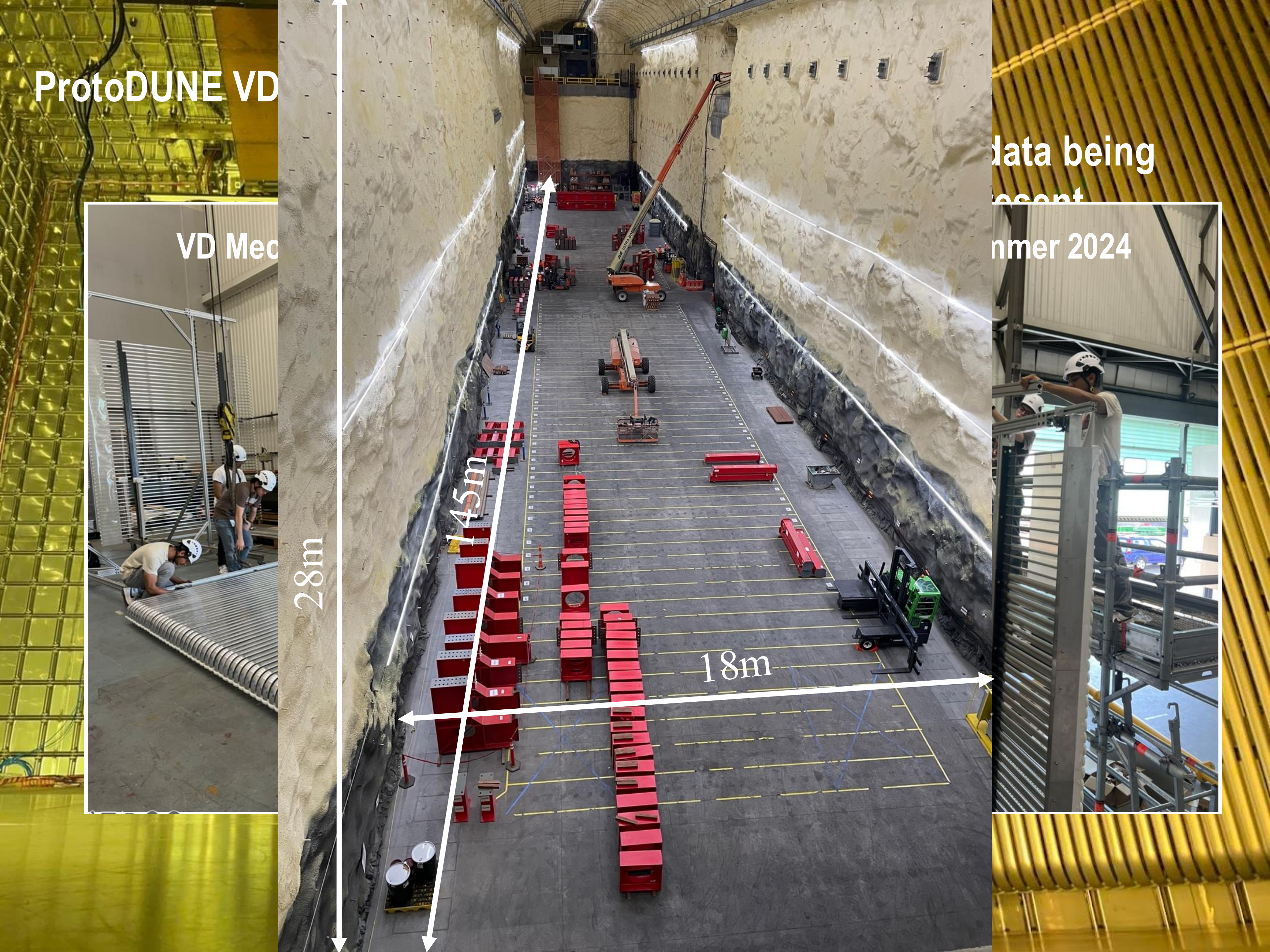
DArk Messenger Searches at an

Who is Jaehoon Yu?

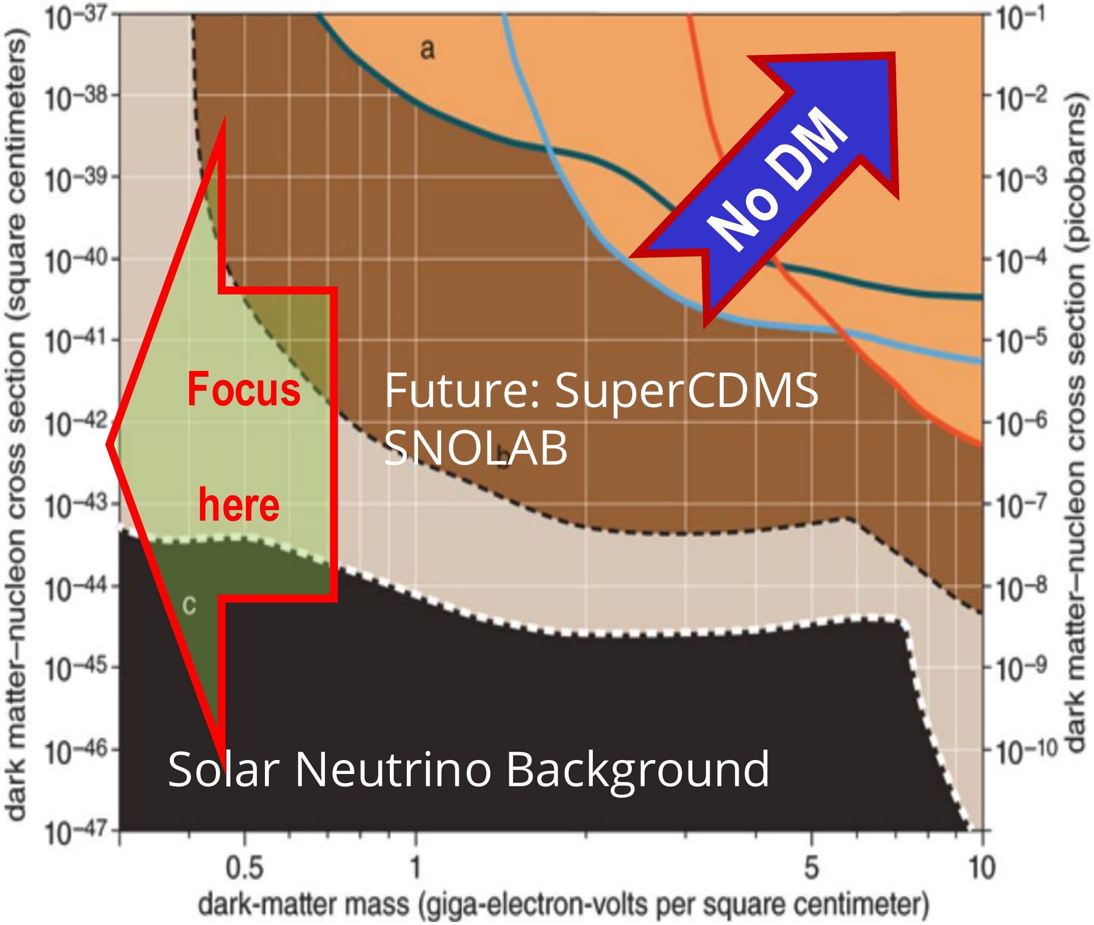
- Professor of physics at U. Texas Arlington (2001 – present)
  - Created and co-leading new DAMSA experiment
  - Created and led the Beyond the Standard Model (BSM) physics group in neutrino experiments in U.S. HEP decadal study, Snowmass2021
  - Founding convener of DUNE BSM@ν group in 2013 (1^{st} in community!)
  - Responsible for field cage construction for the 1^{st} two 17kt DUNE FD – total surface area 3000m^2
    - Constructed several DUNE field cages for ProtoDUNE @ CERN
    - Ready for production this year, 2026!!


