

# Opportunities to Discover Dark Matter and Dark Forces using LCLS-II

Natalia Toro

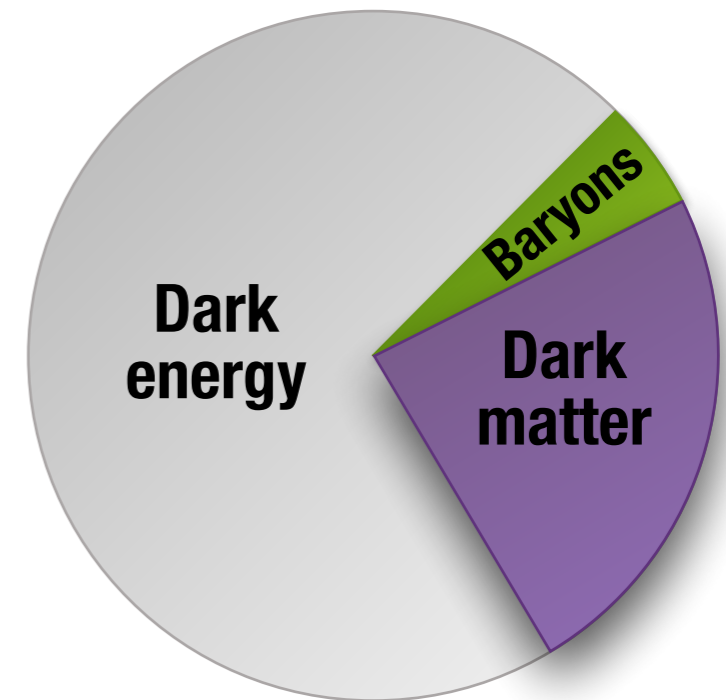
# Outline

- Scientific Goals
- Experimental concepts for exploring dark sector
- Opportunities to do these experiments using LCLS-II linac

without interfering with photon science!

# What is the Universe Made Of?

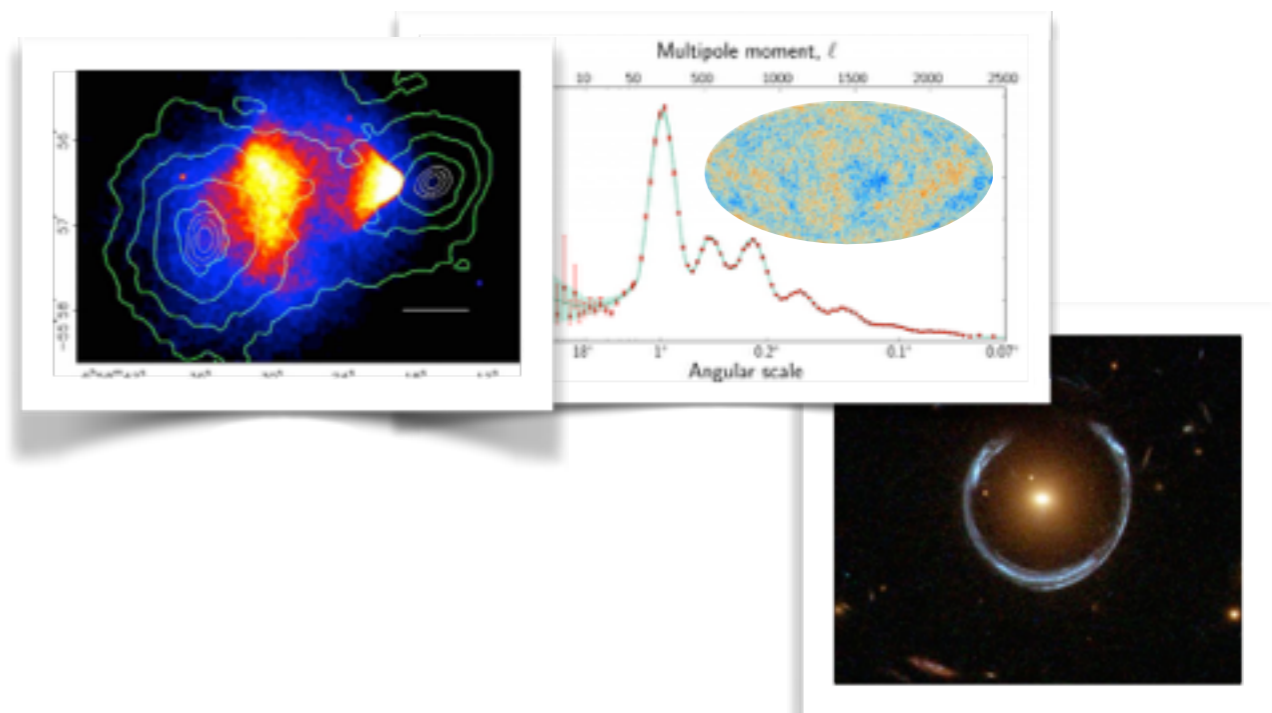
- Mostly Dark Matter
  - To date, seen only through gravitational effects
  - Identity and origin are key open questions in cosmology (and P5 science driver)



