The Jefferson Lab of the Future

Mariangela Bondì

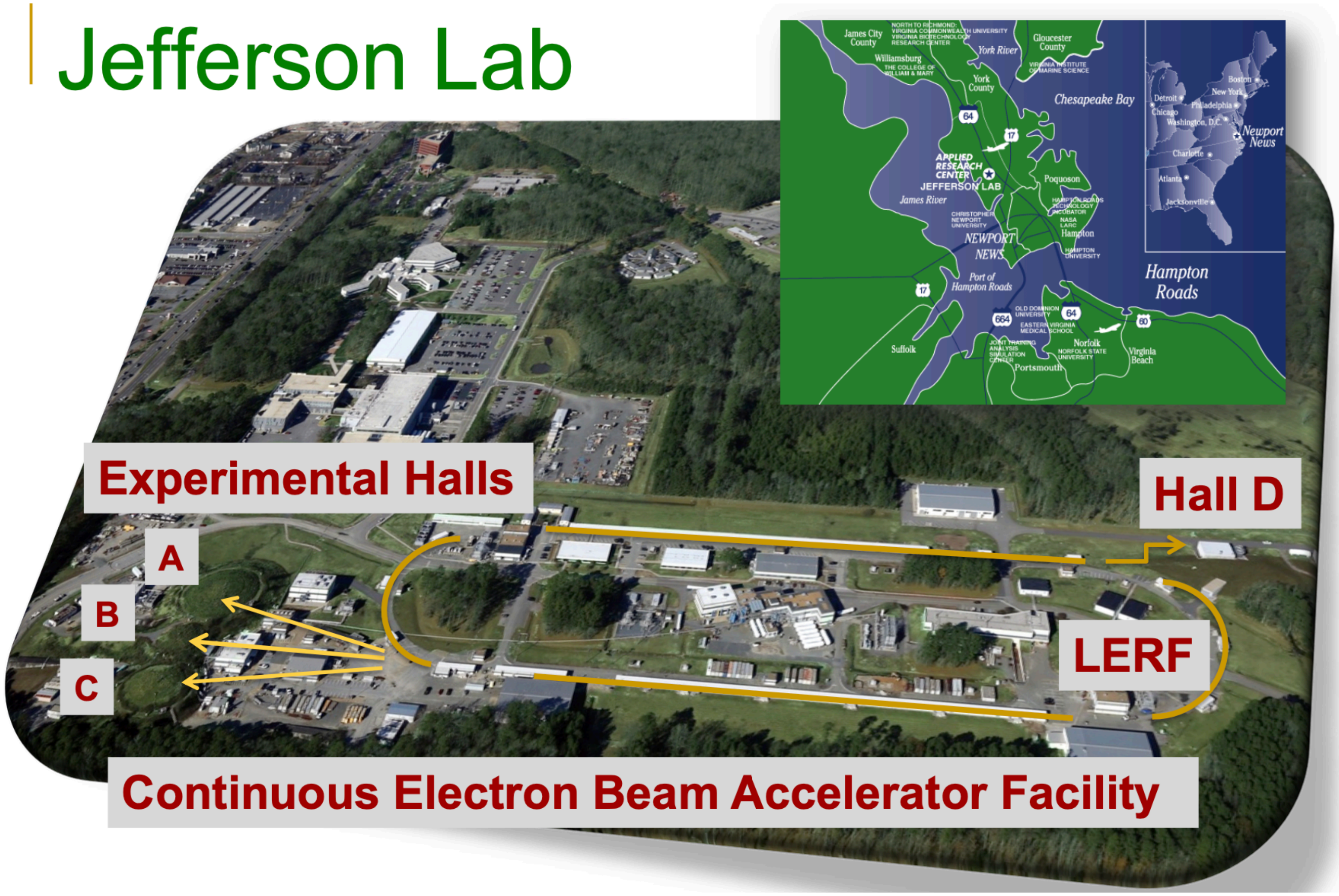
e⁻ JLab12

Jefferson Lab today

CEBAF delivers the world's highest intensity and highest precision multi-GeV electron beams and has been do so for more than 25 years

CEBAF upgrade completed in September 2017

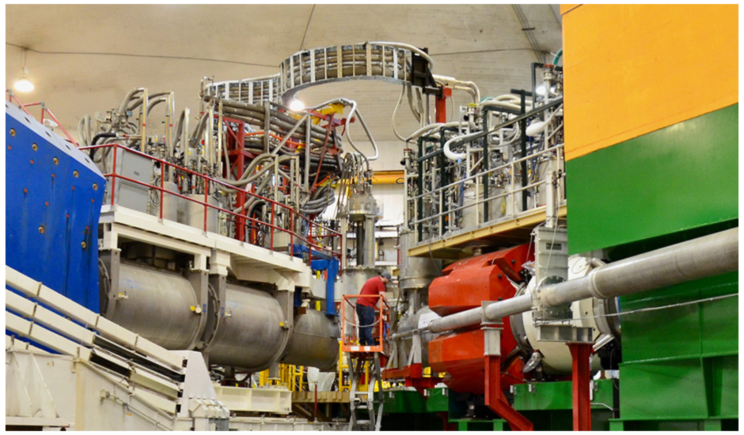
- CW electron beam
- E_{max} = 12 GeV
- I_{max} = 90 μA
- Pol_{max} ~90%



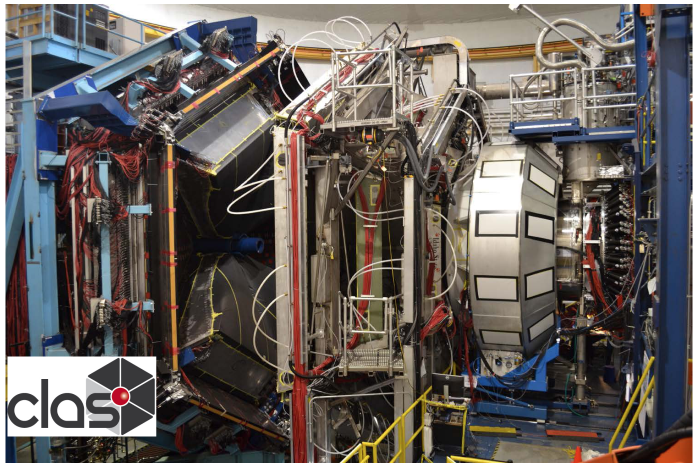
Physics operation

- 4 Halls running simultaneously since January 2018

Jefferson Lab today



HALL C - precision determination of valence quark properties in nucleons and nuclei



HALL B - understanding the 3D nucleon structure, hadron spectroscopy and nuclear effects

HALL D - exploring origin of confinement by studying exotic mesons

HALL A - form factors and PDFs, hyper nuclear physics, Physics BSM

Jefferson Lab Scientific mission

- What is the role of gluon excitations in the spectroscopy of light mesons?
- Where is the missing spin in the nucleon?
- Can we reveal a novel landscape of nucleon substructure through 3D imaging at the femtometer scale?
- What is the relation between short range N-N correlation, the partonic structure of nuclei and the nature of the nuclear force?
- Can we discover evidence for physics beyond standard model of particle physics?