ProtoDUNE VD
28m
145m
18m

Physics Motivation For DSP

- Direct searches have challenges in kinematic reach, leaving low mass range un-explored

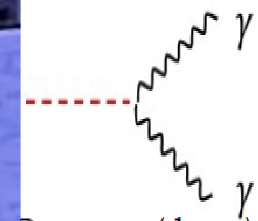
- Strategy:
  - Search for dark sector particles in unexplored kinematic regime
  - Make and discover DSPs in an accelerator
  - Establish the infra to better understand DM



What is DAMSA?

- A very short baseline, **table-top scale** dark sector particle (DSP) search and **discovery** experiment at high intensity, yet capable beams
- Stands for **DA**ark **M**essenger **S**earches at an **A**ccelerator (DAMSA, pronounced da-am-sa)
  - 담사 (潭思) = 깊은생각 – Rumination or Reflection
    - J. Yu *et al*., PRD 107, L031901 (2023)
    - Conceptual Design Report, arxiv: 2601.15255 (2026)
- Goal is to discover a portal particle to the Dark Matter World at a particle accelerator and provide crucial data for the fundamental theory in a controlled environment
- DAMSA can be at any accl. facility, including CERN

- Photons
sector pa
  - Bench
(ALP)
the Pri
- **Produce**
possible
- **Capture**
wide a m
possible
- **Mitigate**
from neu
two EM
- **Place th**
to the be



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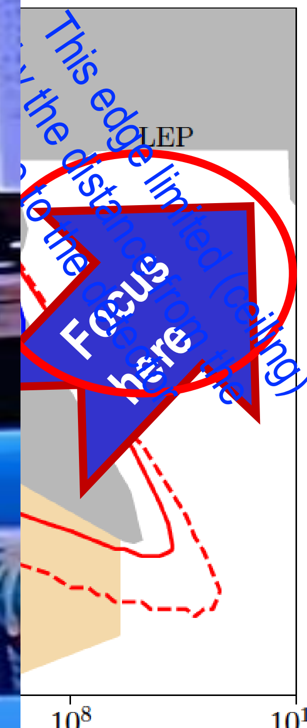


