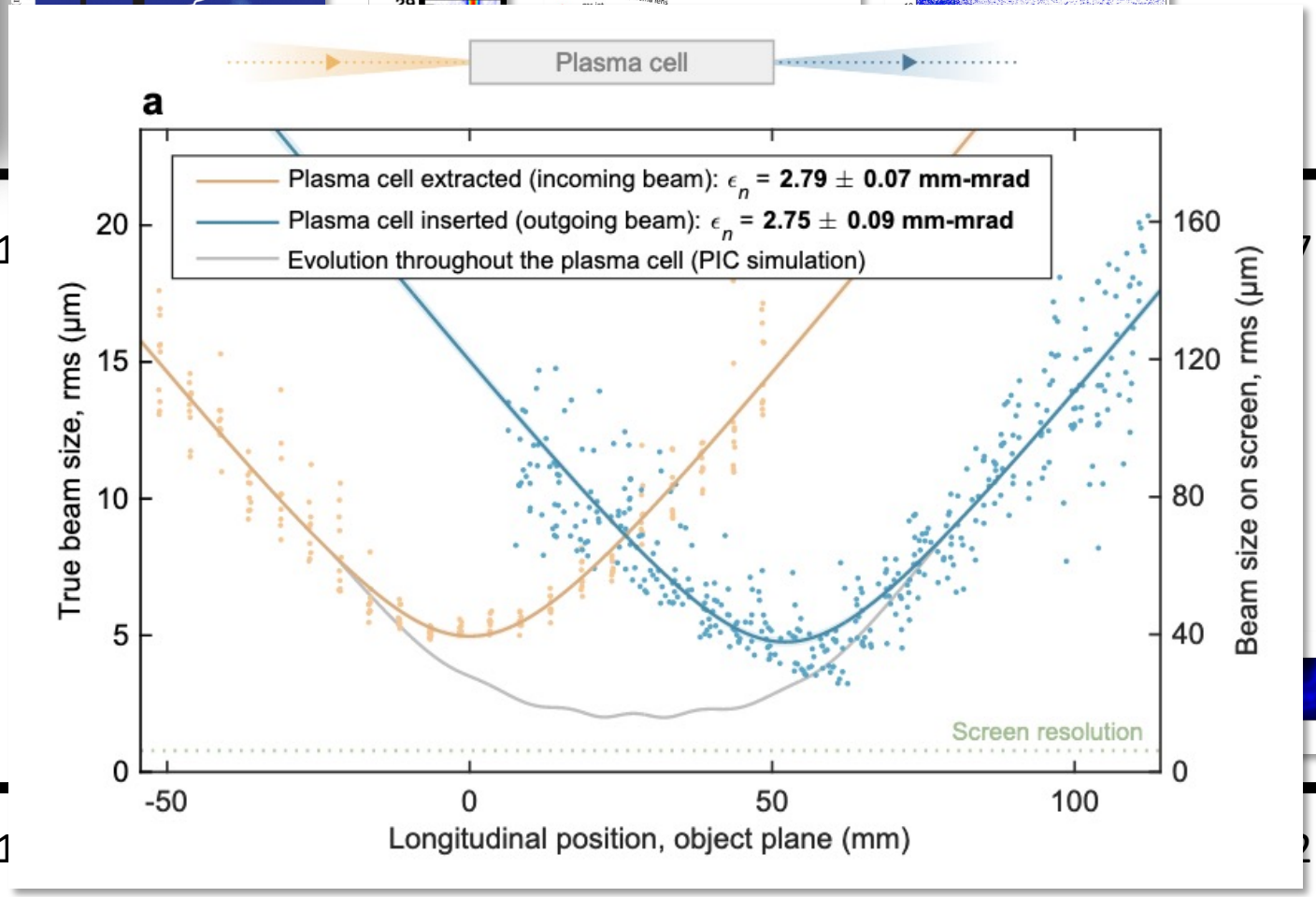


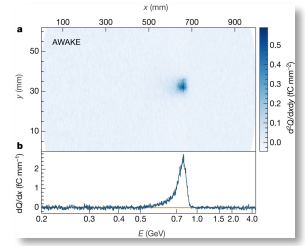
2013

201




2018

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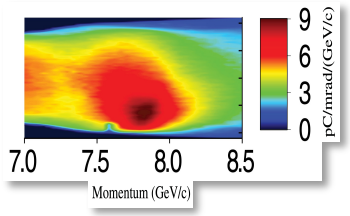
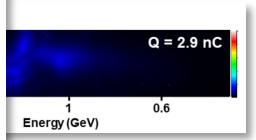
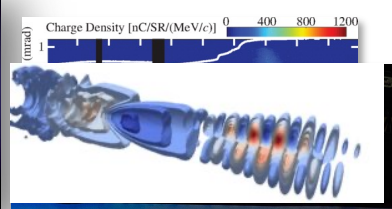