**Building for Discovery**  
Strategic Plan for U.S. Particle Physics in the Global Context

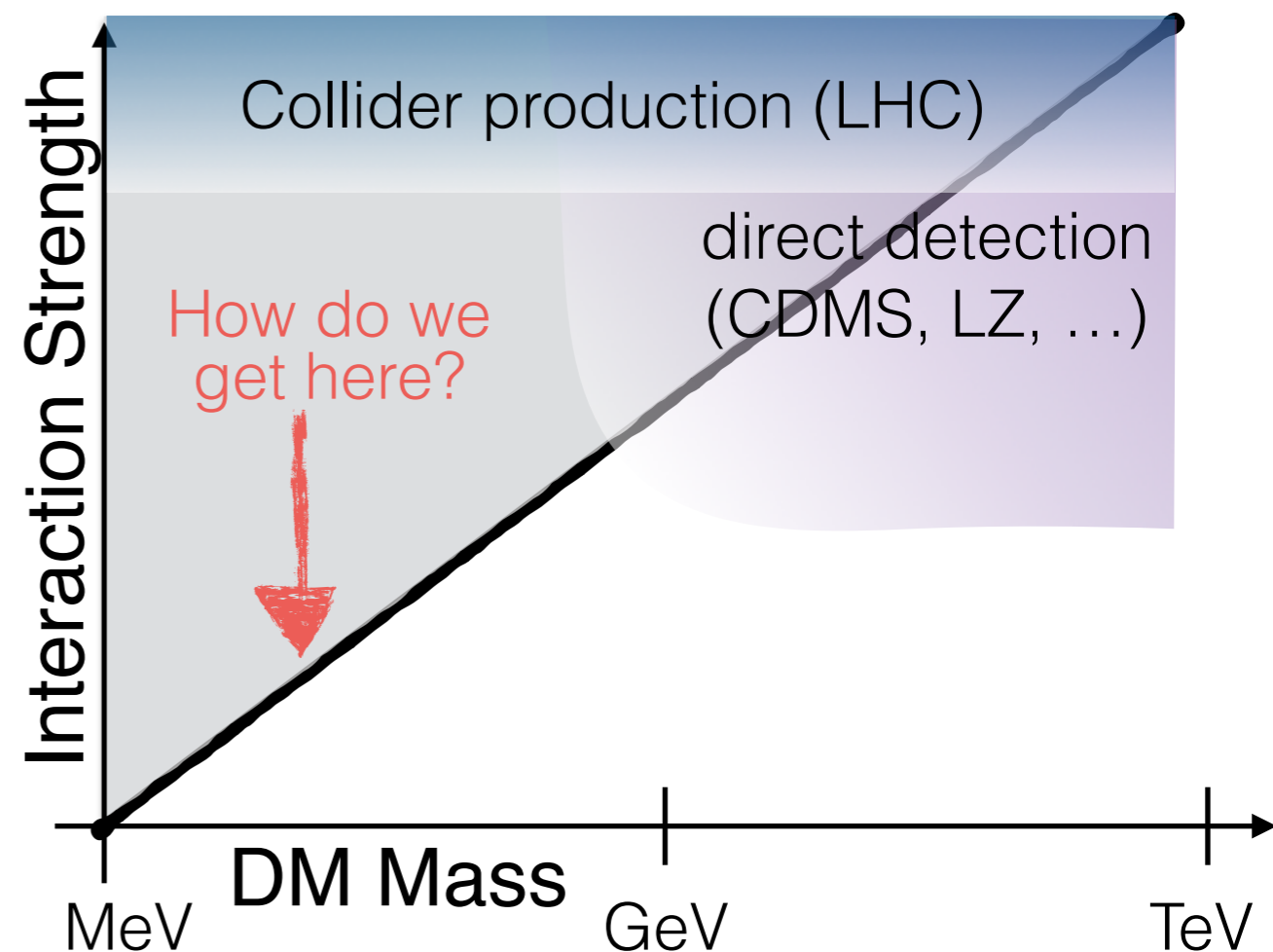
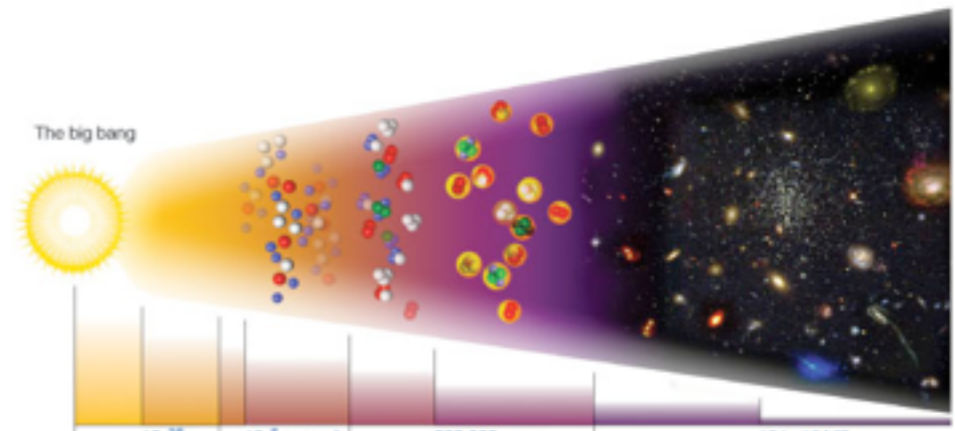


Report of the Particle Physics Project Prioritization Panel (P5) May 2014



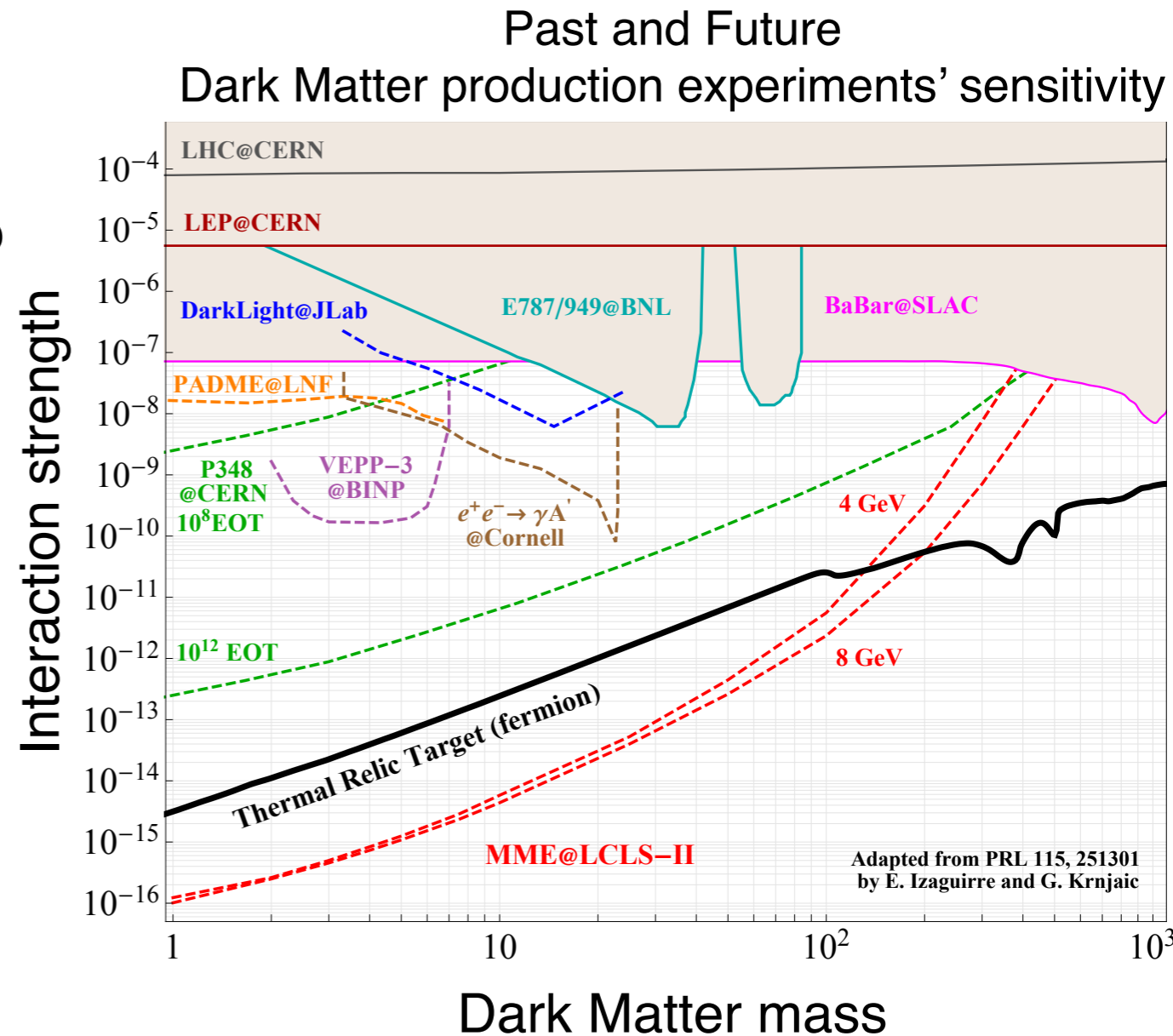
# What is the Universe Made Of?