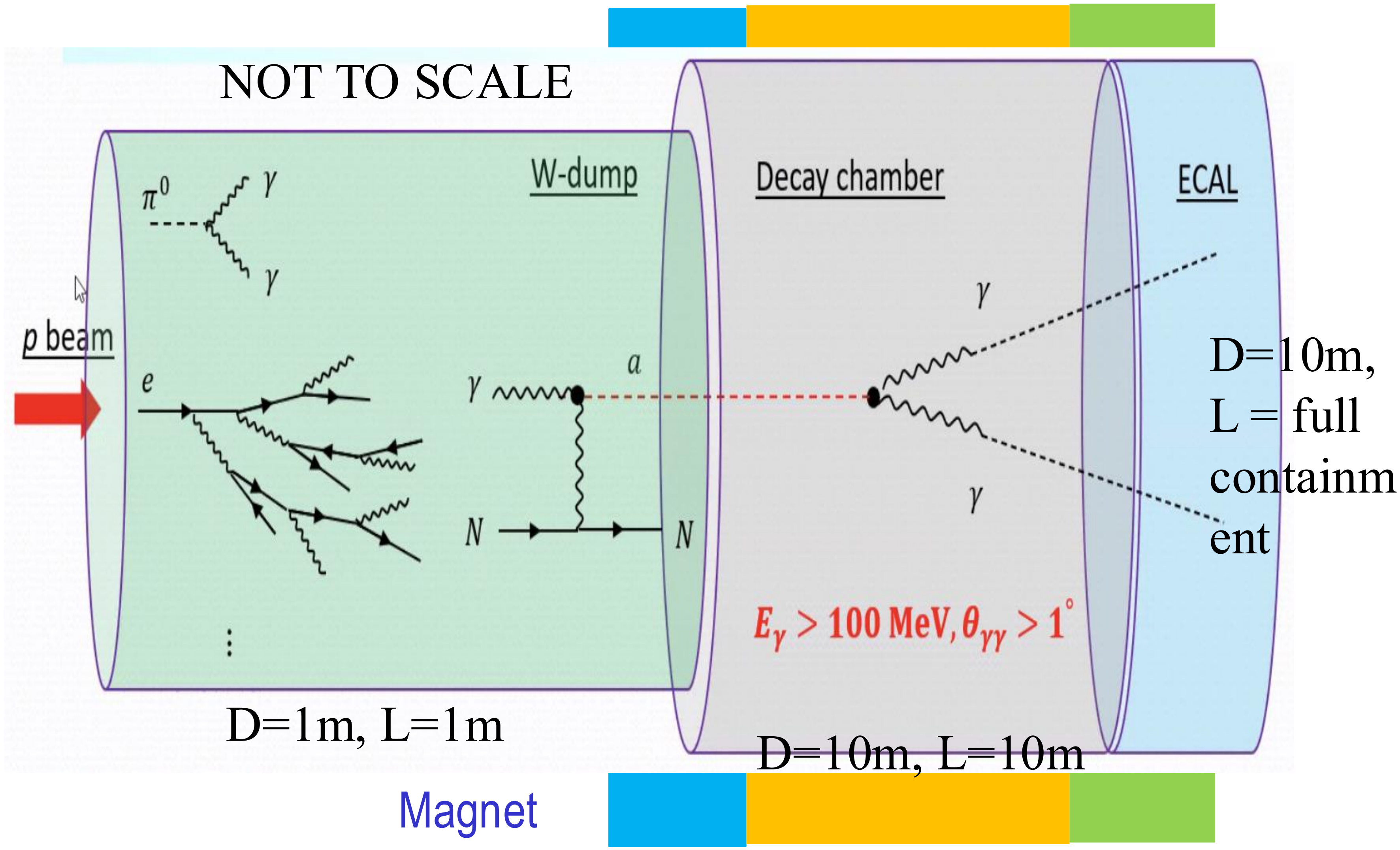
The three key elements

- The bad
- The beam

- The ugly
- The dump

- The good
- The detector

Detector Concept Design



Physics Driven DAMSA Detector

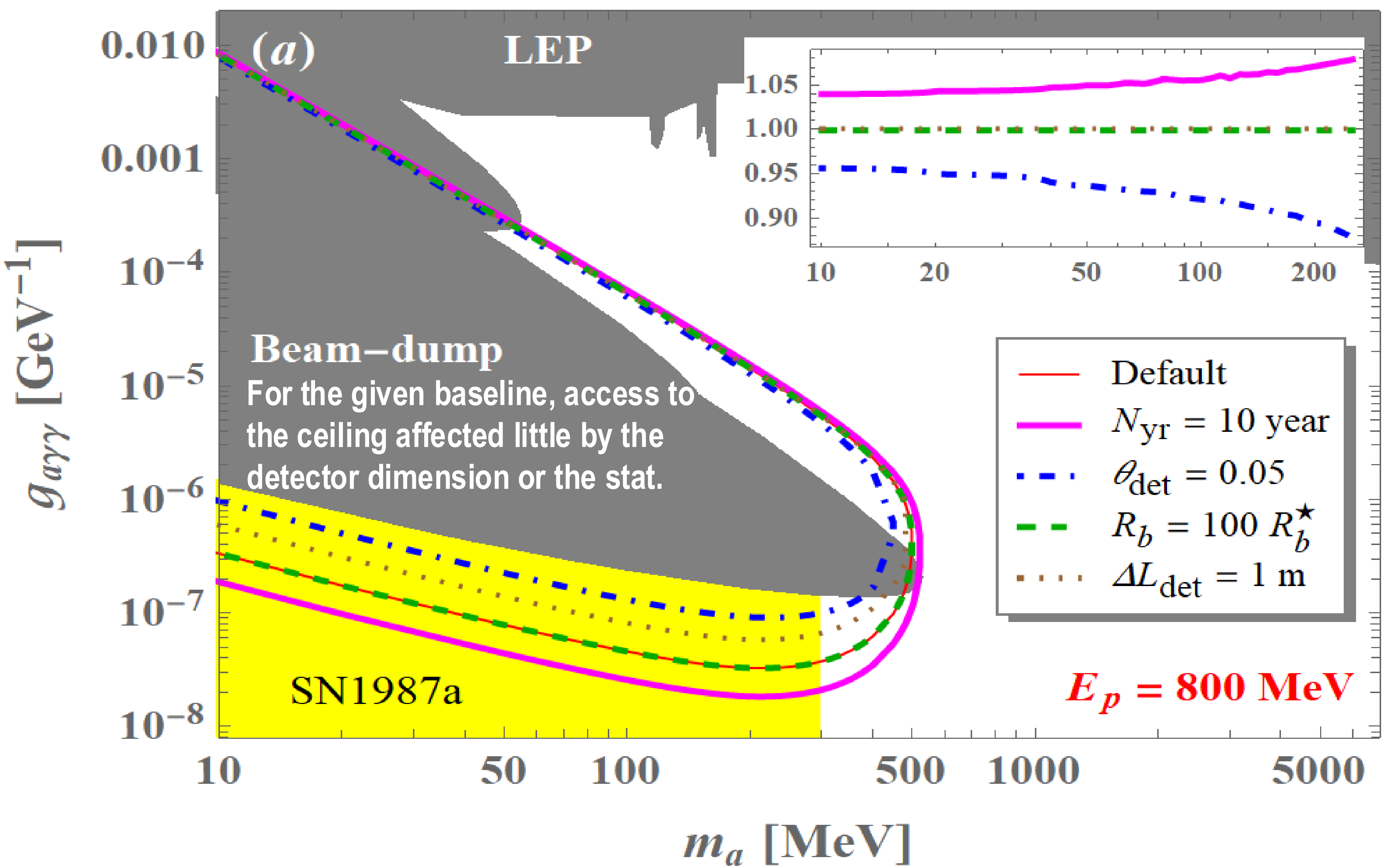
- Discover dark sector particles beyond 2γ ALP, such as
  - Dark photon / ALP to e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$?
  - HNL, Low mass dark matter, etc
- Based on the signal and neutron background mitigation studies, using GEANT4 ➔ Detector requirements
  - Fine granularity for a **superb shower position and angular resolutions** for 2 EM particle vertex pointing & DCA precision better than 1cm in the vacuum decay volume
  - **Fast timing** capability at sub-ns level (~100ps) for two EM particle arrival time differences
  - Capability of measuring up to 500 MeV photons with as **fine a mass resolution** as accomplishable
  - Capability to **distinguish charged particles** from neutrals

Mo ... ing

- The qu ... ace with a dran ...
  0. Co ... N_{yr}=1yr
  1. Sr ... =3mo
  2. Re ... 10^{-2})
  3. Re ... 1m (10^{-3})
  4. Re ... 2)

Proto ...