12 GeV experimental program is in full swing

- 33 experiments completed out of 91 approved
- ~8 years of physics ahead (~ 30 week/years)

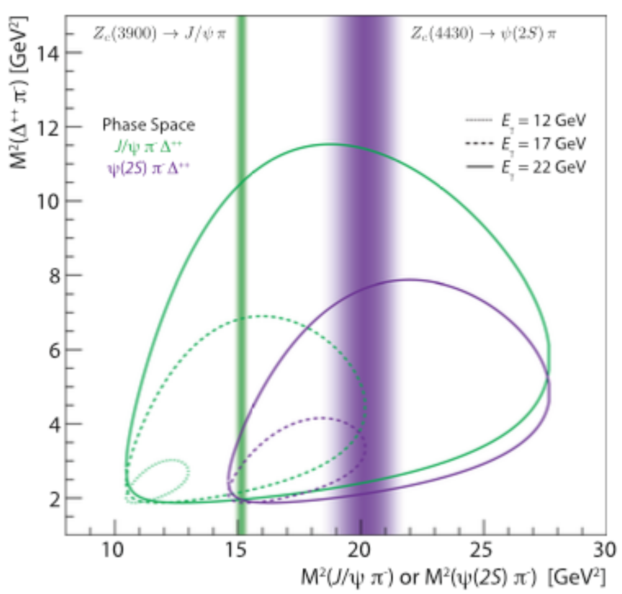
Future opportunities @ CEBAF

- **Higher energy**
- **High luminosity**
- **Positron beam**

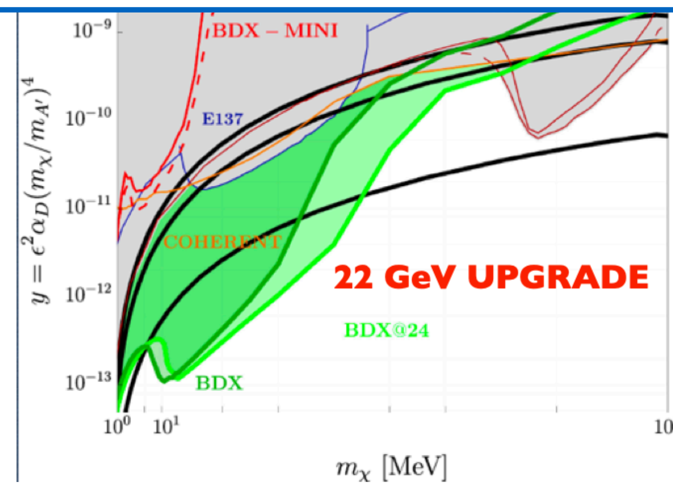
Jefferson Lab 22 GeV

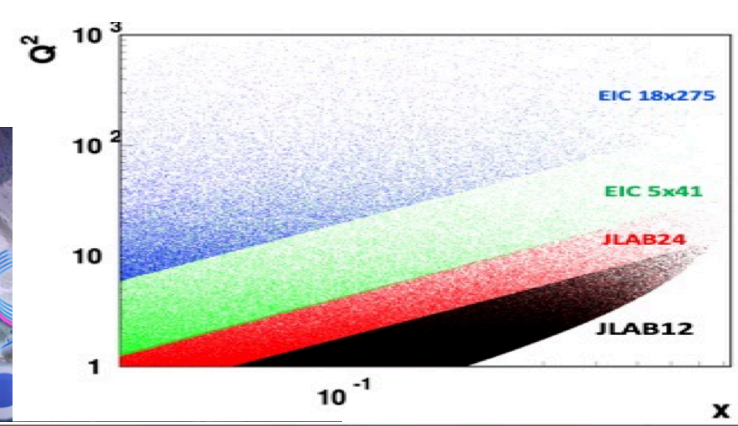
Why JLAB@22GeV?

- A new territory to explore: charm and light quarks in the same experiment
- A better insight into our current program: enhancement of the phase space
- A bridge between JLAB@12GeV and EIC: low to high energy theory validation with high precision
- Utilize largely existing or already-planned experimental halls equipment



Dark matter - Beam Dump experiment





Eur. Phys. J. A (2024) 60:173
https://doi.org/10.1140/epja/s10050-024-01282-x
THE EUROPEAN PHYSICAL JOURNAL A
Review

Strong interaction physics at the luminosity frontier with 22 GeV electrons at Jefferson Lab