- A hint of more interactions
  - Dark Matter (DM) coupled to familiar matter  $\rightarrow$  thermal production in early Universe
  - Simple explanation of DM's origin for MeV ( $e^-$  mass) to TeV masses
  - Sharp target: **minimum** interaction strength for given DM mass

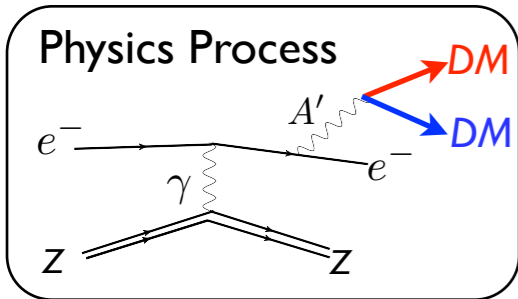


# Exploring Light and Slight Dark Matter

- Most powerful way to study Dark Matter sector: controlled terrestrial experiments
  - Collide particles with enough energy to produce DM and related particles
  - Production rate proportional to interaction strength
- We do this at LHC, but low-mass/weak-coupling calls for different strategy
  - beam-on-target, not beam-on-beam
  - use electrons (point particles)
  - High repetition (MHz–GHz)  $e^-$  beam is ideal tool for exploring this physics.

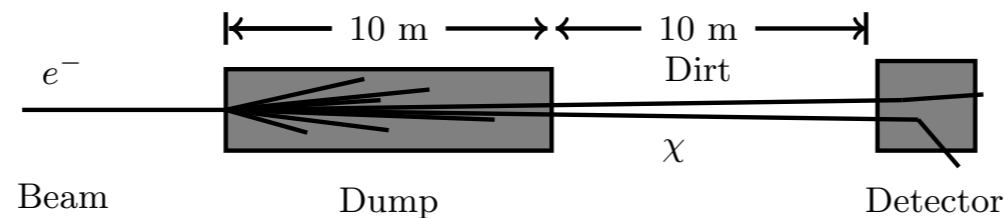


# Searching for Dark Matter



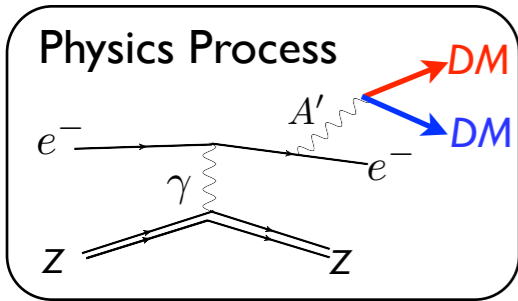
DM production process can be exploited in two complementary ways

- [High intensity] Produce DM (rare) & detect scattering in downstream detector (also rare)



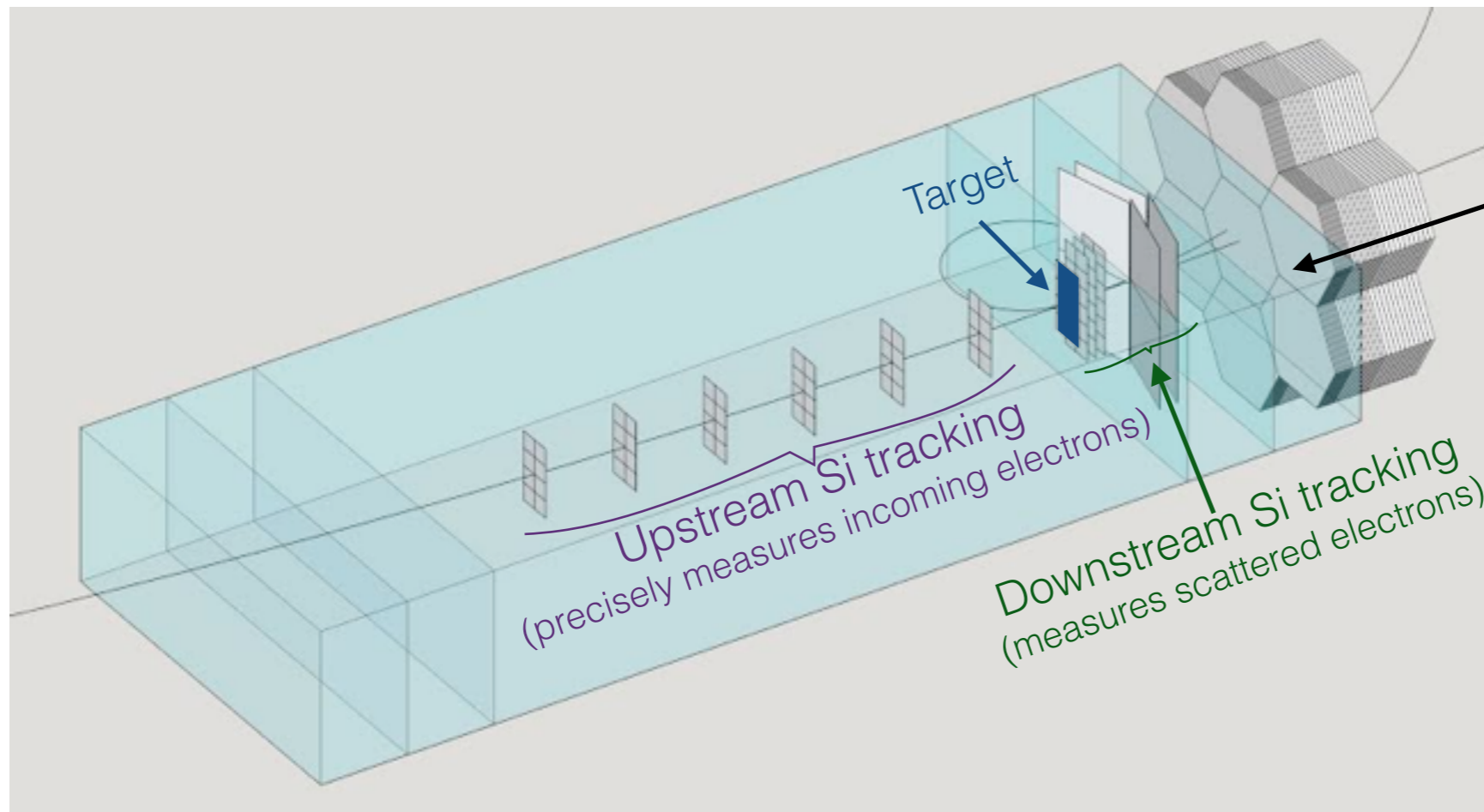
- [Low intensity] Identify DM production by **absence** of visible particles carrying energy away from interaction

# Searching for Dark Matter II

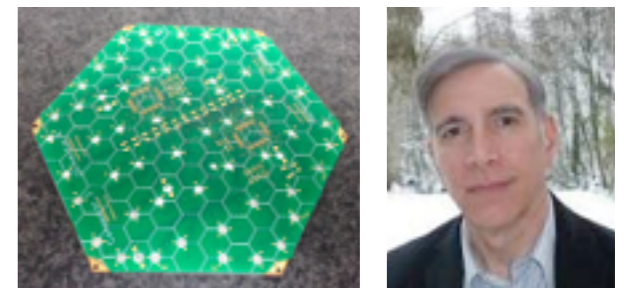


Track beam electrons through target one at a time, look for energy loss + transverse kick indicative of heavy particle production...

