

CSN3 Referee's meeting  
July 10, 2024

# **The Beam Dump eXperiment - BDX Status and plans**

M.Battaglieri (INFN), M.Bondi (INFN), A.Celentano (INFN), M.DeNapoli (INFN), R.DeVita (JLab), G.Krnjaic (FNAL)

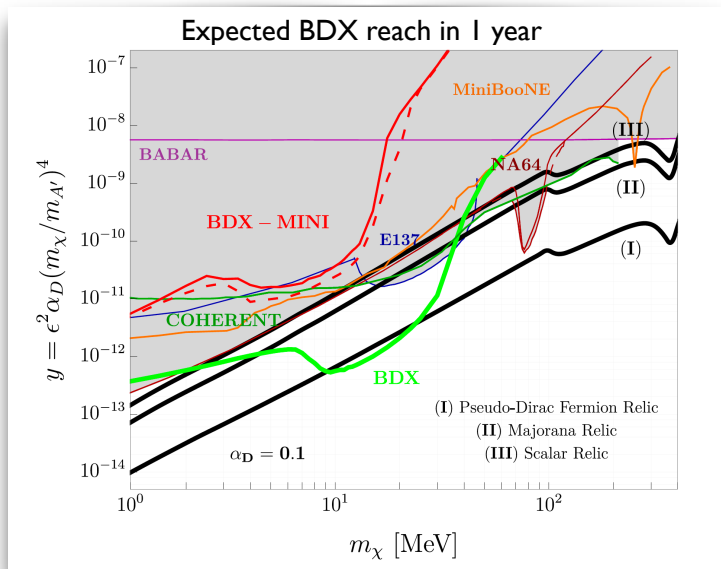
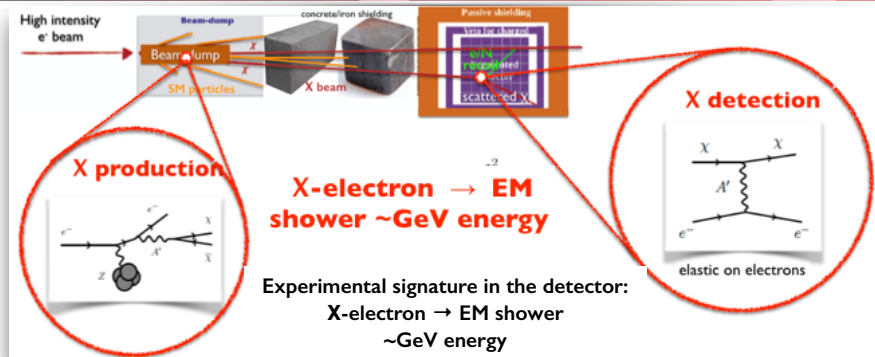
# The Beam Dump eXperiment - BDX

Spokespersons:  
 M.Battaglieri (INFN), M.Bondi (INFN), A.Celentano (INFN), M.DeNapoli (INFN), R.DeVita (JLab), G.Krnjaic (FNAL)

★ Unique experiment able to **PRODUCE** and **DETECT** Light Dark Matter (LDM)

Two-step process:

- I) An electron radiates an  $A'$  and the  $A'$  promptly decays to a  $\chi$  (DM) pair
- II) The  $\chi$  (in-)elastically scatters on an  $e^-$ /nucleon in the detector producing a visible recoil (GeV)



★ BDX will improve by 2 orders of magnitude current exclusion limits in LDM parameter space with sensitivity to the most viable scenarios (eg. relic LDM)

★ JLab offers the best condition for BDX:

- A high energy beam: 11 GeV
- The highest available electron beam current:  $\sim 65 \mu\text{A}$
- The highest integrated charge:  $10^{22}$  EOT (41 weeks)
- Fully parasitic wrt Hall-A physics program (Moeller experiment)

★ Approved by JLab PAC-46 in July 2018 (reconfirmed in 2023 by PAC-51) with maximum scientific rating (A) and waiting for scheduling

★ Presented, discussed, and included in SNOWMASS-21 report (RF6-RF0)

★ BDX would take advantage of the future 11 GeV positron beam and 20+ GeV upgrade