A. Accardi[1], P. Achenbach[2], D. Adhikari[3], A. Afanasev[4], C. S. Akondi[5], N. Akopov[6], M. Albaladejo[7], H. Albataineh[8], M. Albrecht[2], B. Almeida-Zamora[9], M. Amaryan[10], D. Androić[11], W. Armstrong[12], D. S. Armstrong[13], M. Arratia[14], J. Arrington[15], A. Asaturyan[16], A. Austregesilo[2], H. Avakian[2], T. Averett[13], C. Ayerbe Gayoso[13], A. Bacchetta[17], A. B. Balantekin[18], N. Baltzell[2], L. Barion[19], P. C. Barry[2], A. Bashir[2,20], M. Battaglieri[21], V. Bellini[22], I. Belov[21], O. Benhar[23], B. Benkel[24], F. Benmokhtar[25], W. Bentz[26], V. Bertone[27], H. Bhatt[28], A. Bianconi[29], L. Bibrzycki[30], R. Bijker[31], D. Binosi[32], D. Biswas[3], M. Boër[3], W. Boeglin[33], S. A. Bogacz[2], M. Boglione[34], M. Bondí[22], E. E. Boos[35], P. Bosted[13], G. Bozzi[36], E. J. Brash[37], R. A. Briceño[38], P. D. Brindza[10], W. J. Briscoe[4], S. J. Brodsky[39], W. K. Brooks[24,40,41], V. D. Burkert[2], A. Camsonne[2], T. Cao[2], L. S. Cardman[2], D. S. Carman[2], M. Carpinelli[42], G. D. Cates[43], J. Caylor[2], A. Celentano[21], F. G. Celiberto[44], M. Cerutti[17], L. Chang[45], P. Chatagnon[2], C. Chen[46,47], J.-P. Chen[2], T. Chetry[33], A. Christopher[1], E. Christy[2], E. Chudakov[2], E. Cisbani[23], I. C. Cloët[12], J. J. Cobos-Martinez[48], E. O. Cohen[49,50], P. Colangelo[51], P. L. Cole[52], M. Constantinou[53], M. Contalbrigo[19], G. Costantini[17,29], W. Cosyn[33], C. Cotton[43], A. Courtoy[168], S. Covrig Dusa[2], V. Crede[5], Z.-F. Cui[54], A. D'Angelo[55], M. Döring[4], M. M. Dalton[2], I. Danilkin[56], M. Davydov[35], D. Day[43], F. De Fazio[57], M. De Napoli[22], R. De Vita[21], D. J. Dean[2], M. Defurne[27], W. de Paula[75], G. F. de Téramond[167], A. Deur[2], B. Devkota[28], S. Dhital[1], P. Di Nezza[58], M. Diefenthaler[2], S. Diehl[59,60], C. Dilks[61], M. Ding[62], C. Djalali[63], S. Dobbs[5], R. Dupré[64], D. Dutta[28], R. G. Edwards[2], H. Egiyan[2], L. Ehinger[65], G. Eichmann[66], M. Elaasar[67], L. Elouadrhiri[2], A. El Alaoui[24], L. El Fassi[28], A. Emmert[43], M. Engelhardt[68], R. Ent[2], D. J. Ernst[69], P. Eugenio[5], G. Evans[70], C. Fanelli[13], S. Fegan[71], C. Fernández-Ramírez[31,72], L. A. Fernandez[20], I. P. Fernando[43], A. Filippi[73], C. S. Fischer[59], C. Fogler[10], N. Fomin[74], L. Frankfurt[49], T. Frederico[75], A. Freese[76], Y. Fu[77], L. Gamberg[78], L. Gan[16], F. Gao[79], H. Garcia-Tecocoatzi[21], D. Gaskell[2], A. Gasparian[80], K. Gates[81], G. Gavalian[2], P. K. Ghoshal[2], A. Giachino[82], F. Giacosa[83], F. Giannuzzi[51], G.-P. Gilfoyle[84], F.-X. Girod[2], D. I. Glazier[81], C. Gleason[85], S. Godfrey[86], J. L. Goity[1,2], A. A. Golubenko[35], S. Gonzàlez-Solís[87], R. W. Gothe[88], Y. Gotra[2], K. Griffioen[13], O. Grocholski[89], B. Grube[2], P. Guèye[77], F.-K. Guo[90,91], Y. Guo[92], L. Guo[33], T. J. Hague[15], N. Hammoud[82], J.-O. Hansen[2], M. Hattawy[10], F. Hauenstein[2], T. Hayward[60], D. Heddle[37], N. Heinrich[93], O. Hen[65], D. W. Higinbotham[2], I. M. Higuera-Angulo[94], A. N. Hiller Blin[95], A. Hobart[64], T. Hobbs[12], D. E. Holmberg[13], T. Horn[2,96], P. Hoyer[97], G. M. Huber[93], P. Hurck[81], P. T. P. Hutauruk[98], Y. Ilieva[88], I. Illari[4], D. G. Ireland[81], E. L. Isupov[35], A. Italiano[22], I. Jaegle[2], N. S. Jarvis[99], D. J. Jenkins[3], S. Jeschonnek[100], C.-R. Ji[101], H. S. Jo[102], M. Jones[2], R. T. Jones[60], D. C. Jones[2], K. Joo[60], M. Junaid[93], T. Kageya[2], N. Kalantarians[103], A. Karki[28], G. Karyan[6], A. T. Katramatou[104], S. J. D. Kay[71], R. Kazimi[2], C. D. Keith[2], C. Keppel[2], A. Kerbizi[105], V. Khachatryan[106], A. Khanal[33], M. Khandaker[107], A. Kim[60], E. R. Kinney[108], M. Kohl[1], A. Kotzinian[6,109], B. T. Kriesten[2,110], V. Kubarovsky[2], B. Kubis[111], S. E. Kuhn[10], V. Kumar[93], T. Kutz[65], M. Leali[112,113], R. F. Lebed[114], P. Lenisa[115], L. Leskovec[116], S. Li[15], X. Li[65], J. Liao[106], H.-W. Lin[77], L. Liu[59], S. Liuti[43], N. Liyanage[43], Y. Lu[117], I. J. D. MacGregor[81], D. J. Mack[2], L. Maiani[118], K. A. Mamo[12], G. Mandaglio[119], C. Mariani[3], P. Markowitz[33], H. Marukyan[6], V. Mascagna[29,113], V. Mathieu[120], J. Maxwell[2], M. Mazouz[121], M. McCaughan[2], R. D. McKeown[2], B. McKinnon[81], D. Meekins[2], W. Melnitchouk[2], A. Metz[53], C. A. Meyer[99], Z.-E. Meziani[12], C. Mezrag[12], R. Michaels[2], G. A. Miller[76], T. Mineeva[24], A. S. Miramontes[94], M. Mirazita[58], K. Mizutani[2], A. Mkrtchyan[6], H. Mkrtchyan[6], B. Moffit[2], P. Mohanmurthy[65], V. I. Mokeev[2], P. Monaghan[37], G. Montaña[2], R. Montgomery[81], A. Moretti[123], J. M. Morgado Chàvez[27], U. Mosel[59], A. Movsisyan[6], P. Musico[21], S. A. Nadeeshani[28], P. M. Nadolsky[126], S. X. Nakamura[124], J. Nazeer[1], A. V. Nefediev[125], K. Neupane[88], D. Nguyen[2], S. Niccolai[64], I. Niculescu[122], G. Niculescu[122], E. R. Nocera[34], M. Nycz[43], F. I. Olness[126], P. G. Ortega[127], M. Osipenko[21], E. Pace[55], B. Pandey[128], P. Pandey[10], Z. Papandreou[93], J. Papavassiliou[129], L. L. Pappalardo[115], G. Paredes-Torres[94], R. Paremuzyan[2], S. Park[2], B. Parsamyan[73,109], K. D. Paschke[43], B. Pasquini[17], E. Passemar[2,106,129], E. Pasyuk[2], T. Patel[1], C. Paudel[33], S. J. Paul[14], J.-C. Peng[130], L. Pentchev[2], R. Perrino[51], R. J. Perry[120], K. Peters[131], G. G. Petratos[132], W. Phelps[4,37], E. Piasetzky[49], A. Pilloni[22,119], B. Pire[133],