...and make sure nothing else is carrying away energy.

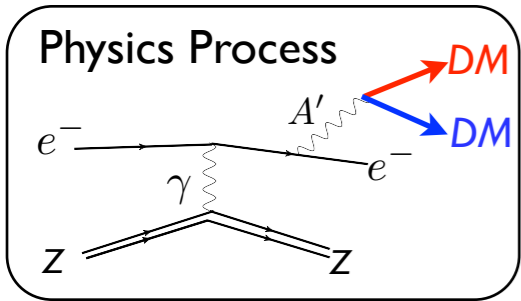


High-granularity calorimeter (CMS Phase-II upgrade prototype?)  
catch visible scattering products



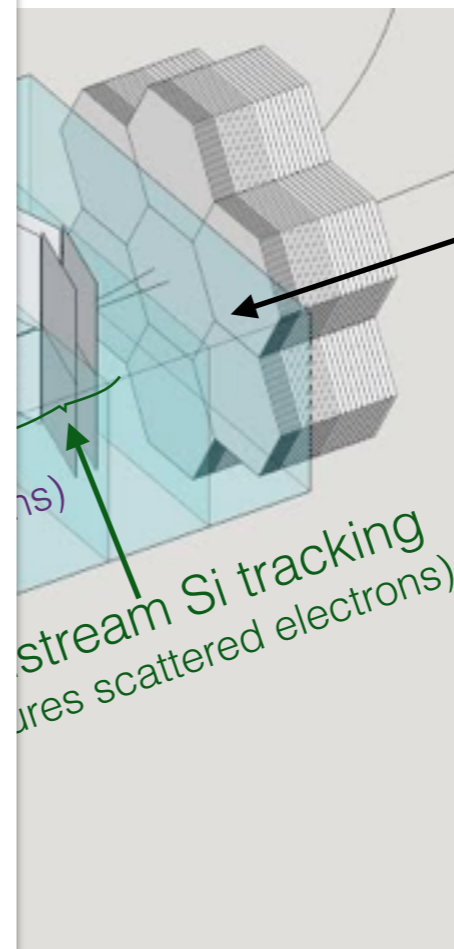
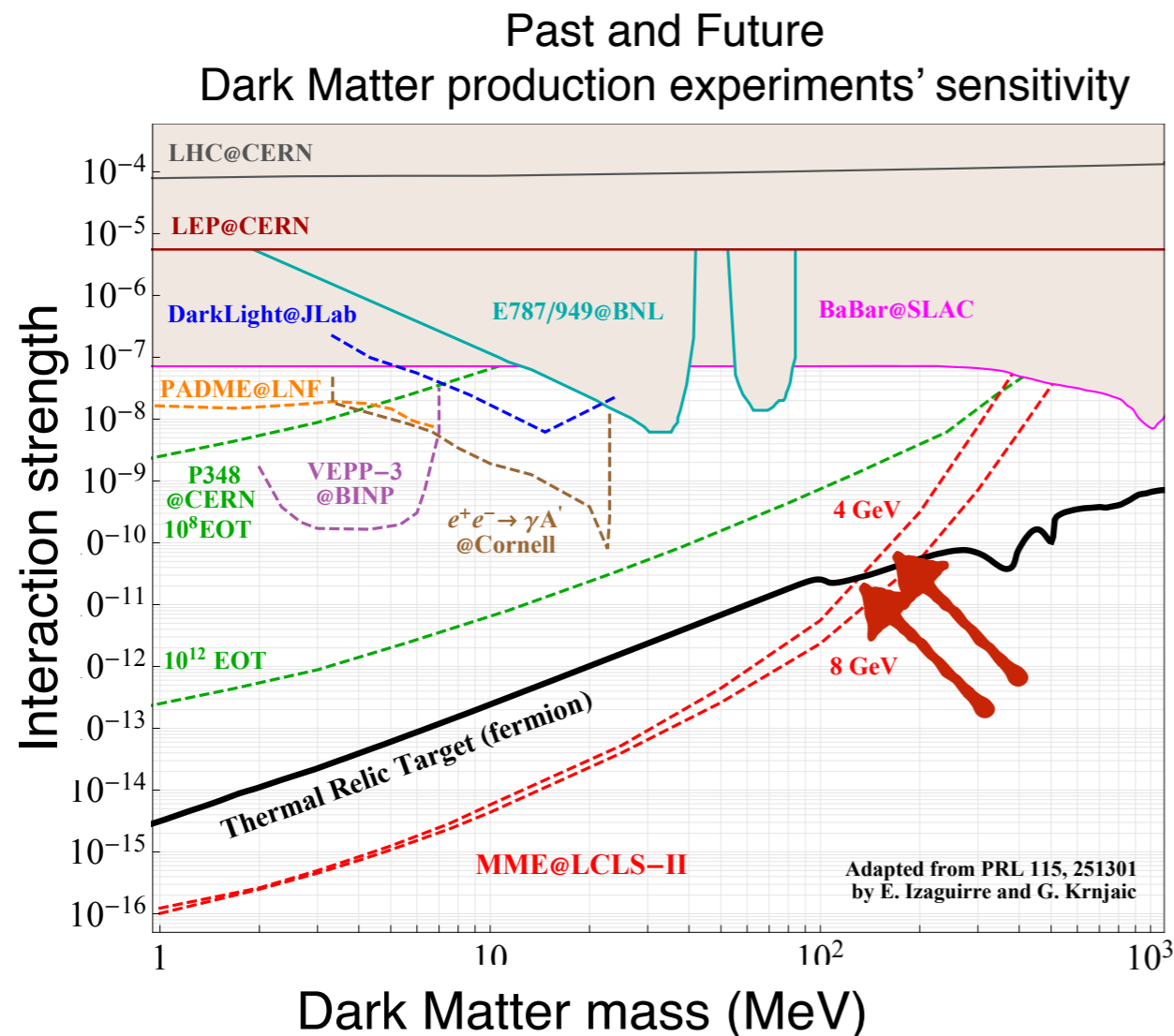
Joe Incandela (UCSB)

# Searching for Dark Matter II

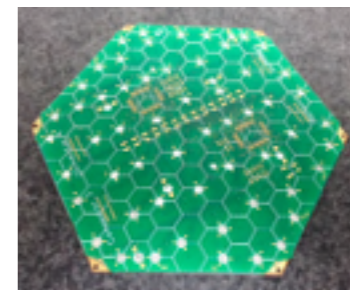


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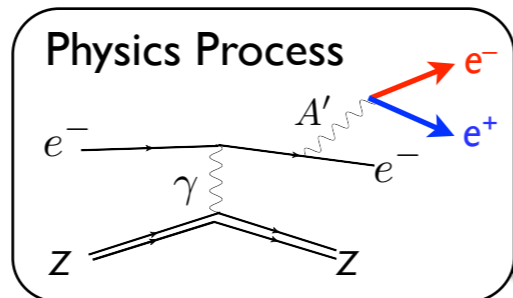