Impact of Exp. Param. to the Ceiling



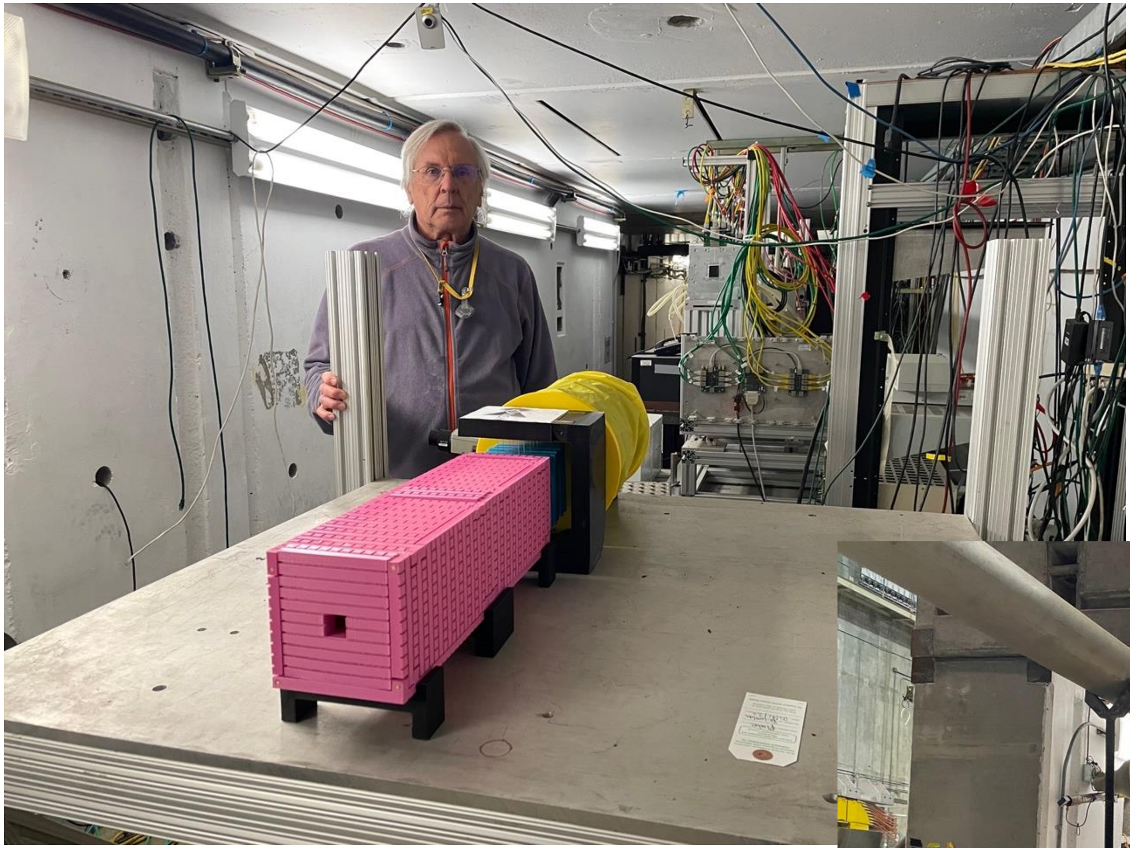
DAMSA Pathfinder Strategy

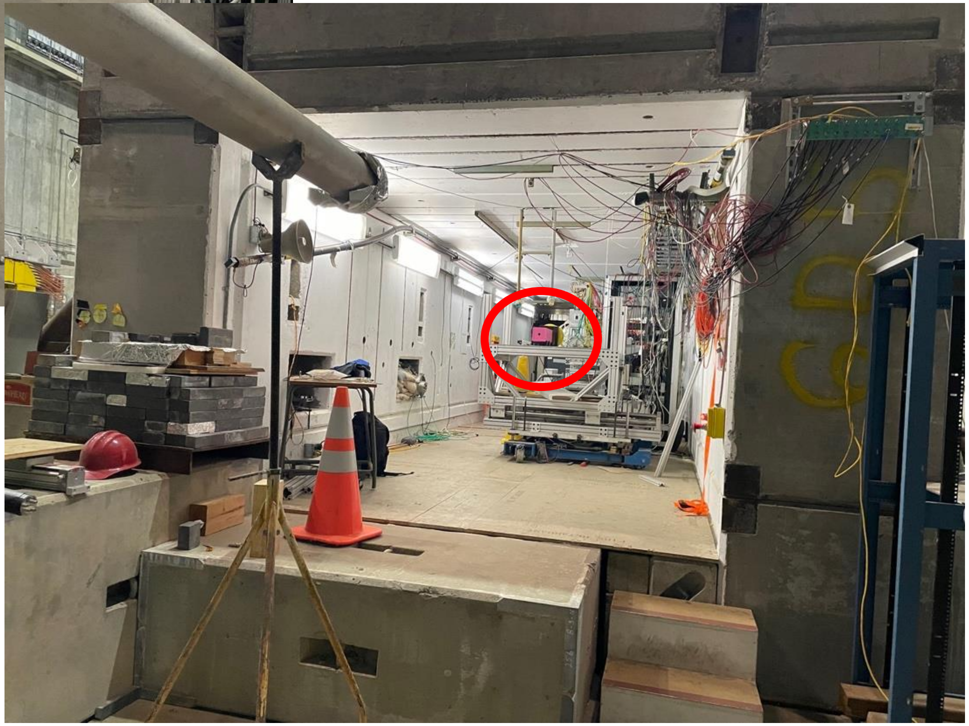
- Given the confidence of Little DAMSA sensitivity, DAMSA can be a very small detector ➔ **DAMSA becomes more REAL!!**
- Primary goals are to demonstrate
  - Physics case feasibility ➔ can we access the target parameter space?
  - Background validation and handling ➔ did we make a mistake?
  - Physics before other p-beam dump facility (e.g. BDF@CERN) is ready
    - Produce physics, as the collaboration builds up the experiment and seek funds
- Strategy for the pathfinder
  - Find a pathway to focus on physics case feasibility test
    - Need a facility that has as little neutron background from the dump as possible
  - Electron beams will do better job than hadron beams
  - Produce physics every phase

The DAMSA Pathfinder Experiment

- **The goal: Mount and complete a <u>physics pathfinder in the next 3 yrs</u>**
- Beam: 8GeV e-beams at SLAC's LESA ➔ greatly reduced neutron backgrounds, compared to proton beams, provides flexibility
- Target: 5cm x 5cm x 15cm W target (~43X_0)
- Vacuum decay chamber : 10cm (r) x 30cm (L)
  - Enable the two EM particles from the vertex in vacuum to be separated
- Detector: 6 layers of 10cmx10cm Si tracker under B=1T permanent magnet +

DAMSA at SLAC's LESA?





Beam Related Background Mitigation

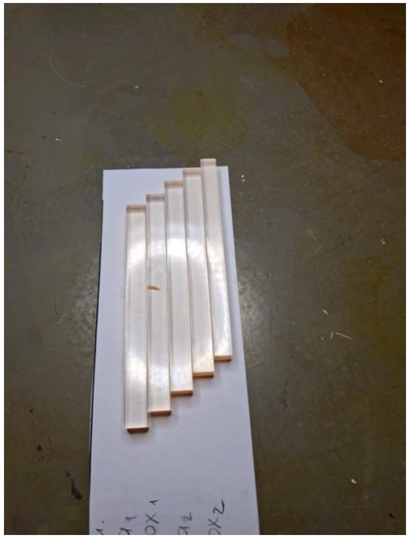
- Two beam related background components
  - Fast component : Particles exiting from the target/dump, immediately enter the experiment together with the signal
  - Slow component : Particles (primarily neutrons) lingering around after a beam interaction, entering the experiment at random times and affecting the subsequent beam interactions
- Beam configurations could help mitigating and minimizing both the components
  - Adjusting the number of particles in each beam pulse for fast components (10^4 e/pulse)
  - Adjusting the beam pulse separation (or the repetition rate) for slow components, allowing slow neutrons to be absorbed by the water in atmosphere before the next pulse (>10μs)
- Beat the remaining background using detector capability

DAMSA Detector Requirements

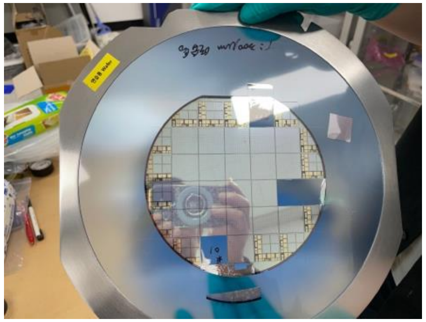
- Physics driven requirements to accomplish
  1. Sub-ns timing difference resolution
  2. Good vertex pointing resolution for $\gamma\gamma$ and e^+e^-
  3. Low E threshold identification of e^+e^-
     - Charge identification to help further background mitigation
  4. As fine an energy resolution as reasonably accomplishable
- A proposed configuration – from up to down stream
  - 20cm(D)x30cm(L) vacuum chamber
  - ~6 rad-hard Si-tracking layers under B field for charge ID
  - 44cm depth ($24.5X_0$) of highly granular CsI total absorption ECAL

DAMSA – The ECAL & the Tracker

- U. of Chicago built CsI ECAL for K-TeV experiment at Fermilab and the KOTO experiment at KEK
  - Timing resolution of 200ps accomplished
  - 14 blocks of $5\text{x}5\text{x}50\text{cm}^3$ undoped CsI crystal secured
  - ISMa in Ukrain produced 50 bars of $1\text{x}1\text{x}12\text{cm}^3$
  - SNU, KNU, BNL and UCR working on QC



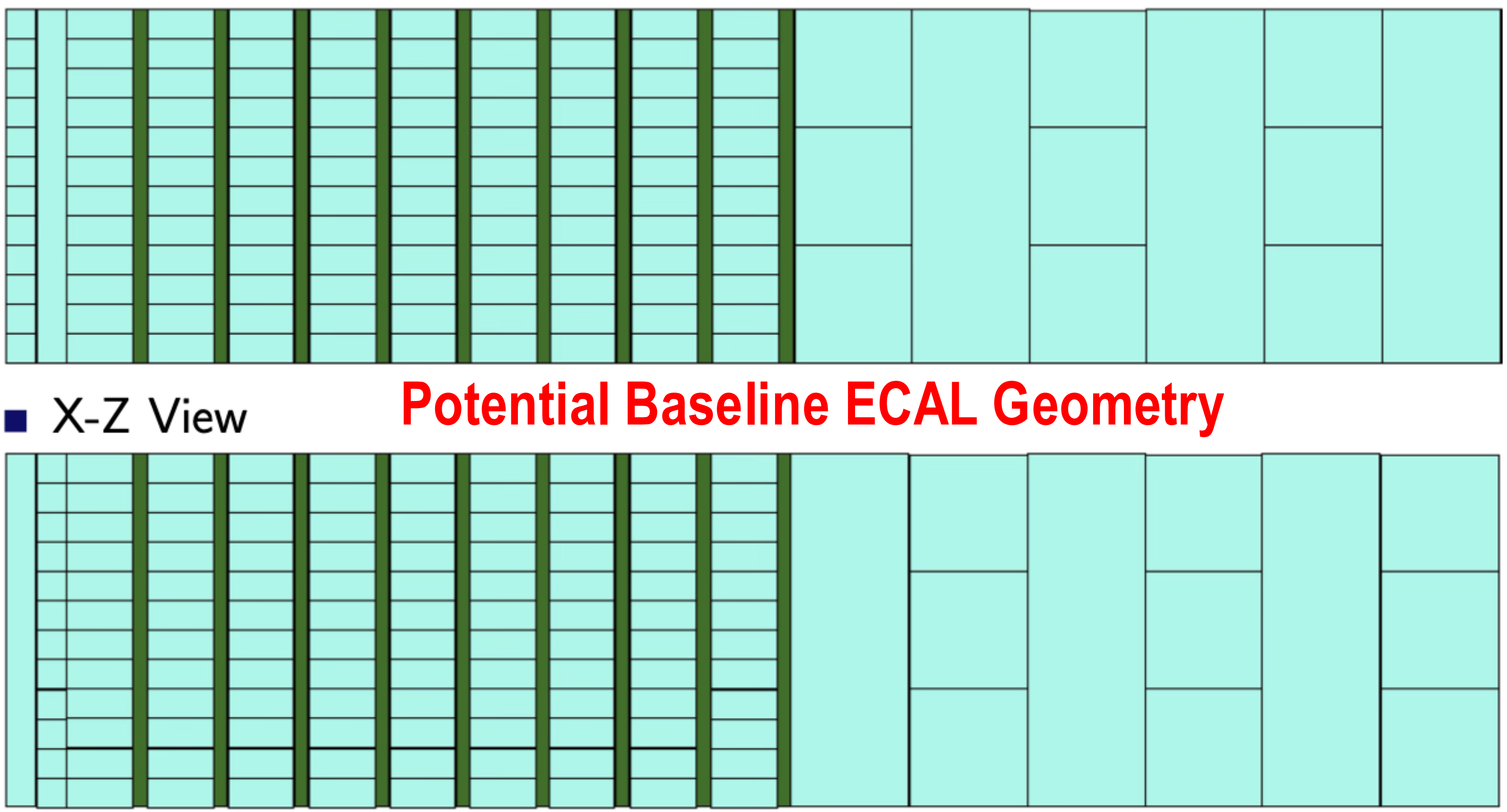
- KNU responsible for CMS forward LGAD detector
- The Low Gain Avalanche Diode (LGAD) consists of 16x16 pixels of $1.3\text{x}1.3\text{mm}^2$
  - Position resolution of 35 – 50 μm
  - Timing resolution per track <35ps (single hit resolution <50ps)