White paper (~450 authors)

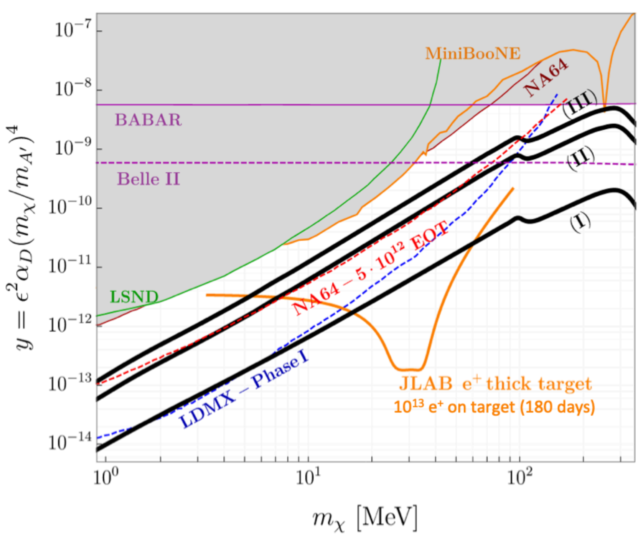
- Charmed and light hadron spectroscopy
- Structure of hadrons: Form Factors, PDFs, TMDs, GPDs, Fragmentation Functions, Fracture Functions
- QCD in Nuclei and associated Nuclear Modifications and Dynamics
- Low energy tests of the Standard Model
- BSM physics

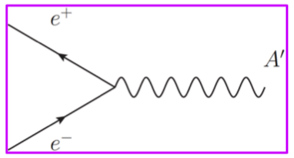
Jefferson Lab positron beam

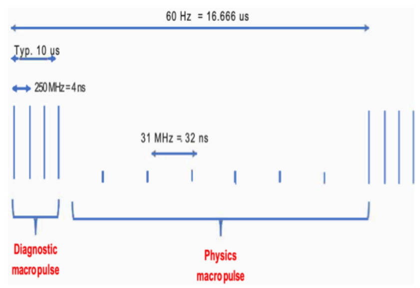
Why Ce+BAF?

- Electromagnetic form factors
- Generalized Parton Distribution - GPD of nucleon
- Test of Standard model
- Beyond Standard Model physics: I.e. Light Dark Matter

Dark matter - missing energy experiment



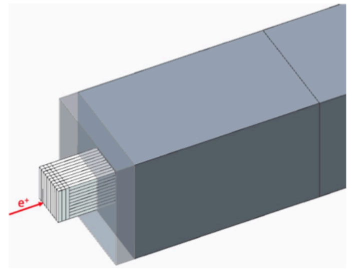




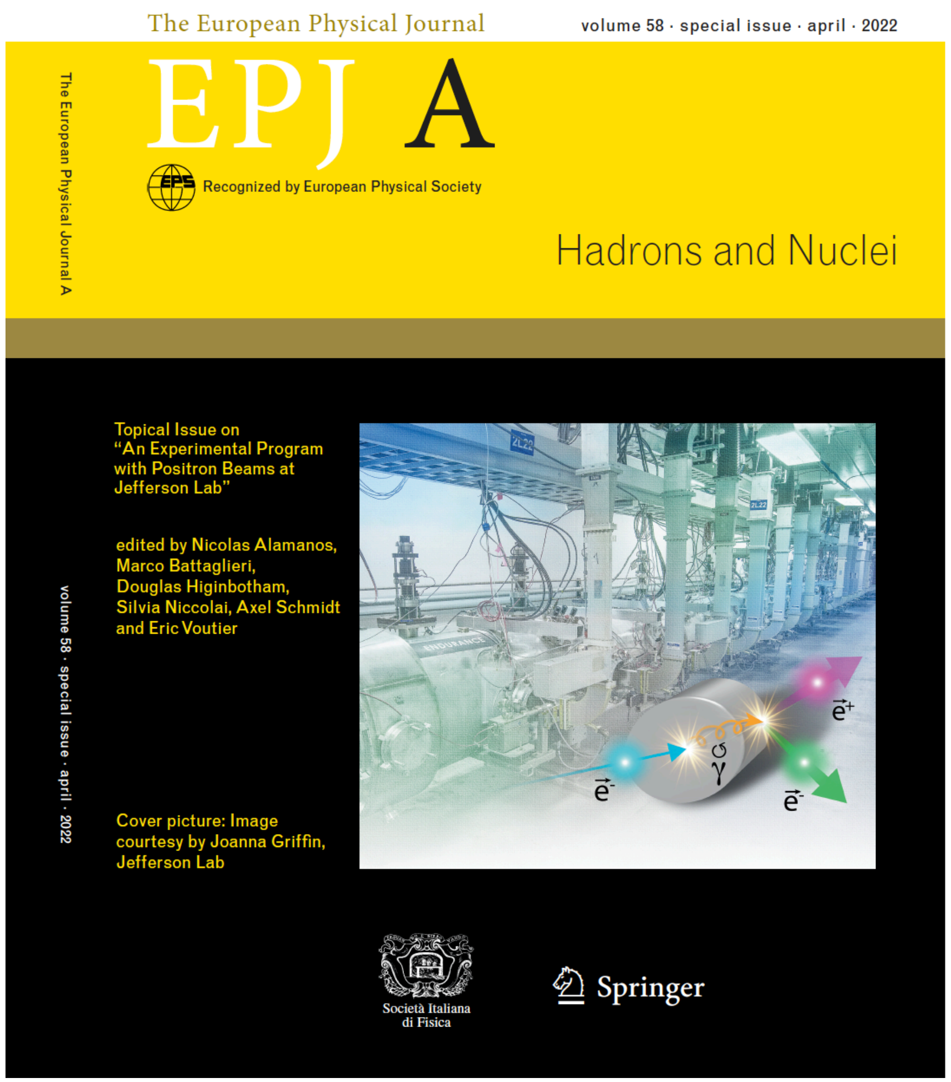
A *specific time structure* of the beam is required to avoid e⁺ beam pile-up in the detector.

