LD2510: AI for Nuclear Physics

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Yr1 Q1: Attempted to secure future funding (Beyond LDRD)

FOA:

- DOE/NP released an FOA *"AI in Nuclear Physics"*
- JLab staff submitted LOI(s) to this call in FY25Q1

Potential future directions for proposals:

- Application of Attention technologies for LGT simulations, JLab Expt & Theory data analysis
- Development of AI Agents for Nuc. Theory research

Our LOI(s) were not encouraged to move forward

- Took time away from current LDRD
- Was valuable learning experience
- Project realigned towards delivering most impact on NP

Office of CRITICAL AND EMERGING TECHNOLOGIES

DOE is Advancing the AI Innovation Ecosystem

Artificial Intelligence and Machine Learning Applied to Nuclear Science and Technology

Notice of Funding Opportunity (NOFO) Number: DE-FOA-0003458

Two main thrusts - text and inverse functions

Thrust: Text - Use LLMs to interpret questions for a transformation

Query: *"What is the maximum range of <kinematic variable> in the reaction <reaction name> data coverage"*

Thrust: Transformation - Use "Attention Technology" to transform data

E.g., PDFs to DIS proton cross sections ⟺ DIS proton cross sections to PDFs

Outcome: put the two together - greatly facilitates data impact studies

Application #1: Use LLMs as translators between parton level information and observable level information

Translate PDFs to DIS proton cross sections
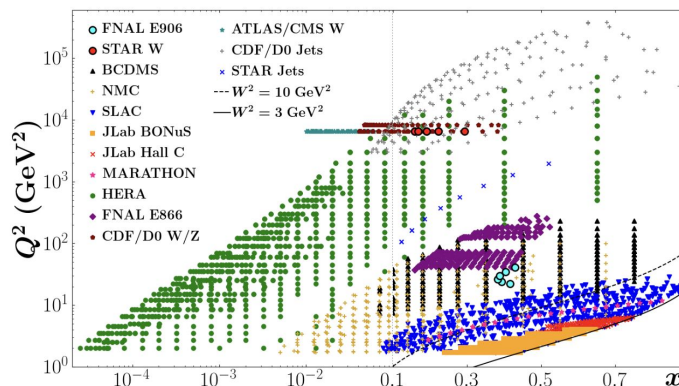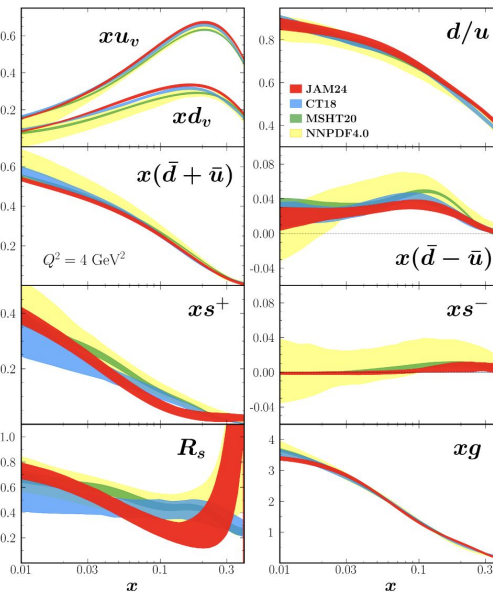Input (11, 100, 100)
Output (100,100)

Translate DIS proton cross sections to PDFs
Input (100,100)
Output (11, 100, 100)

**Goal: use LLMs as an inverse function
Q: what if we give less/more DIS cross sections across phase space**

Application #2: Use LLMs as translators between parton level information and event level information

Translate PDFs to DIS events
Input (11, 100, 100)
Output (10000,140,10)

Translate DIS events to PDFs
Input (10000,140,10)
Output (11, 100, 100)

Goal: use LLMs as an inverse function
Q: how does the answer change with the number of events?
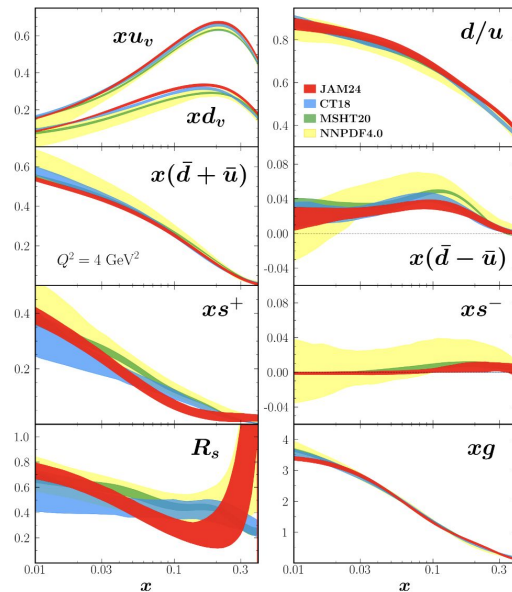

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[19]: mceg.events

[19]: array([[[ 5.10135016e+00, -3.01159129e+00, -2.19225992e+00,
          1.10000000e+01,  9.90733488e-01, -1.00000000e+00],
         [ 1.34395447e+00,  1.94976737e+00,  8.41362054e-01,
          2.21200000e+03,  1.12042463e-01,  1.00000000e+00],
         [ 3.54972589e+00,  1.62421139e+00,  9.78571093e-01,
         -2.21200000e+03,  1.84542315e-01, -1.00000000e+00],
         ...,
         [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
          0.00000000e+00,  0.00000000e+00,  0.00000000e+00],
         [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
          0.00000000e+00,  0.00000000e+00,  0.00000000e+00],
         [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
          0.00000000e+00,  0.00000000e+00,  0.00000000e+00]],