★ BDX Collaboration: more than 100 researchers from 18 institutions (US, Italy, Germany, UK, Korea) signed the BDX proposal

# BDX in CSN3

**INFN  
Commissione  
Scientifica  
Nazionale III  
Sep 19 2017**

## BDX proposal submission to JLab Program Advisory Committee

LOI presented to JLab PAC42 (2014)

- prepare a full proposal

BDX Proposal to JLAB PAC 44 (2016)

- Conditionally Approved (C2)
- beam-on bg
- full simulation (~10<sup>22</sup> EOT)

BDX Proposal update to JLAB PAC 45 (2017)

- in situ beam-on bg tests
- simulation strategy

Tests/simulations results to JLAB PAC 46 (2018) Full approval with scientific rating (C1)

## BDX presentation to INFN-CSN3

CSN3 Mar14 Roma CSN3 Sep14 Bari CSN3 Feb15 Roma CSN3 Sep15 Cagliari CSN3 Sep216 Perugia



**Summary and Recommendation:** BDX could become the definitive beam dump experiment at electron accelerators, based at Jefferson Lab, it would use the CEBAF high-intensity beam and modern technologies for electron design, staged and data acquisition, to achieve the most stringent limits (or to make the first discovery) of a class of dark matter particles. The collaboration is encouraged to proceed with a full proposal to the laboratory, but the PAC emphasizes that the collaboration needs to start a full proposal to make it be eventually approved. Experimentally, a fully funded and complete design needs to be presented, including both simulation and measurements with CSN3-BDX or otherwise that demonstrate an sensitivity to both detection channels as well as its ability to reject cosmic ray backgrounds with better accuracy over time. Theoretical, it must be made clear that models are tested through comparison against the possible measurement, as well as the extent to which these models are (or are not) addressed in other experiments at other laboratories. Finally, the PAC notes that the laboratory needs to fund and commence a plan that would have the experiment well in advance, and recommends that the laboratory require an approved proposal before scheduling access time with beam as part of the design process.

While simulations are an essential tool in understanding background conditions, they are not sufficient to design an experiment. The BDX collaboration is therefore encouraged to think more about benchmarking their simulations with measurements on site.

**Summary:** The collaboration should continue working with JLab to carry out the proposed tests, towards achieving full approval as a subsequent PAC.

- Approved by JLab PAC46 in Aug 2018 with maximum scientific rating (A)
- ... followed by a long journey to seek infrastructure funds
- Meanwhile: proposals to DOE-FOA, NSF and the Moore Foundation, BDX-MINI deployment and results, PAC51 jeopardy defence
- We are currently investigating BDX (2 options) and/or BDX-PIPE

A roadmap towards BDX	Completion
Theory and physics case	100%
Detector R&D: signal detection and BG rejection	100%
Detector prototyping: cosmic BG assessment	100%
Detector prototyping: beam-related BG assessment	spring 2018 (12 GeV available in Hall-A)
BDX proposal submission to JLab Program Advisory Comm	C2-Approved; full approval summer 2018
Costs estimate	baseline fully defined
Funds procurement	full PAC approval required
The BDX Collaboration	Lobbying started
Costs optimization	custom electronics ready for 2018
TDR	2018-2019
Infrastructure and detector construction	2020-2022 (?)
<b>Running BDX</b>	
	2022-2025 in parallel Moeller exp

2014	2015	2016	2017	2018	2019	2020 - 2022
Theory and physics case	BDX prototype	R&D cosmic bg assessment	R&D cosmic EM shower	R&D BDX-Hodo	R&D Trigger/less DAQ	BDX detector construction
BDX Conceptual design	R&D cosmic bg assessment	R&D 1ech Cd-matrix	R&D custom RADC	R&D beam-on assessment	BDX TDR	