$$E_{miss} = E_{beam} - E_{CAL}$$

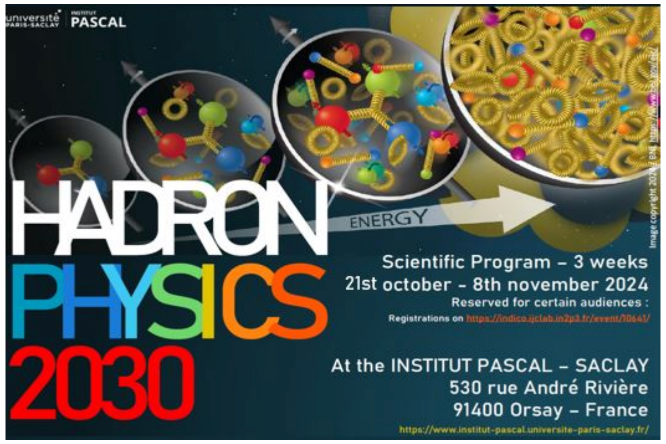
$$m_{A'} = \sqrt{2 m_e E_{miss}}$$



*An **active thick target** completed with an **hadronic calorimeter** constitute the experimental set-up.*



White paper (~250 authors)

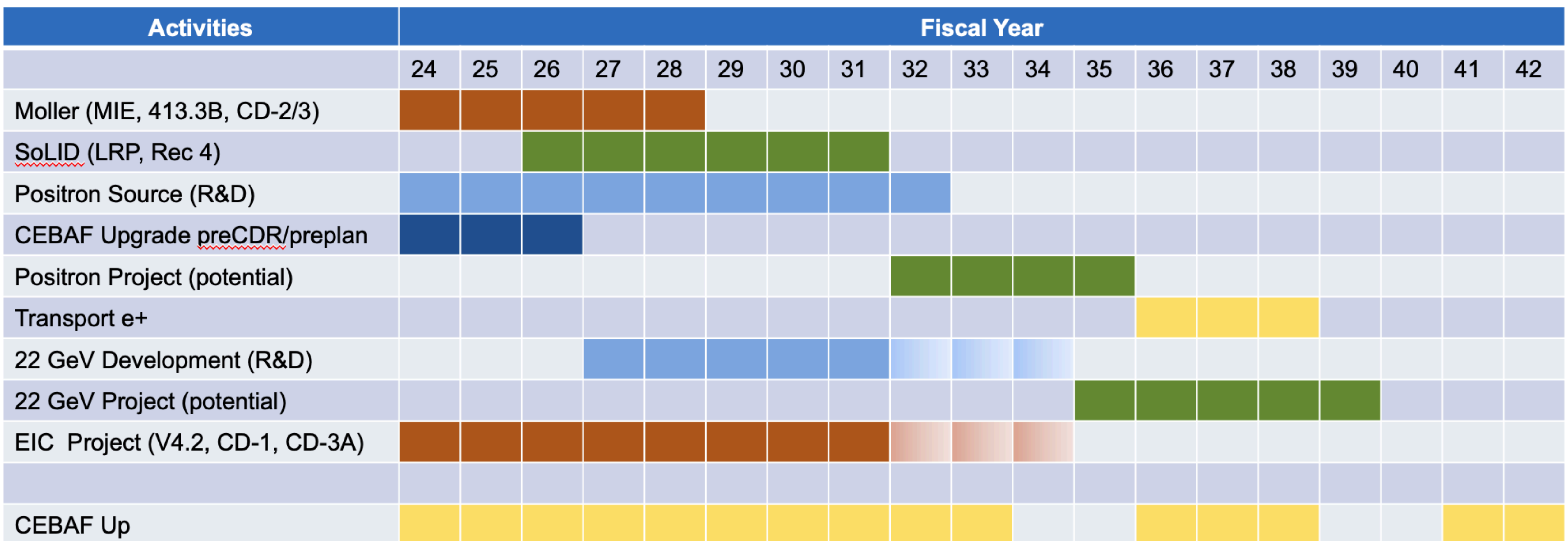


The Positron Experimental Program at JLab has formally started with the C1 **approval of 6 proposals** validating the 3 pillars of the JLab Positron White Paper and constituting 3 calendar years of single hall running.

JLAB upgrades timeline

Jefferson Lab

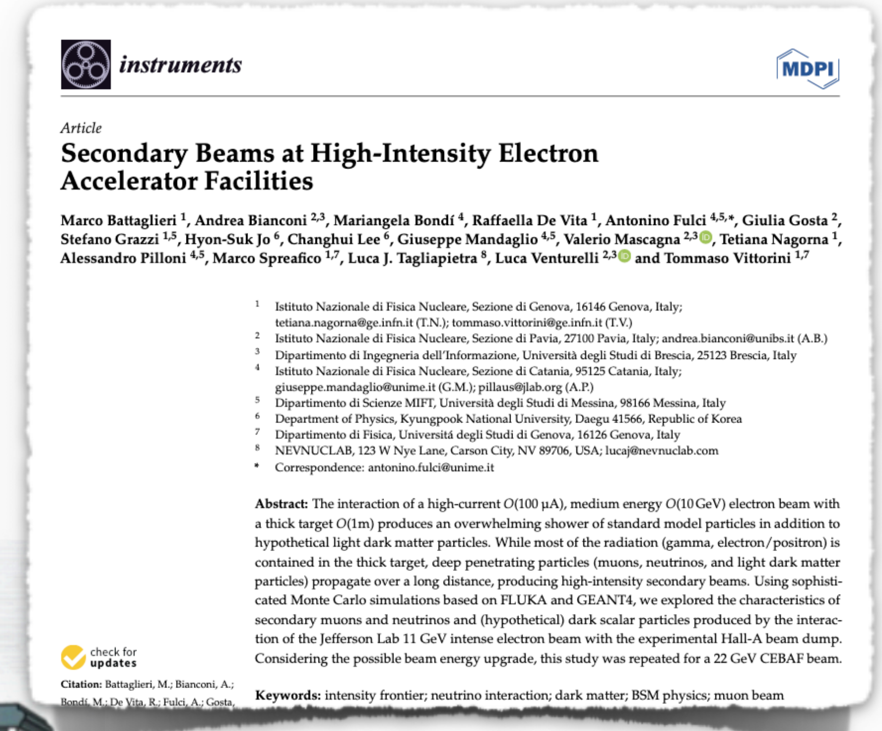
- Accelerator team has worked up an early schedule and cost estimate
  - Schedule assumptions based on a notional timing of when funds might be available (near EIC ramp down based on EIC V3 profile)
  - For completeness, Moller and SoLID (part of 12 GeV program) are shown; positron source dev shown
- EIC Project is shown