- High radiation tolerance ➔ DAMSA can be a testing ground

Phase 1 Detector & ECAL Geom.

- Phase 1 ➔ The a2γ demonstrator @ LESA 8 GeV e
  - Build a pathfinder with only W target, vacuum decay chamber and an ECAL + charged particle veto counters which occupy the same location and space as the tracker



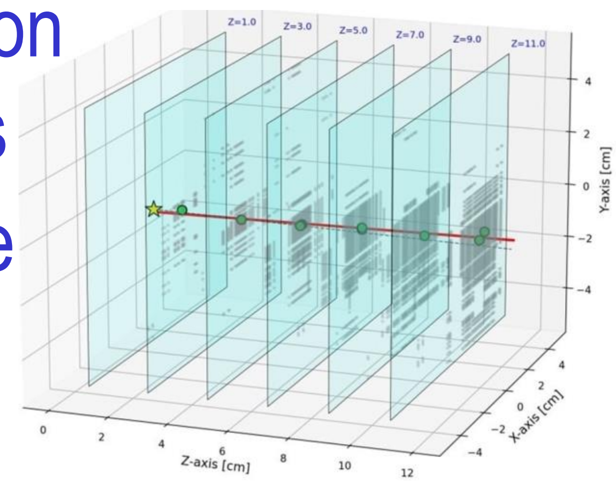
- X-Z View

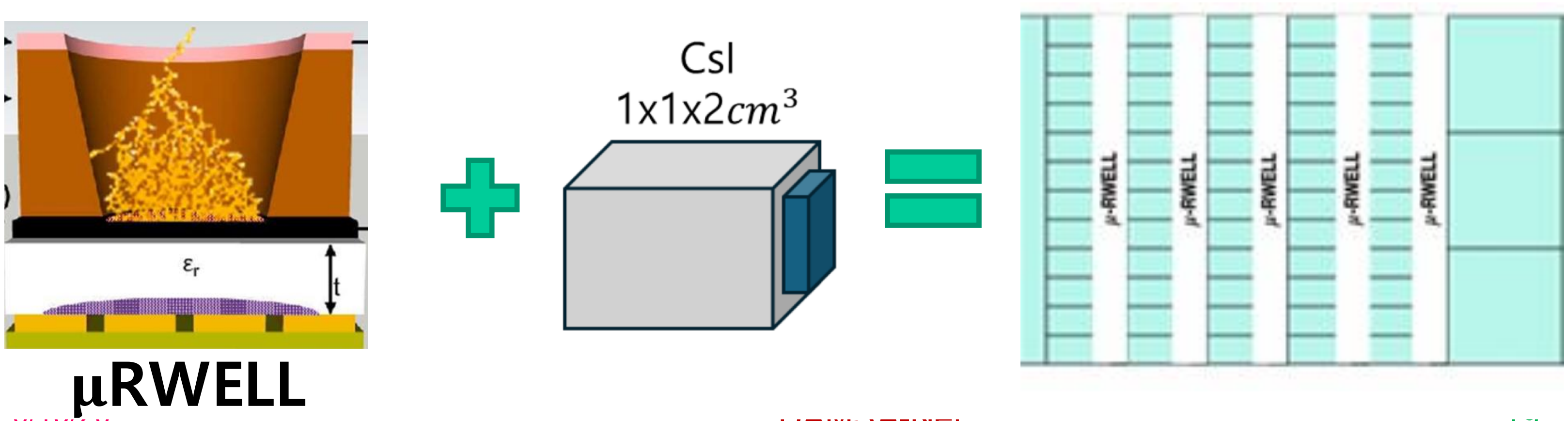
Potential Baseline ECAL Geometry

- Y-Z View

Total Absorption Tracking ECAL, TATE

- ECAL is essential for background mitigation & signal id
- A new idea of sandwiching tracking layers in between CsI
- µRWell R&D at SNU close to application
- Other thin and precise tracking devices
- Innovative approach that can boost the position, energy and mass resolutions