Costs	BDX detector		~0.725M (0.475M)	
	Infrastructure at			~1.5M
<b>Calorimeter</b>	CSi(Tl) crystals	~900	refurbishing, wrapping	20k
	(6x6) mm <sup>2</sup> SiPM	~900	new procurement	50k
	Front-End RO and cables	~900ch	new procurement	35k
	Mechanical		design, procurement	15k
<b>Inner Veto</b>	Plastic scintillator	~4 m <sup>2</sup> , 8 paddles	new procurement	25k
	(3x3) mm <sup>2</sup> SiPM	~90	new procurement	5k
	mechanical		design, procurement	5k
<b>Outer Veto</b>	Plastic scintillator	~12 m <sup>2</sup> , 30 paddles	new procurement	50k
	PMT	28	refurbishing	5k
	mechanical		design, procurement	10k
<b>DAQ</b>	CAEN V1725	1000	procurement (custom boards)	500k (250k)
	Shielding	Lead bricks	~500	refurbishing

## JLab commitments

- ★ Create a new area (pit) for the BDX detector (~\$1.5M)
- ★ Install ~2m long lead wall into the BD vault or in the BDX pit (~\$0.5M)
- ★ Provide the FE electronics (crates and fADC) for the BDX detector (~\$1.2M)
- ★ Negotiate BDX crystal's calorimeter with FAIR (PbWO<sub>4</sub>), SLAC (CsI(Tl)), CERN (BGO)
- ★ Support tech support to BDX installation and operations

## BDX commitments

- ★ Support JLab in BDX infrastructure design by running simulation and engineering advices
- ★ Seek funds from funding agencies (DOE, NSF, INFN, JAPAN) to build the BDX detector (plastic scintillator, SiPMs, cables, mechanics, ...)
- ★ Develop an SRO-DAQ for BDX
- ★ Deploy, install, commission, and operate the BDX detector (4 or 5 modules in total) to collect  $10^{22}$  EOT by 2030
- ★ Develop traditional and AI-supported analysis frameworks to optimize and extend the BDX rich

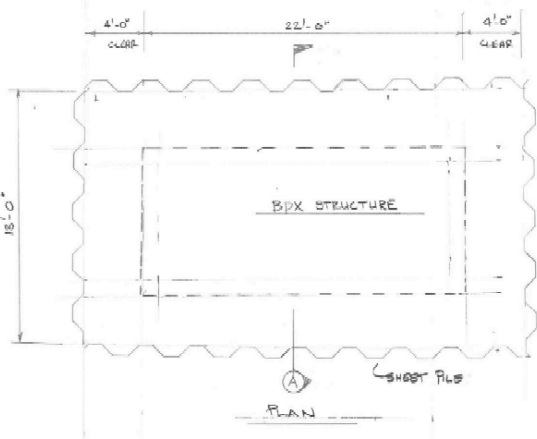
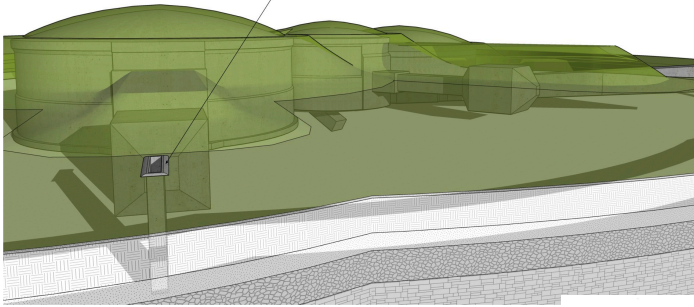
## INFN commitments (Y2025)

- ★ Fund and build the first module of the BDX detector
- ★ Support JLab in the infrastructure design and crystal procurement (CERN and FAIR)

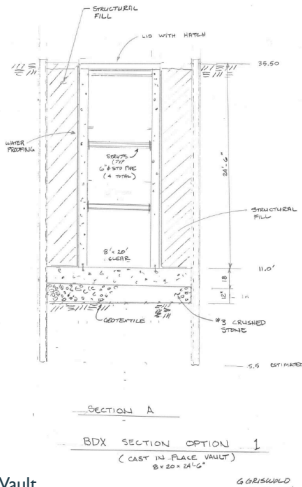
# BDX infrastructures

★ The cost estimate is ~\$1.2M (+ \$0.5M overhead). If no showstoppers are found, the final design will be awarded to an A&E firm.