Credit to D. Dean

JLAB secondary beam

- CEBAF provides a high-intensity e- beam for extracted-beam experiments
  - The machine can sustain up MW power (100 uA @10GeV, 200uA @5GeV)
  - Hall-A receives ~50-70uA @ 11GeV
- High-intensity secondary beams are produced in the dump(s) fully parasitically
  - Muons,
  - Neutrinos,
  - LDM particles (if exists)



instruments

MDPI

Article

Secondary Beams at High-Intensity Electron Accelerator Facilities

Marco Battaglieri [1], Andrea Bianconi [2,3], Mariangela Bondí [4], Raffaella De Vita [1], Antonino Fulci [4,5,*], Giulia Gosta [2], Stefano Grazzi [1,5], Hyon-Suk Jo [6], Changhui Lee [6], Giuseppe Mandaglio [4,5], Valerio Mascagna [2,3], Tetiana Nagorna [1], Alessandro Pilloni [4,5], Marco Spreafico [1,7], Luca J. Tagliapietra [8], Luca Venturelli [2,3] and Tommaso Vittorini [1,7]

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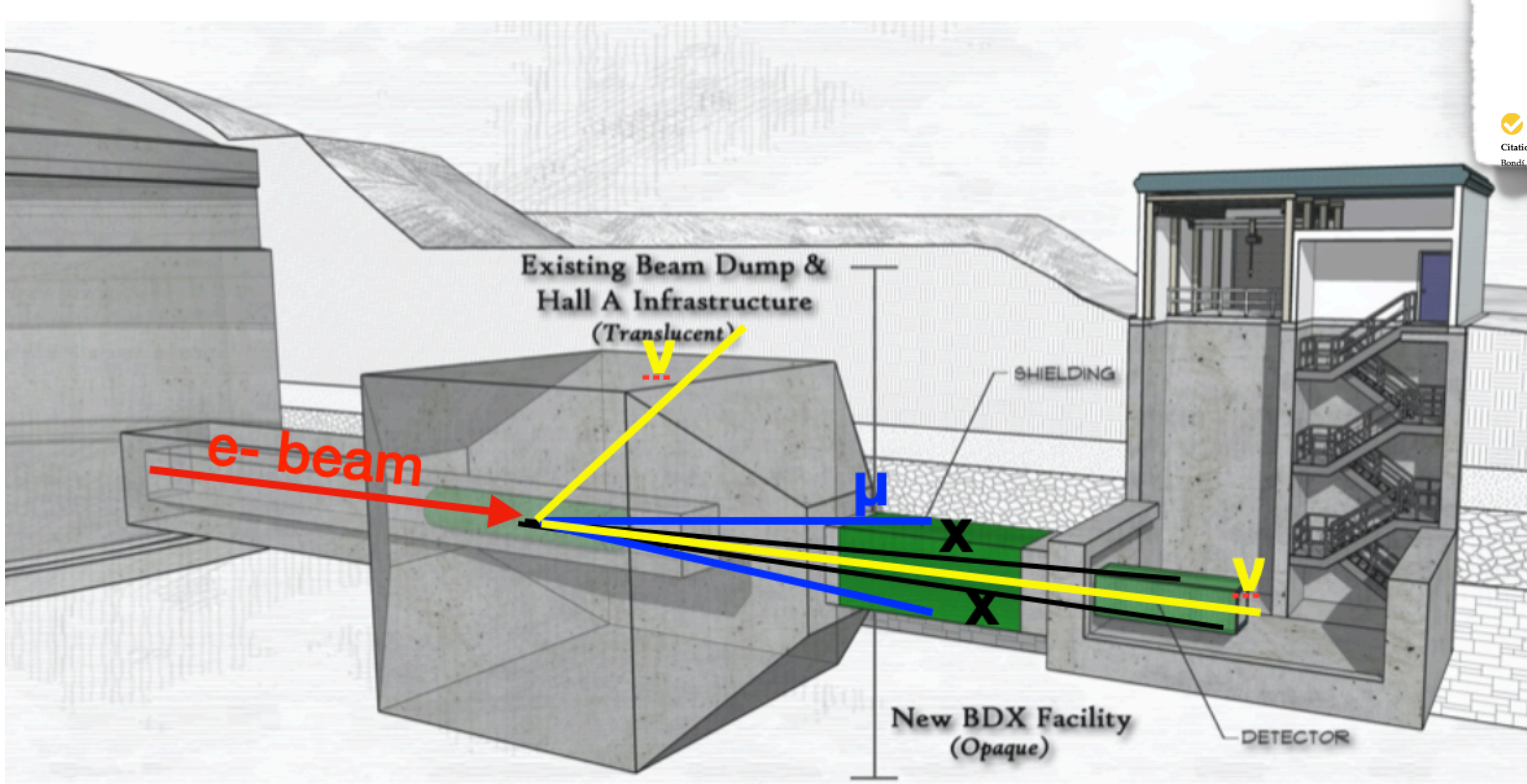
Abstract: The interaction of a high-current $O(100\,\mu A)$, medium energy $O(10\,GeV)$ electron beam with a thick target $O(1m)$ produces an overwhelming shower of standard model particles in addition to hypothetical light dark matter particles. While most of the radiation (gamma, electron/positron) is contained in the thick target, deep penetrating particles (muons, neutrinos, and light dark matter particles) propagate over a long distance, producing high-intensity secondary beams. Using sophisticated Monte Carlo simulations based on FLUKA and GEANT4, we explored the characteristics of secondary muons and neutrinos and (hypothetical) dark scalar particles produced by the interaction of the Jefferson Lab 11 GeV intense electron beam with the experimental Hall-A beam dump. Considering the possible beam energy upgrade, this study was repeated for a 22 GeV CEBAF beam.