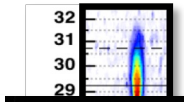



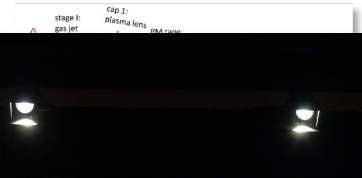

Emittance Preservation in a Plasma Wakefield Accelerator
C. Lindstrom et al, (under review), (2022)

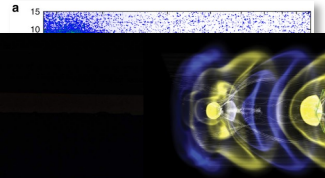
# Research Progress Since Last Snowmass/P5

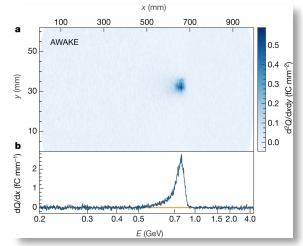




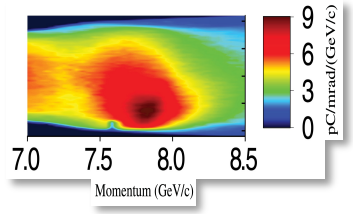


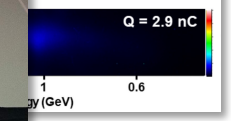


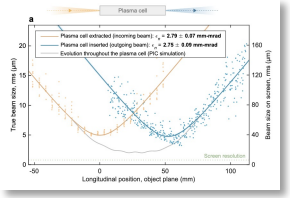

2013

2018



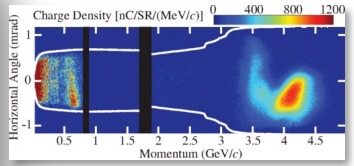
2018

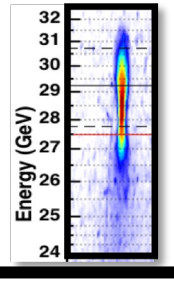
2023

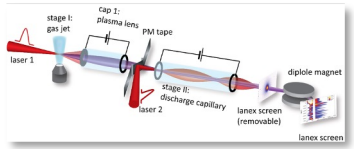
WarpX Exascale Computing Team
Wins ACM Gordon Bell Prize

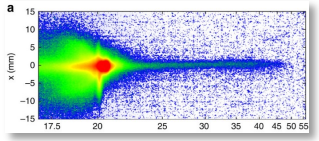
# Research Progress Since Last Snowmass/P5