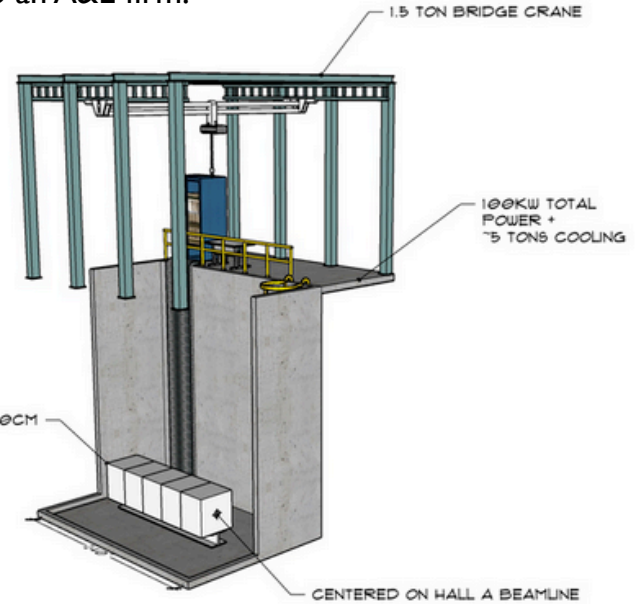
LINED TRENCH VAULT  
OPENING 3' WIDE X 20' LONG X 30' DEEP  
PROTECTED AGAINST GROUNDWATER  
ENCROACHMENT AND ALIGNED WITH HALL A  
BEAM DUMP.



Cast-in-Place Vault

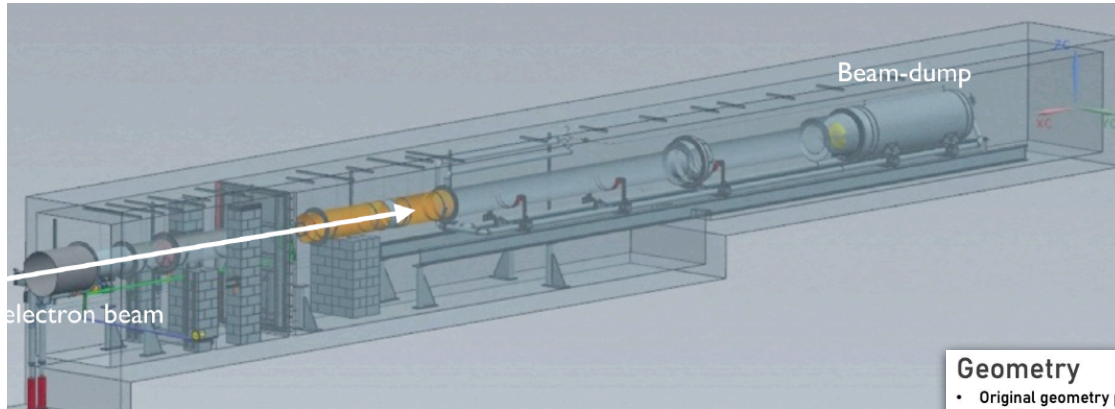


5 MODULES AT 80CM X 100CM X 100CM



★ Mechanical design underway (JLab-Facility Management and INFN-GE MachDesign)

# BDX infrastructures

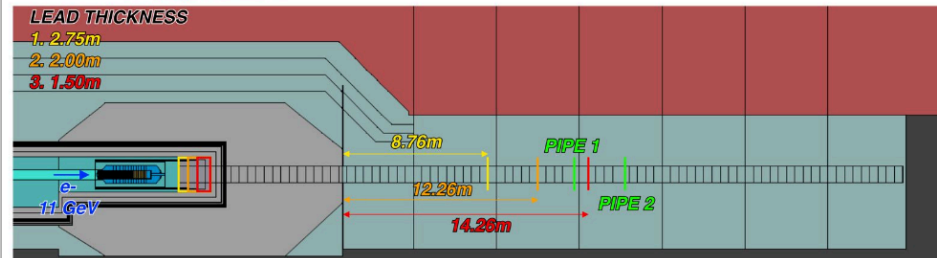


*A.Fulci study in progress*

- ★ Adding 1-2m lead wall downstream of the beam dump to shield penetrating particles (muons)