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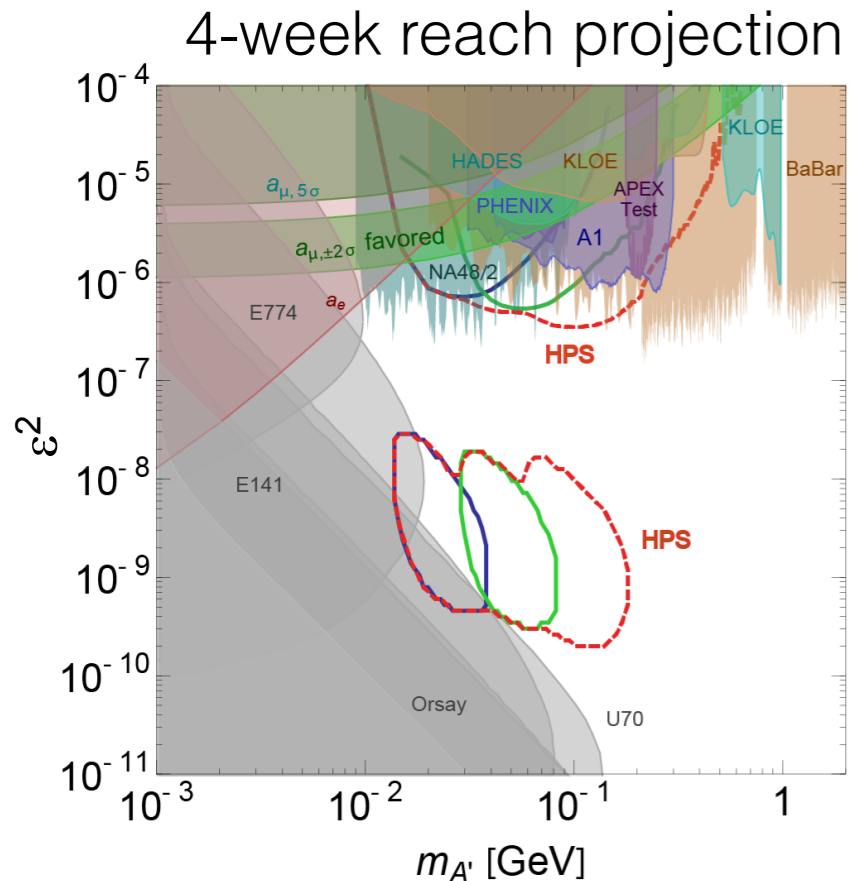
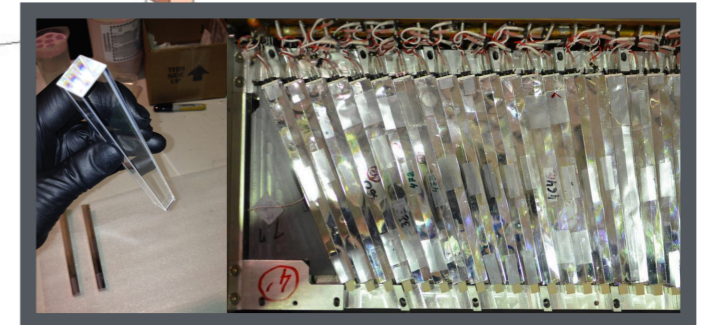
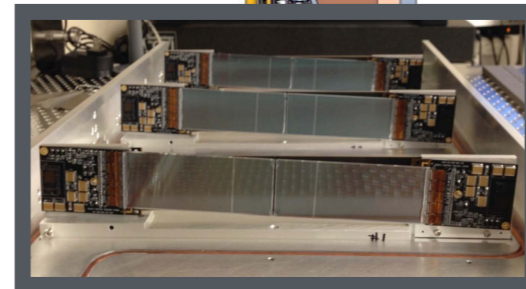
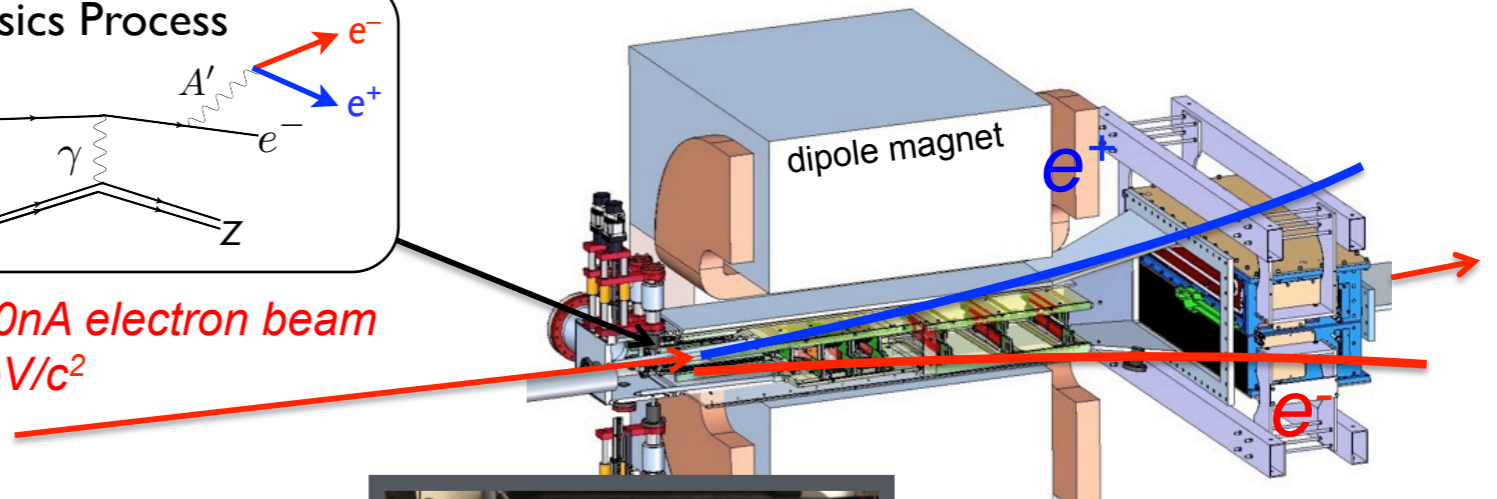


# Example: HPS (and Beyond)

Doesn't look for the dark matter itself, but for new force through which DM could interact