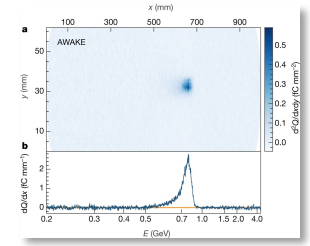


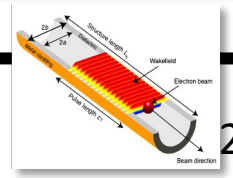


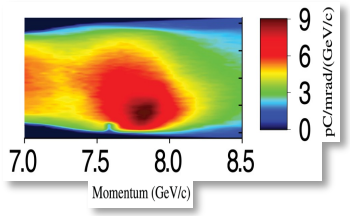



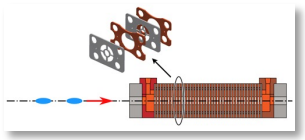



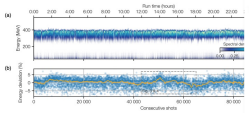



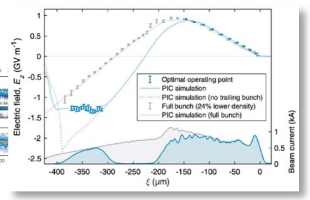



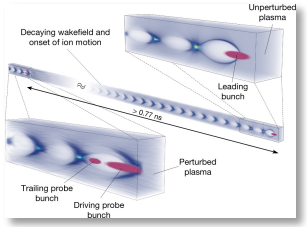

2013 2014 2015 2016 2017 2018

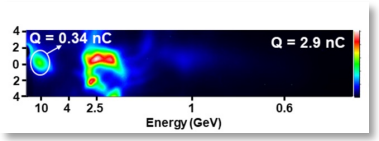


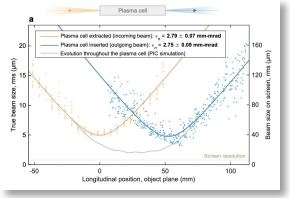







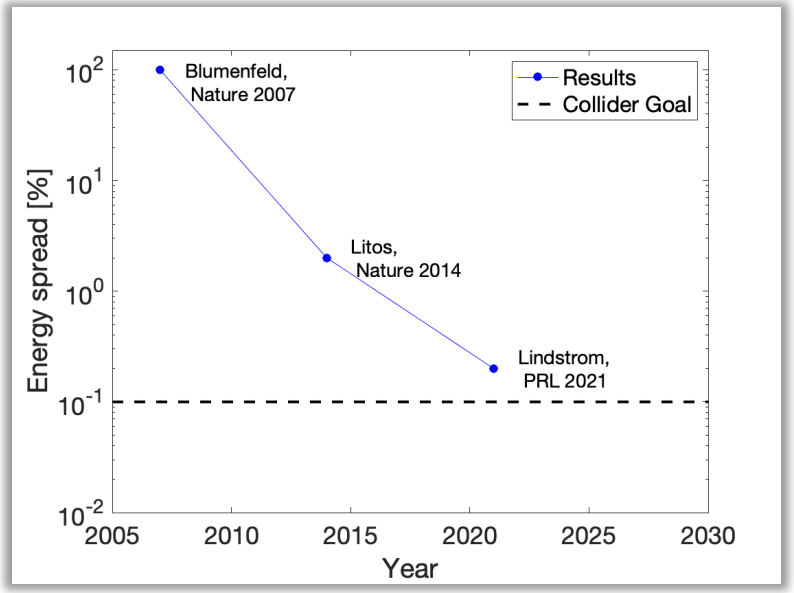



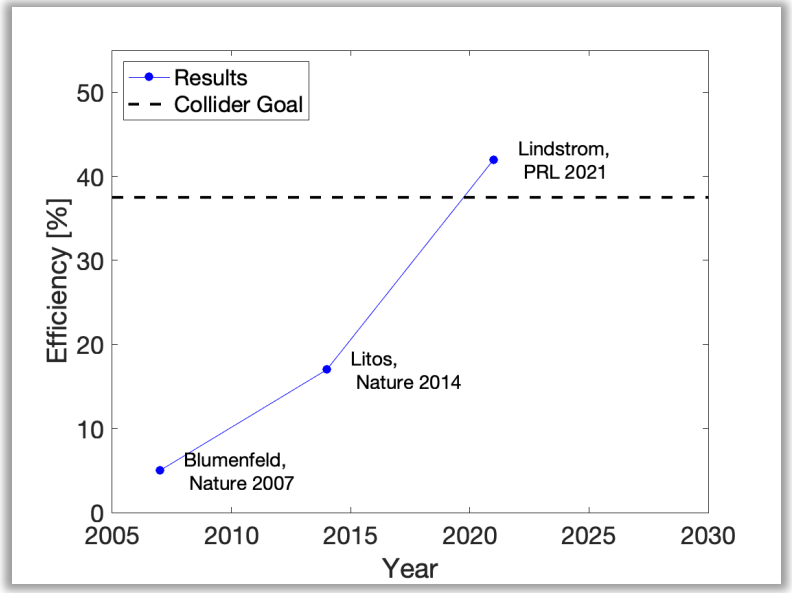



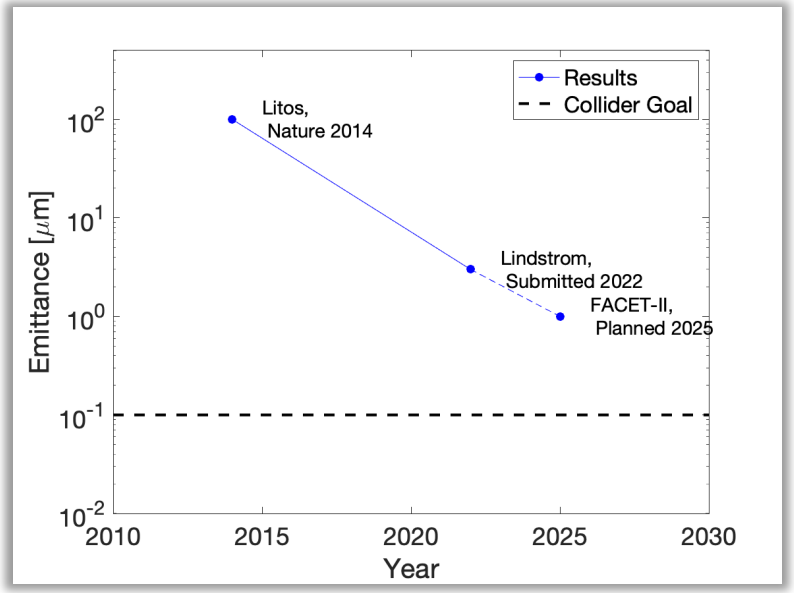




2018 2019 2020 2021 2022 2023

# Measurable Progress Toward Collider Goals




Plasma wakefield accelerators are approaching and *exceeding* the beam quality targets for a Linear Collider.