## Geometry

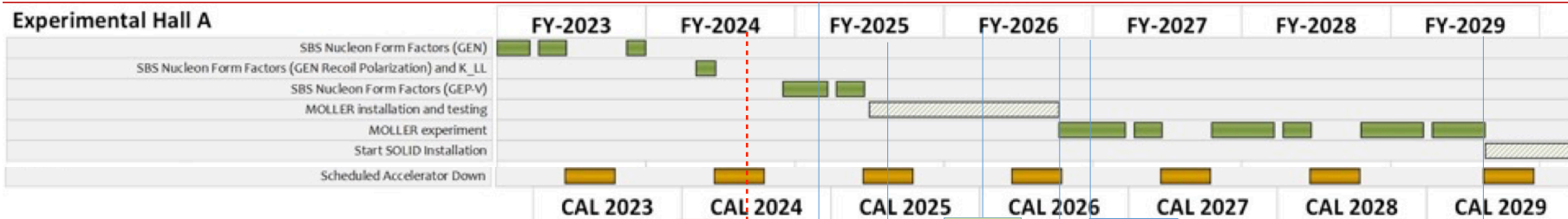
- Original geometry provided by Lorenzo Zana
  - Added a lead block after the beam dump
    - 2.13 x 2.13 x 2.75 m (~141 ton) – e- simulated: ~1e8
    - 2.13 x 2.13 x 2.00 m (~102 ton) – e- simulated: ~2e7
    - 2.13 x 2.13 x 1.50 m (~77 ton) – e- simulated: ~3e7
  - Simulated 10 GeV before the shielding (range from concrete vault's end):
    - Range: 8.76 m
    - Range: 12.26 m
    - Range: 14.26 m





# BDX Physics and timeline

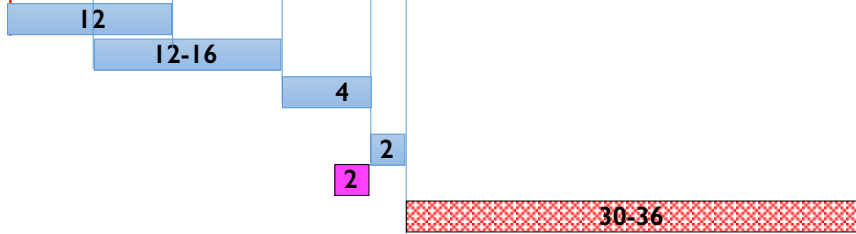
- ★ Renewed interest from G.Krnjaic and D.Rocha to extend BDX physics
- ★ BDX AI/ML-supported analysis
  - re-evaluate BDX-MINI and BDX reach (M.Spreafico, C.Fanelli, P.Moran)
  - neutrino bg (L. Marsicano, M.Holtrop, L.Wolf, A.Pilloni, M.Filippini)



## BDX-HOLE

- I) Funds opportunities for detector (INFN, NSF MRI, DOE, ...)
- II) Prepare and award the tender for BDX infrastructure
- III) BD access and shielding preparation; hole(s) drilled
- IV) infrastructures ready (tent, power, crane, A/C, network)
- V) BDX installation
- V) lead shielding installation in the BD vault

**BDX Run!**



# BDX funds request for 2025

▪ <b>BDX: First/5 module deployment (shared between INFN-GE INFN-CT and INFN-PV)</b>	<b>150k</b>	<b>(15k)</b>
– Plastic scintillators for IV, EV:	60k (PV)	
– SiPM: x56 3x3 mm <sup>2</sup> for Vetos and and x200 6x6 for crystals	25k (CT)	
– WLS fibers	5k (PV)	
– Crystals: x200 CsI(Tl)/BGO refurbishing	2k (GE)	
– Lead foils for passive veto	5k (CT)	
– FEE (preamps and PS)	10k (GE)	
– Mechanical structure	5k (GE)	
– DAQ workstation (all detector)	10k (GE)	
– Slow controls	5k (GE)	
– Cables	15k (CT)	
– Chiller (sj BGO crystals)		(10k)
– Transportation to JLab (CERN if L3 crystals)	8k (GE)	(5k)

**Waiting for a written statement from lab leadership  
before formalize 2025 funding requests**