Neutron Background Reduction Summary

- Benchmark Beam Parameters -

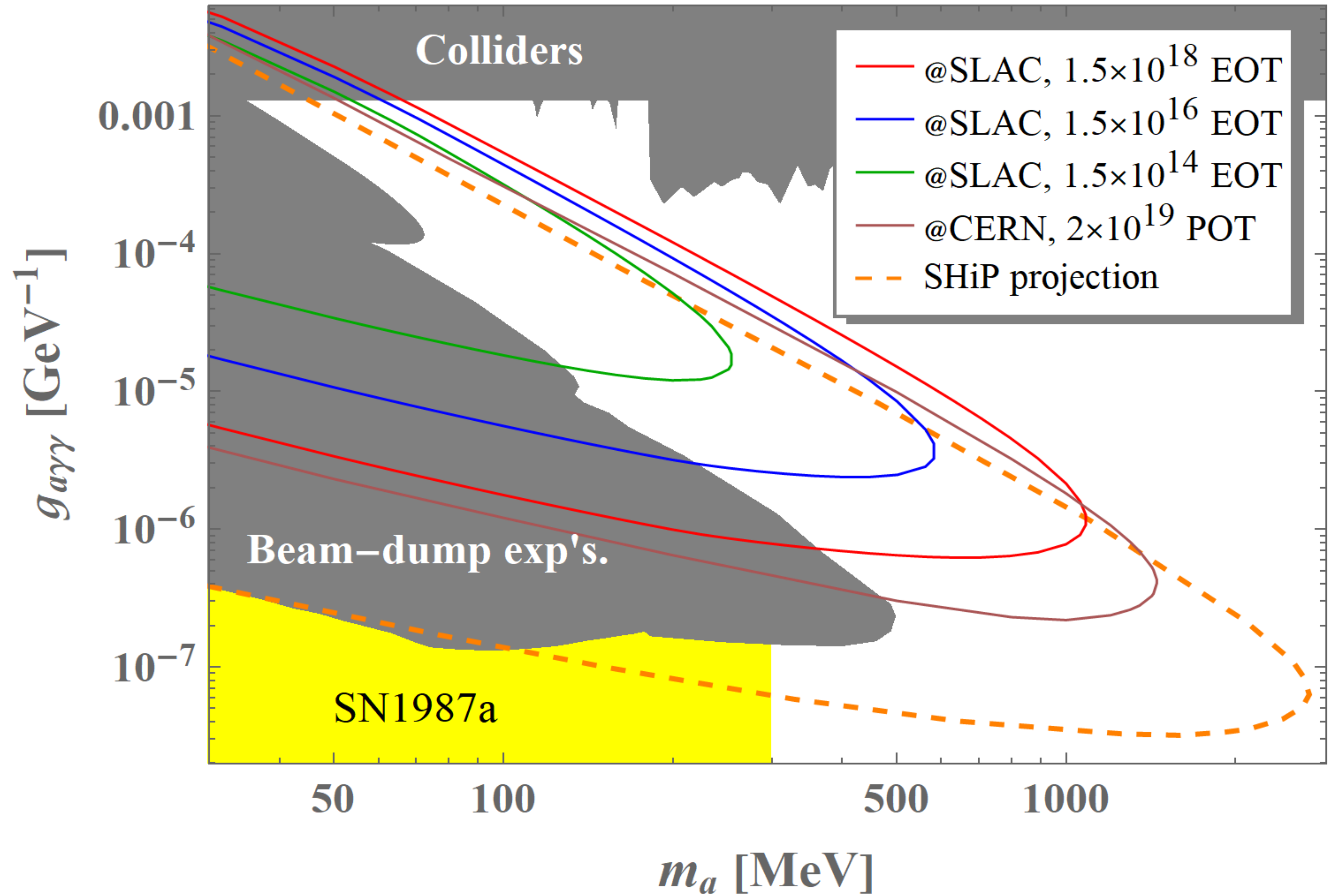
Beam energy (E_{beam}) : 600 MeV
Beam current (I_{beam}) : 660 μA
Beam power (P_{beam}) : 400 kW
Protons-on-target per year : 1.3×10^{23}

Description	Symbol	Numbers
Protons per pulse	n_p	4.8×10^7
Beam induced neutrons	n_n	1.29×10^5
Neutron-induced photons	n_γ	2.74×10^5
n_γ after 15 MeV threshold cut	$n_{\gamma,th}$	25.1
Neutron-induced photons hitting the detector	$n_{\gamma,th,det}$	2.94
< 40 ns arrival time cut	$n_{\gamma,th,det,TOA}$	1.47
Number of photon pair combinations	$n_{\gamma\gamma}$	< 1
Cut	**Symbol**	**Efficiency**
Fiducial volume cut	$\epsilon_{fid.vol.}$	6.13×10^{-1}
DCA < 1 cm	ϵ_{DCA}	4.23×10^{-3}
$\Delta TOA < 0.1$ ns	$\epsilon_{\Delta TOA}$	2.01×10^{-1}
Back-tracing	$\epsilon_{backtrace}$	4.16×10^{-2}
Invariant mass ($29MeV < m_{inv} < 31MeV$)	$\epsilon_{m_{inv}}$	1.46×10^{-2}
Invariant mass ($99MeV < m_{inv} < 101MeV$)	$\epsilon_{m_{inv}}$	1.25×10^{-3}
Invariant mass ($199MeV < m_{inv} < 201MeV$)	$\epsilon_{m_{inv}}$	2.02×10^{-5}

neutron-induced photons are reduced by (1 / 2.74e-5) = **3.6e-6**

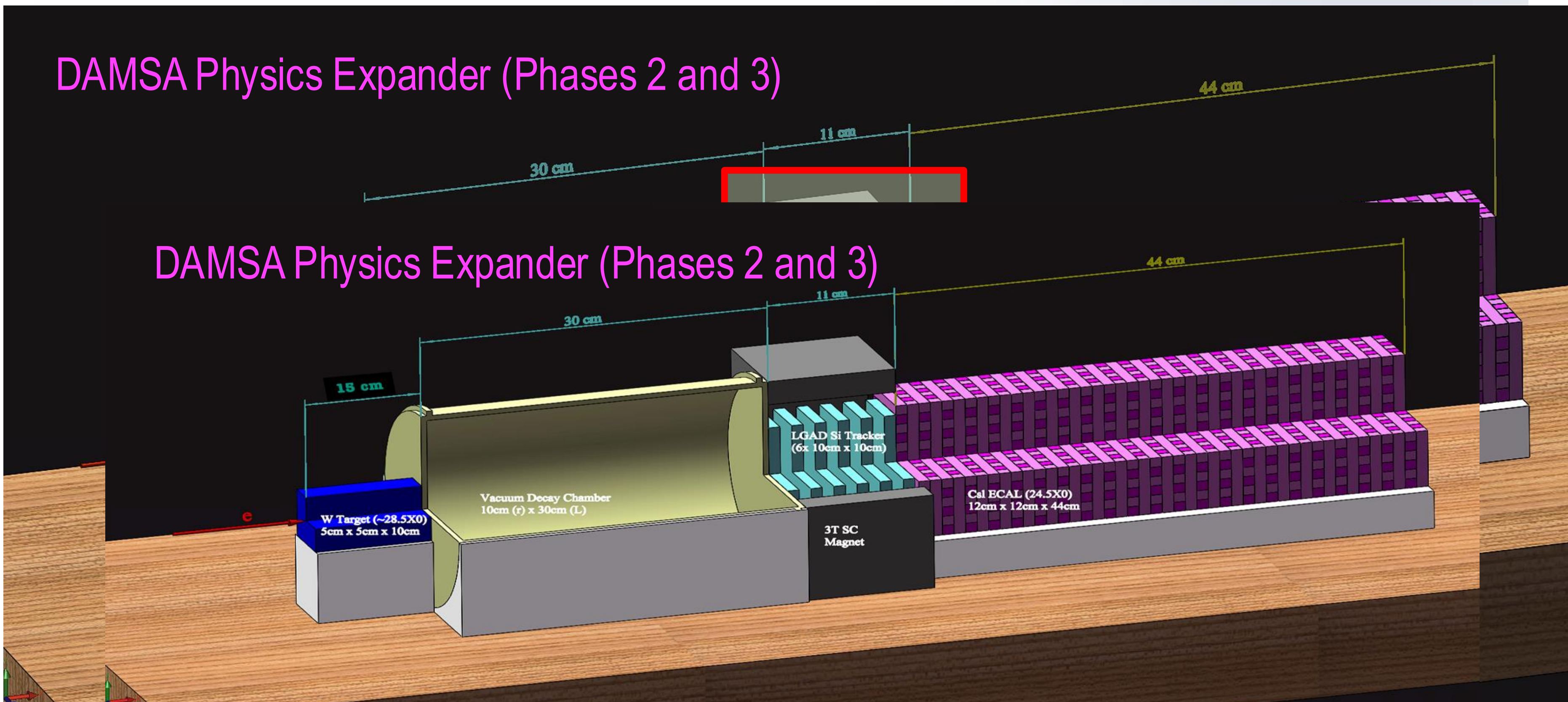
Overall rejection factors
1.92e-7
9.51e-9
1.54e-10