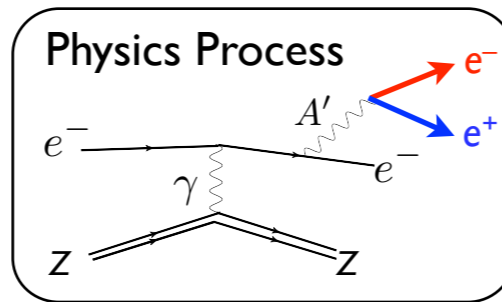


50-200nA electron beam  
1-6GeV/c<sup>2</sup>

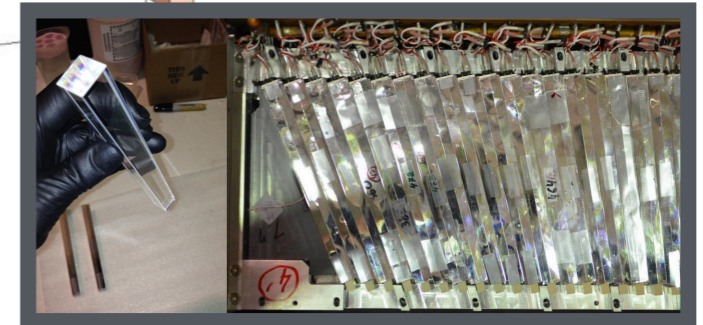
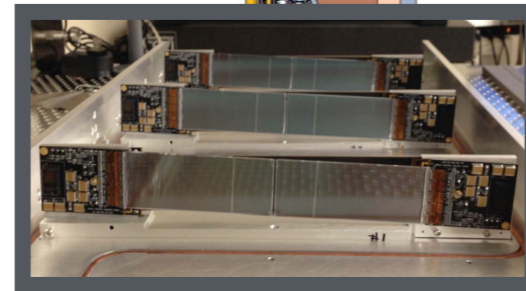
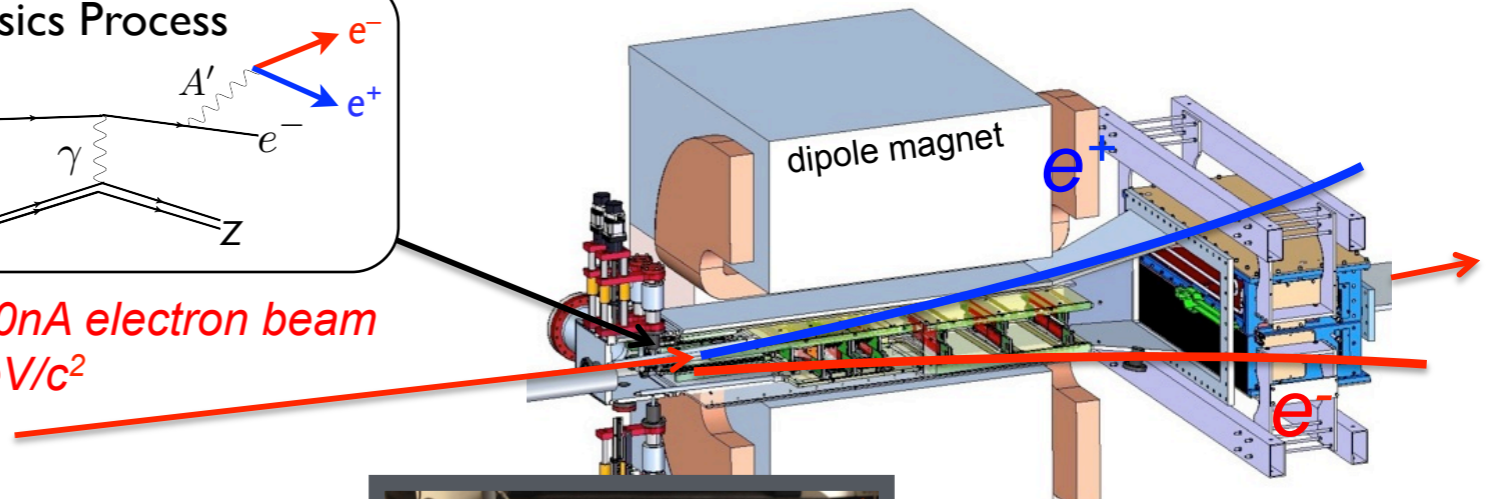