check for updates

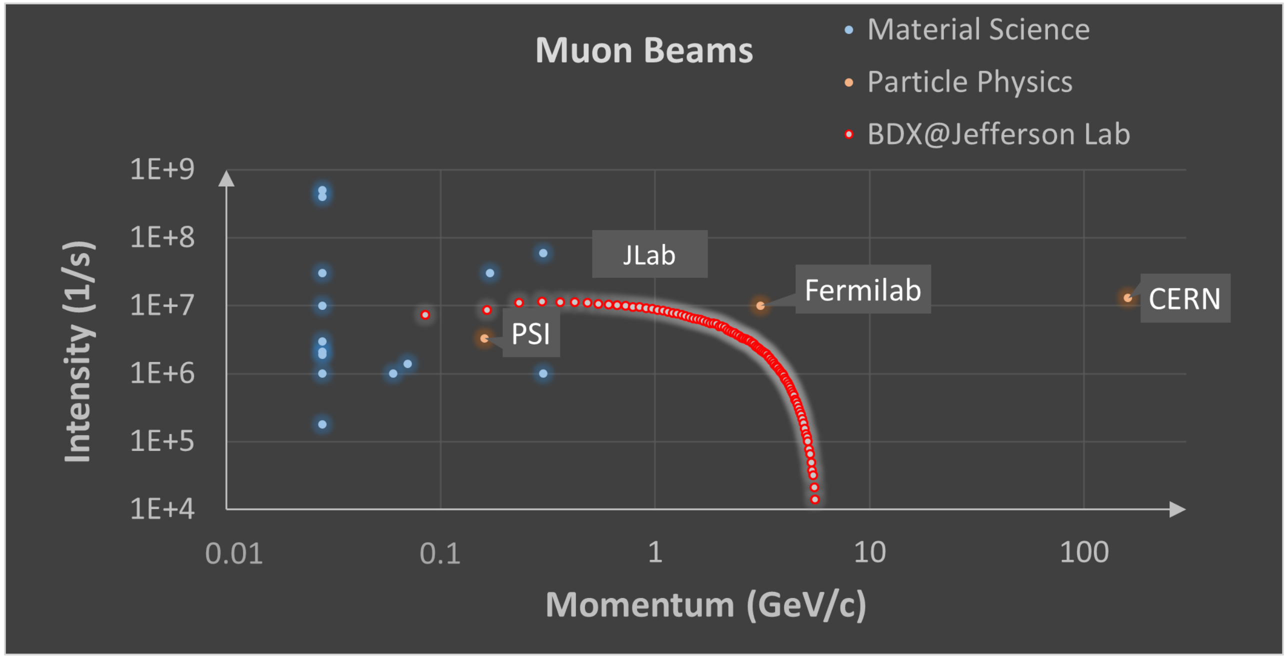
Citation: Battaglieri, M.; Bianconi, A.; Bondí, M.; De Vita, R.; Fulci, A.; Gosta,

Keywords: intensity frontier; neutrino interaction; dark matter; BSM physics; muon beam

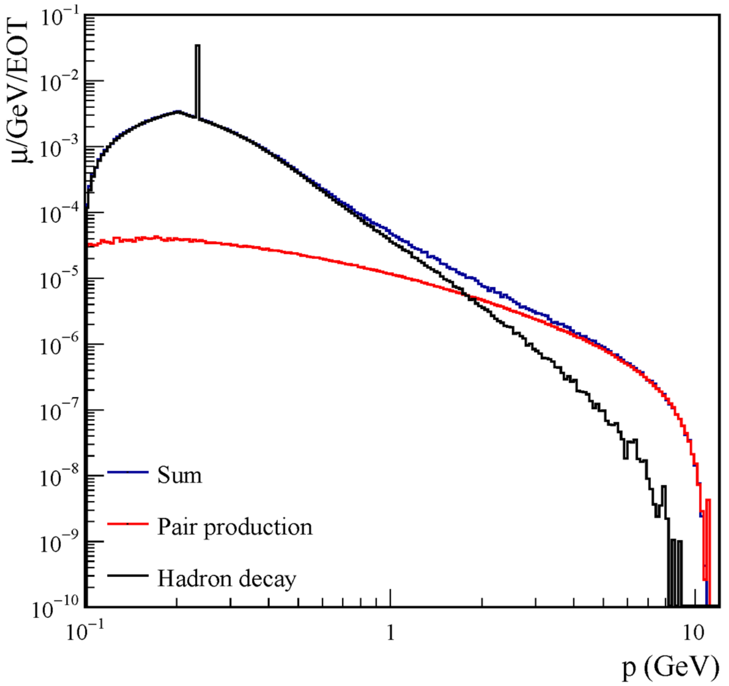


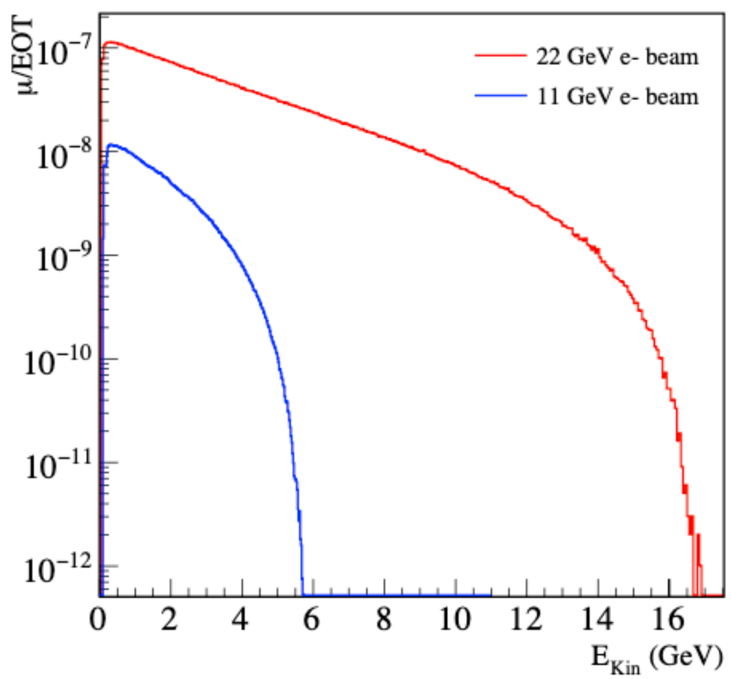
Muon flux @ JLAB

Jefferson Lab



Beam Energy	Flux μ/EOT		σ_x (cm)	σ_y (cm)
	100×100 cm^2	25×25 cm^2		
11 GeV	9.8×10^{-7}	1.5×10^{-7}	24.6	25.1
22 GeV	7.6×10^{-6}	1.9×10^{-6}	20.9	20.9