DAMSA Sensitivity @SLAC 8GeV e



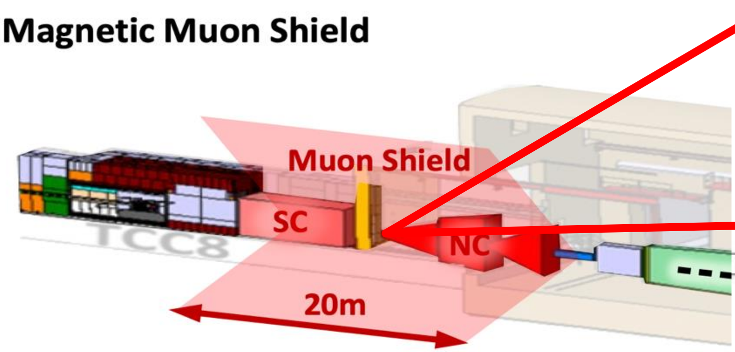
DAMSA – Phased Approach

- Phase 0 ➔ e-beam background validator
  - Measure and validate the MC neutron and photon bck counts
- Phase 1 ➔ The a2γ demonstrator @ LESA 8GeV e-beam
  - Build a path finder with only W target, vacuum decay chamber and an ECAL + charged particle veto counters which occupy the same location and space as the tracker

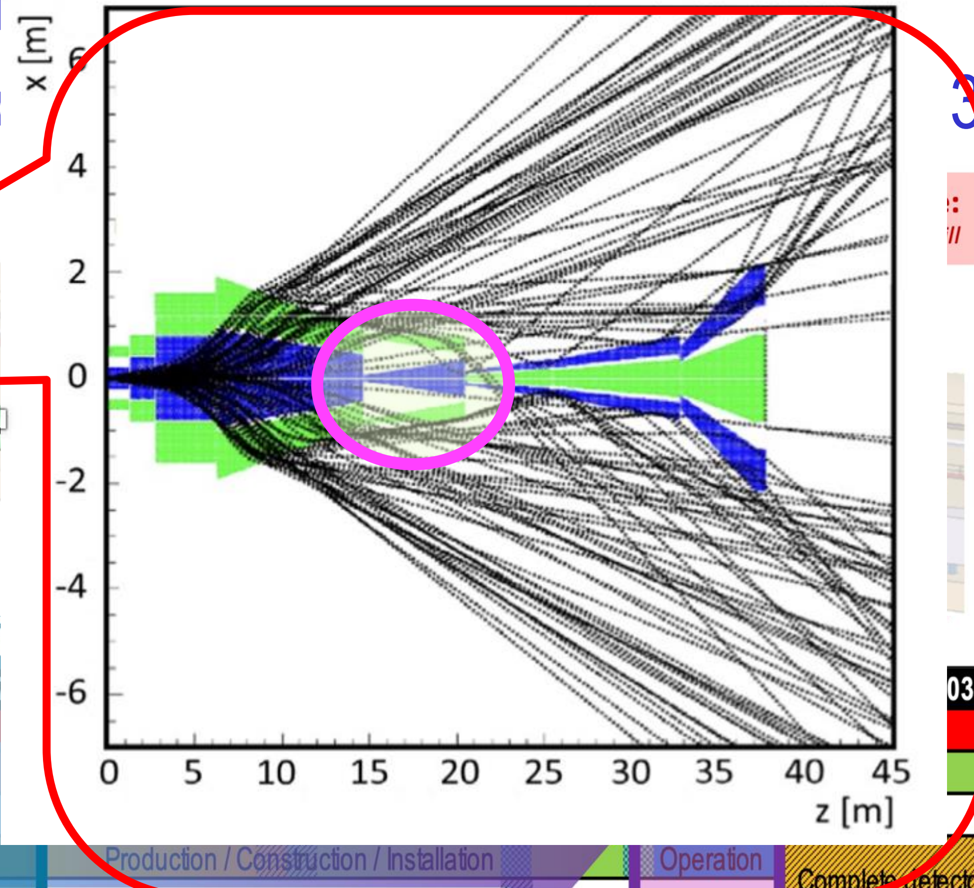


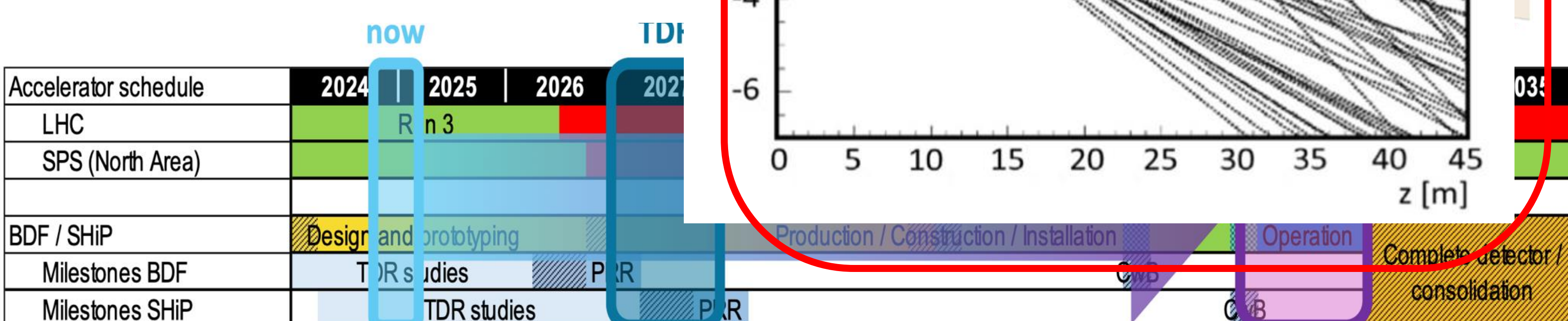
DAMSA@CERN BDF (2504.02923)