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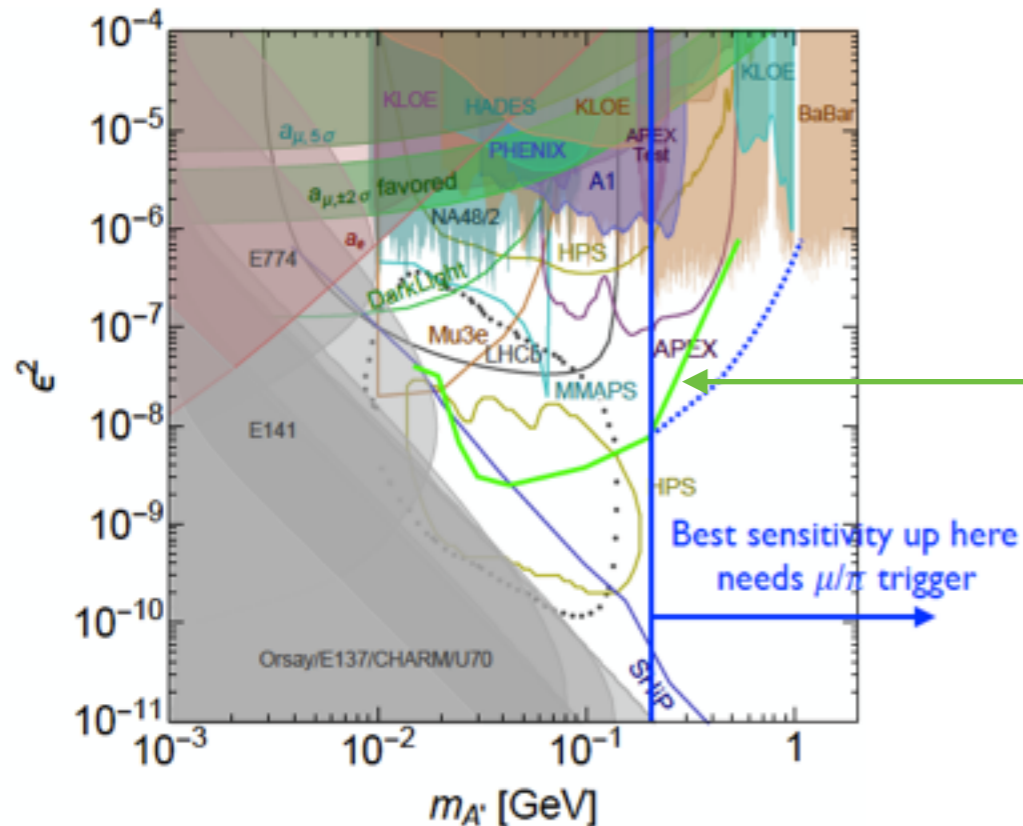
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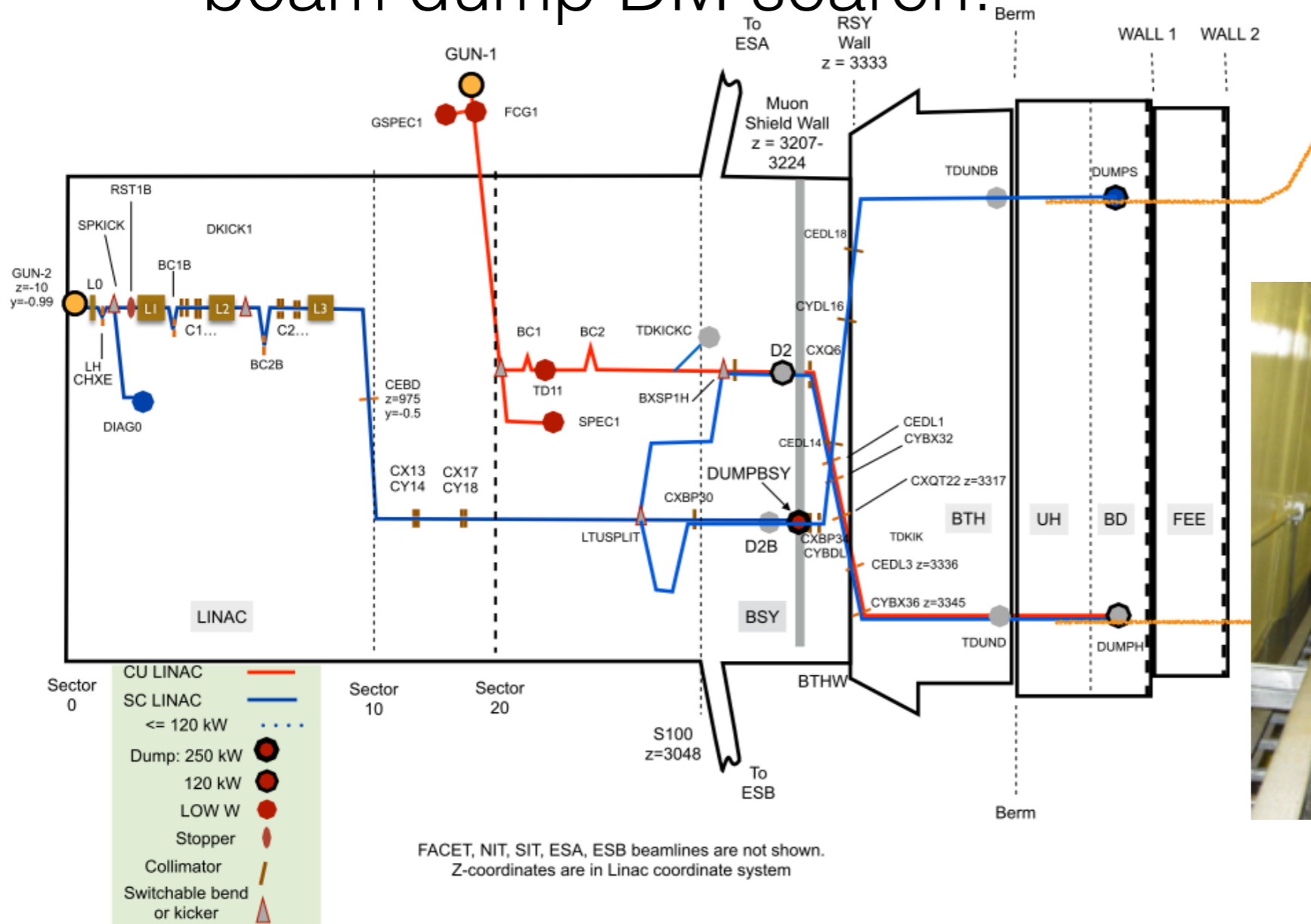
150 days a 1  $\mu$ A w/ 2.5%  $X_0$  target,  $E_{\text{beam}} = 11$  GeV



Moving tracking outside of magnet allows higher current  $\Rightarrow$  new reach (Super-HPS)

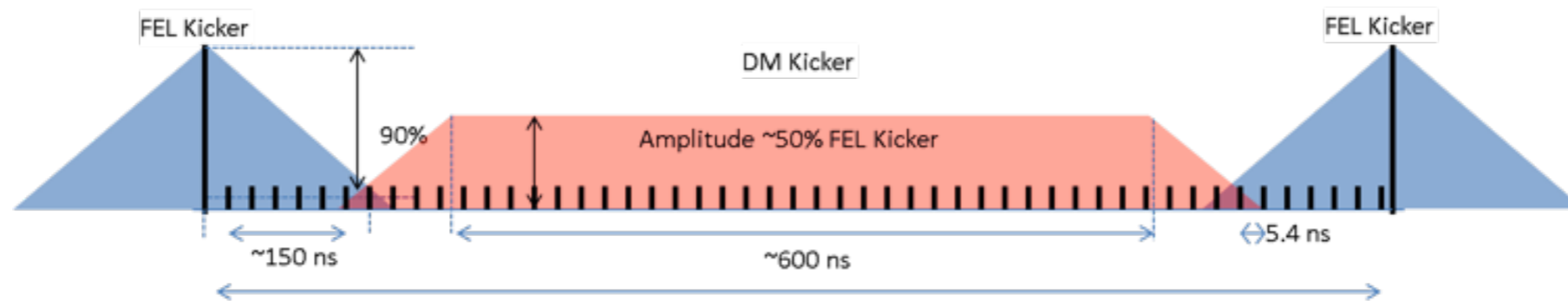
# Opportunities at LCLS-II

- 1) Substantial LCLS-II current will go to BSY dump rather than undulators – good site for high-intensity beam dump DM search!



# Opportunities at LCLS-II

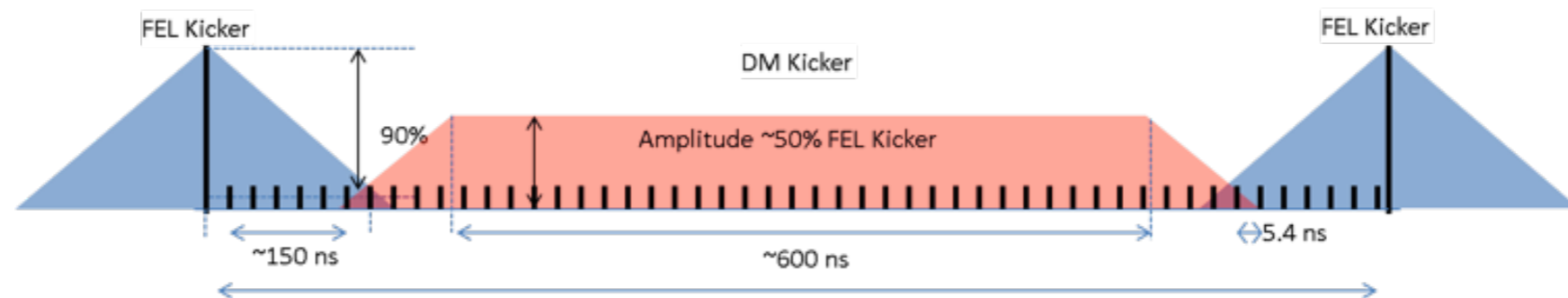
- 1) Substantial LCLS-II current will go to BSY dump rather than undulators – good site for high-intensity beam dump DM search
- 2) In between FEL bunches, linac accelerates  $\sim 200$  “gun dark current” bunches for free



Well suited to Super-HPS and Missing Momentum experiments — what does it take to use this beam, without impacting LCLS-II?