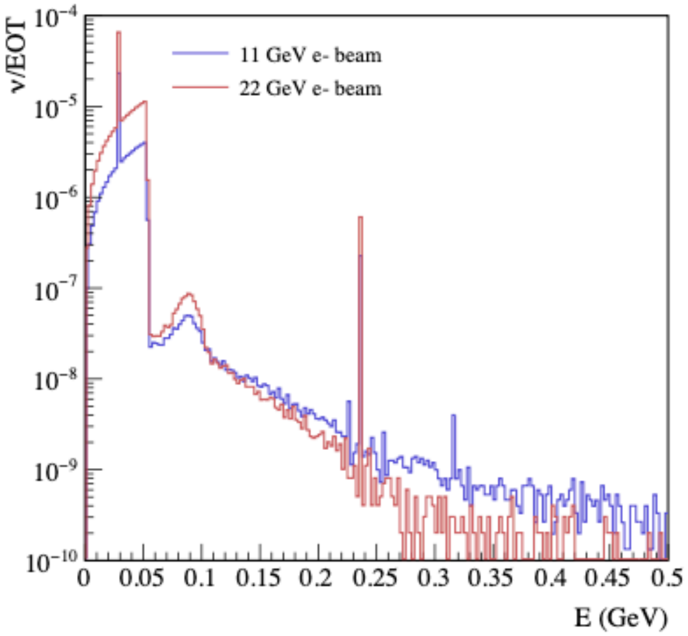


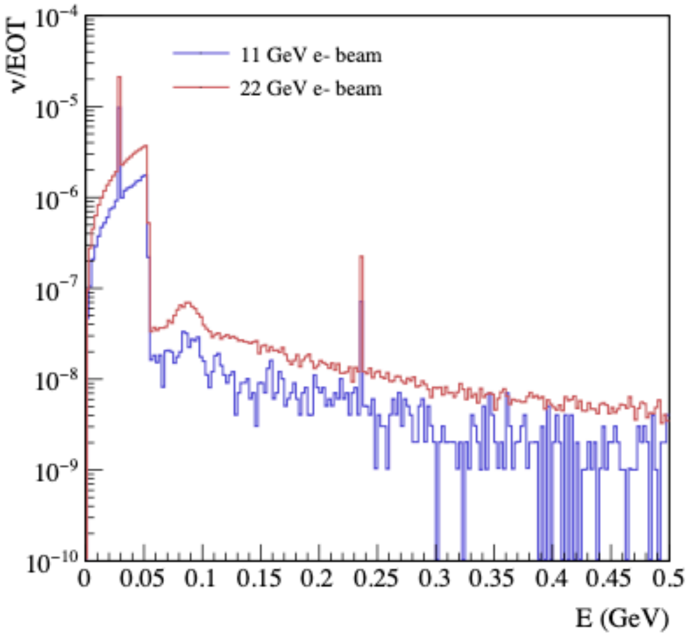


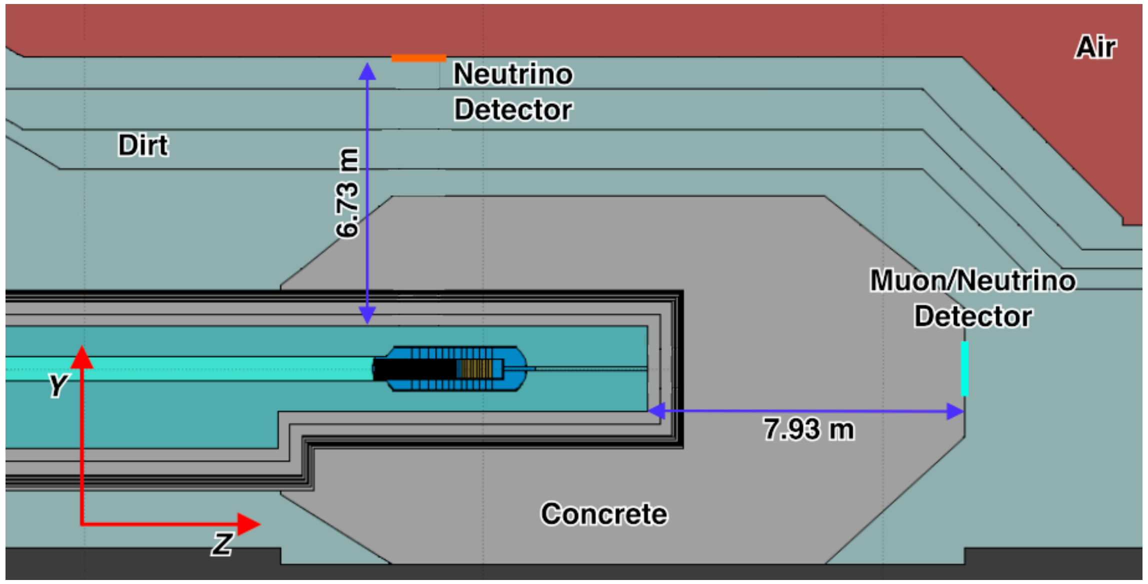
- Exploiting muon beams would enable the search for a possible light gauge boson, which would couple predominantly to muons
  - Such a light boson could be either scalar or a vector mediator
  - Its existence would be a viable explanation of g-2 anomaly
  - *μ3BDX @ JLAB*
    - Fixed-target missing momentum experiment to probe invisibly decaying particle
    - *μBDX @ JLAB*
      - Muon beam dump experiment to probe the visible decay into e+e-(γγ)

Neutrino flux @ JLAB

- Neutrino flux estimated using FLUKA for 11 GeV and 22 GeV primary e- beam on Hall-A BD
- Low energy part due to pion and muon decay at rest
  - π decay produces a prompt 28.5 MeV ν_μ along with a μ witch subsequently decays producing a ν_e ν_μ
- High energy ν from in-flight pion and kaon decay







Beam Energy	Off-Axis Flux [ν/EOT/m^2]	On-Axis Flux [ν/EOT/m^2]
11 GeV	6.7×10^{-5}	2.9×10^{-5}
22 GeV	1.9×10^{-4}	6.3×10^{-5}