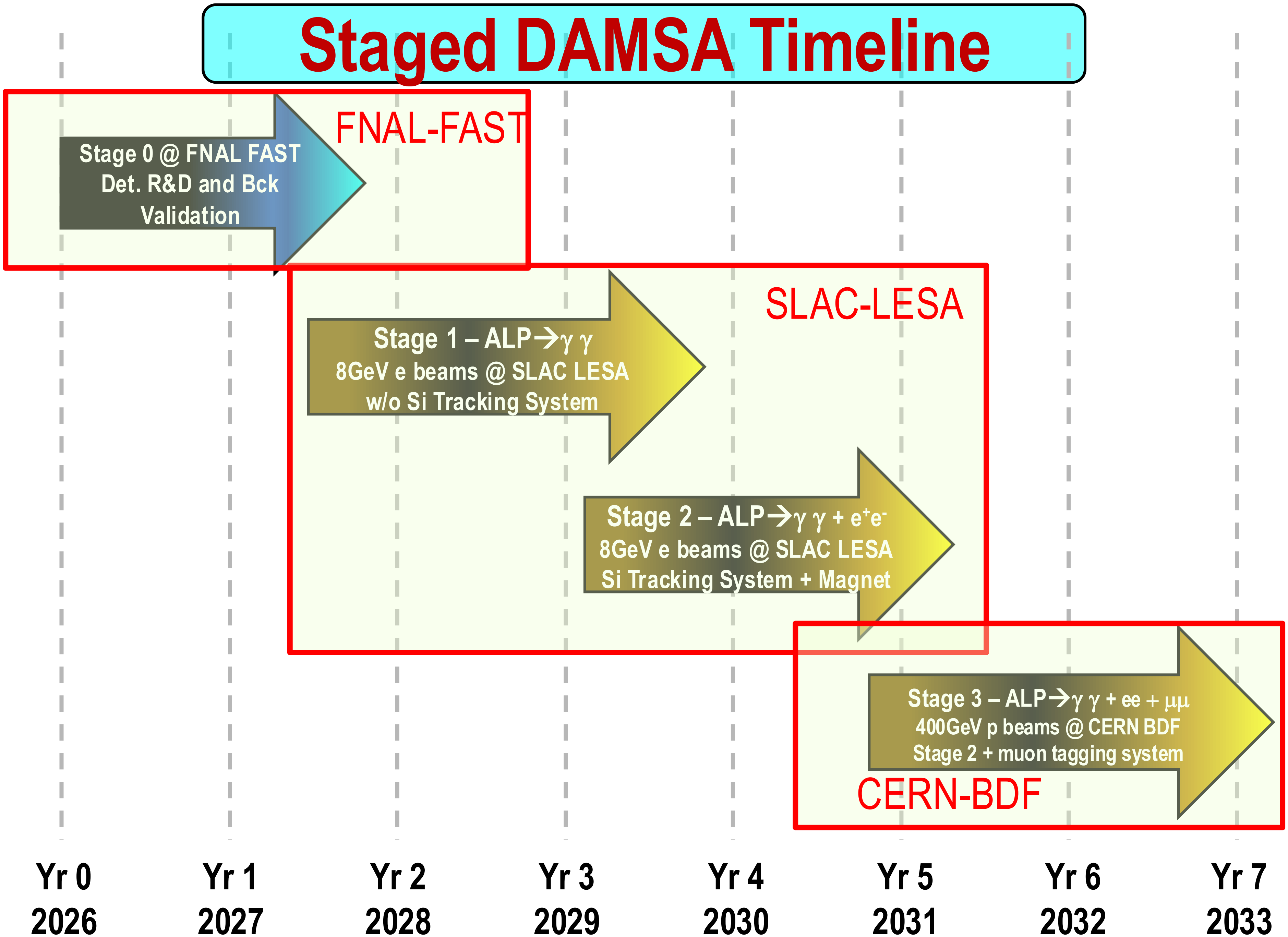
- SHiP approved at CERN SPS ECN3 experimental area
- Plan on completing the construction and begin experiment commissioning in 2032 with
- DAMSA can be placed in fr ... 32



- **Active deflection** of μ with E > 10GeV





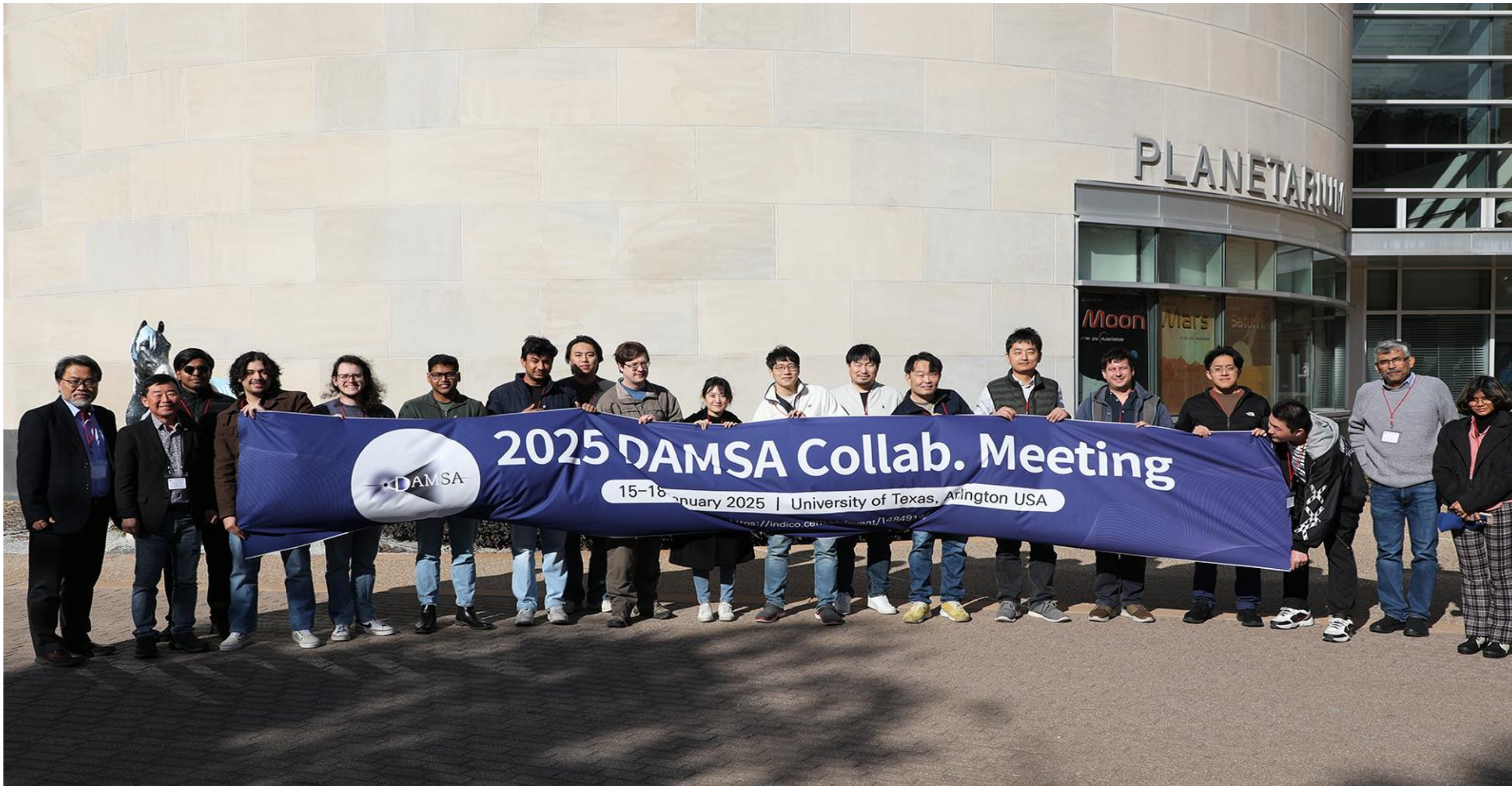

Staged DAMSA Timeline
FNAL-FAST
Stage 0 @ FNAL FAST
Det. R&D and Bck
Validation
SLAC-LESA
Stage 1 – ALP→γ γ
8GeV e beams @ SLAC LESA
w/o Si Tracking System
Stage 2 – ALP→γ γ + e+e-
8GeV e beams @ SLAC LESA
Si Tracking System + Magnet
Stage 3 – ALP→γ γ + ee + μμ
400GeV p beams @ CERN BDF
Stage 2 + muon tagging system
CERN-BDF
Yr 0
2026
Yr 1
2027
Yr 2
2028
Yr 3
2029
Yr 4
2030
Yr 5
2031
Yr 6
2032
Yr 7
2033

Where is the DAMSA experiment?

- DAMSA has been introduced to the community in the past >4 years, more intensely since 2023
  - Multiple presentations made at conferences, workshops and seminars in the U.S., SK, EU and CERN since 2023
  - US funding agencies and facilities (FNAL, SLAC, PAL & CERN) informed
- DAMSA Proto-collaboration established
  - Lead Investigators: J.Yu (UTA), J. Estrada (BNL), UK Yang (SNU)
    - 14 US + 11 SK institutions on DAMSA (still have room for more)
    - A healthy mixture of theorists and experimentalists
  - Funding applications being submitted
  - Collaborators work on crystal characterization & ECAL R&D

Conclusions

- DAMSA is a table-top scale DSP search and **discovery** exp.
  - Potential for an innovative total absorption tracking ECAL



production & discovery in beams, through the strong
partnership with international HEP community