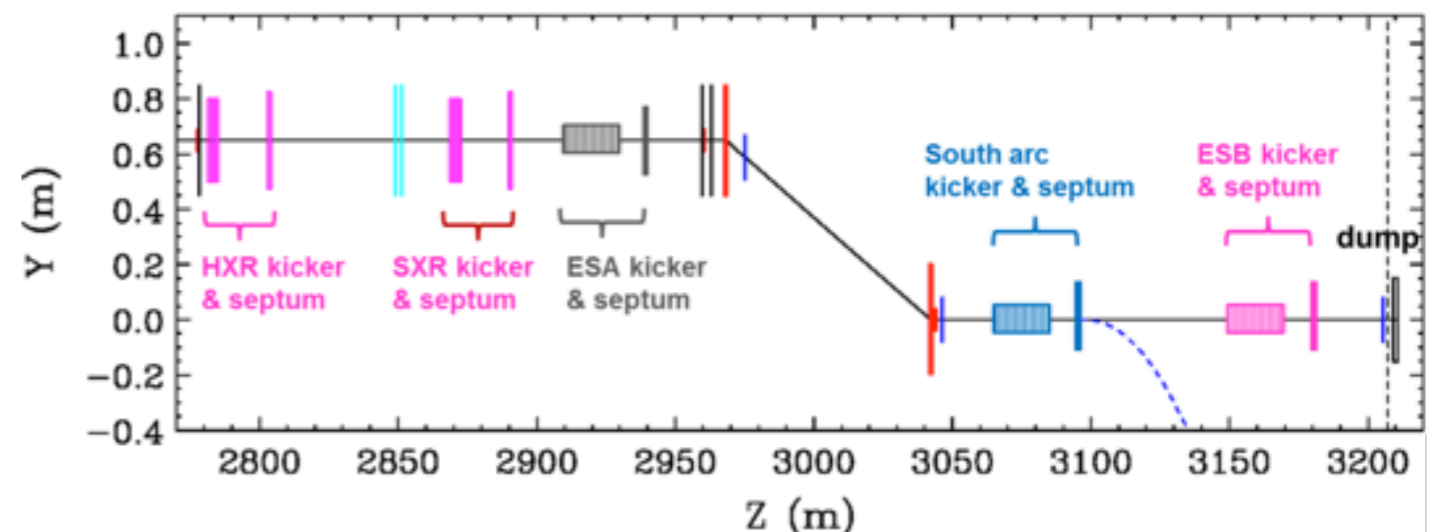
# DArk Sector Experiments at LCLS-II (DASEL)

A beam line fed by new kicker downstream of FEL kickers

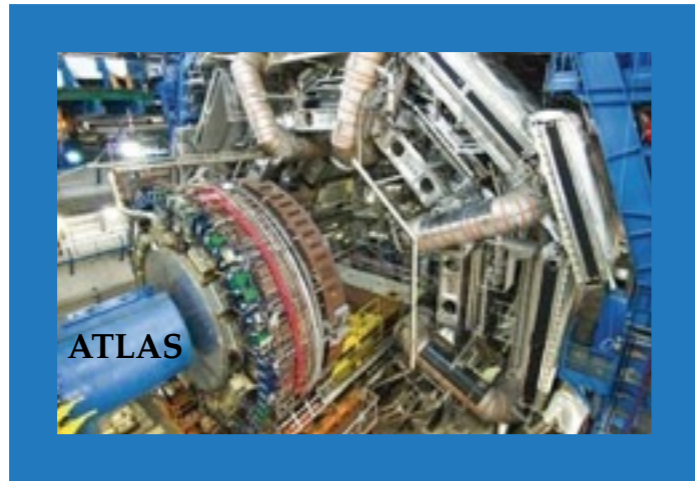


- New gun laser & spoiler/collimator system provide finer control over “dark matter” beam
- Technically feasible locations: End Stations or S. Arc instrumentation area

Pros and cons to each –  
e.g. ESA has most existing infrastructure but limited timeframe



# International Experimental Renaissance

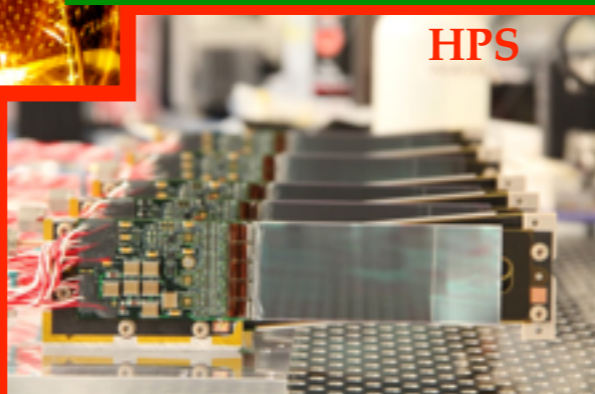
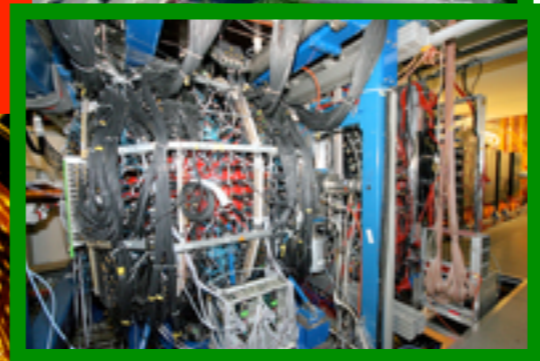
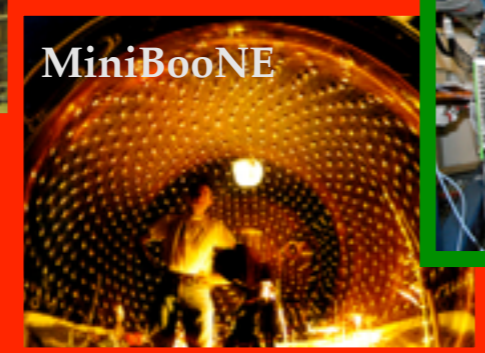


High-energy colliders

High intensity colliders



Fixed Target



SLAC has pioneered this science & continues to do so



# Strong local & international community behind a SLAC Program

*The BDX Collaboration*

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## The Heavy Photon Search test detector

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Tony Beukers, Carsten Hast, Tom  
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Missing Momentum effort nucleating  
around groups at SLAC, UCSB (Joseph  
Incandela) and Minnesota (Jeremy Mans,  
Roger Rusack)

# Summary

- Evidence for dark matter motivates searches for new forces and light Dark Matter particles
- Several ideas for powerful next-generation experiments
  - Search for light dark matter behind beam dump
  - Powerful search for dark matter through electron missing momentum
  - High-intensity new-force search (super-HPS)
- LCLS-II is a natural home for these experiments, both at BSY dump and by directing dark bunches to experimental area