        [[ 5.72855231e+00, -2.88176853e+00,  1.27091147e+00,
          1.10000000e+01,  9.77791497e-01, -1.00000000e+00],
         [ 8.87583315e-01,  8.01165135e-01, -6.82182376e-01,
          2.11000000e+02,  2.29327242e-02,  1.00000000e+00],
         [ 2.42493266e-01,  8.96829944e-01,  1.82879512e+00,
          2.11000000e+02,  7.62876123e-03,  1.00000000e+00],
```

Potential Application: infer intermediate steps in decays

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--------     PYTHIA Event Listing  (complete event)    -------------------------------------------------------------

no        id  name          status     mothers     daughters      colours        p_x        p_y        p_z          e          m
 0        90  (system)        -11     0     0      0     0      0     0      0.000     -0.000      0.001    104.881    104.881
 1      2212  (p+)            -12     0     0      7     0      0     0      0.000      0.000     52.437     52.445      0.938
 2        11  (e-)            -12     0     0      4     0      0     0      0.000     -0.000    -52.436     52.436      0.001
 3         2  (u)             -21     7     7      5     6    101     0      0.000      0.000     11.136     11.136      0.000
 4        11  (e-)            -21     2     0      5     6      0     0      0.000      0.000    -52.437     52.437      0.000
 5         2  (u)             -23     3     4      8     8    101     0     -5.404     -2.044     10.212     11.738      0.330
 6        11  e-               23     3     4      0     0      0     0      5.404      2.044    -51.516     51.839      0.001
 7         2  (u)             -61     1     0      3     3    101     0      0.151      0.403      9.991     10.000      0.000
 8         2  (u)             -62     5     5     10    15    101     0     -5.193     -1.619      9.023     10.541      0.330
 9      2103  (ud_1)          -63     1     0     10    15      0   101     -0.211     -0.425     42.492     42.502      0.771
10       213  (rho+)          -83     8     9     16    17      0     0     -1.718     -0.470      5.220      5.708      1.470
11      -213  (rho-)          -83     8     9     18    19      0     0     -0.919     -0.109      2.883      3.146      0.856
12       111  (pi0)           -83     8     9     24    25      0     0     -2.165     -0.944      4.497      5.082      0.135
13       321  K+               84     8     9      0     0      0     0     -0.066     -0.173      1.300      1.403      0.494
14      3224  (Sigma*+)       -84     8     9     20    21      0     0     -0.279     -0.293     14.130     14.200      1.357
15      -213  (rho-)          -84     8     9     22    23      0     0     -0.257     -0.055     23.486     23.504      0.872
16       211  pi+              91    10     0      0     0      0     0      0.251     -0.048      0.662      0.723      0.140
17       111  (pi0)           -91    10     0     26    27      0     0     -1.969     -0.422      4.558      4.985      0.135
18      -211  pi-              91    11     0      0     0      0     0      0.089      0.135      0.550      0.590      0.140
19       111  (pi0)           -91    11     0     28    30      0     0     -1.008     -0.245      2.333      2.556      0.135
20      3122  (Lambda0)       -91    14     0     31    32      0     0     -0.200     -0.214     13.389     13.439      1.116
21       211  pi+              91    14     0      0     0      0     0     -0.079     -0.079      0.741      0.762      0.140
22      -211  pi-              91    15     0      0     0      0     0     -0.091      0.100     21.409     21.410      0.140
23       111  (pi0)           -91    15     0     33    34      0     0     -0.166     -0.156      2.077      2.094      0.135
24        22  gamma            91    12     0      0     0      0     0     -0.353     -0.101      0.679      0.772      0.000
25        22  gamma            91    12     0      0     0      0     0     -1.813     -0.843      3.819      4.310      0.000
26        22  gamma            91    17     0      0     0      0     0     -0.680     -0.083      1.592      1.733      0.000
27        22  gamma            91    17     0      0     0      0     0     -1.289     -0.339      2.966      3.252      0.000
28        22  gamma            91    19     0      0     0      0     0     -0.709     -0.117      1.562      1.719      0.000
29        11  e-               91    19     0      0     0      0     0     -0.056     -0.016      0.113      0.127      0.001
30       -11  e+               91    19     0      0     0      0     0     -0.242     -0.111      0.657      0.710      0.001
31      2212  p+               91    20     0      0     0      0     0     -0.097     -0.121     10.553     10.596      0.938
32      -211  pi-              91    20     0      0     0      0     0     -0.103     -0.093      2.836      2.843      0.140
33        22  gamma            91    23     0      0     0      0     0     -0.005      0.016      0.040      0.043      0.000
34        22  gamma            91    23     0      0     0      0     0     -0.161     -0.171      2.037      2.051      0.000
                             Charge sum:   0.000          Momentum sum:     -0.000     -0.000      0.000    104.882    104.882
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Budget

Edwards (Theory): 20% years 1 & 2
McSpadden (CST): 40% years 1 & 2
Sato (Theory): 5% years 1 & 2
Orginos (Theory): 20% year 1 only
Goldenberg (CST):
    57% year 1 (FY25)
    80% year 2 (FY26)
Travel: 3K/year for years 1 & 2

Legend: Expenses | Open Obligations | Pending | Funding | 3-Mo Avg Projection

	Oct-24	Nov-24	Dec-24	Jan-25	2/29/2025	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25
YTD Spending	3	9	17	28	50	71	93	114	136	157	179	200
Pending	0	0	0	28	50	71	93	114	136	157	179	200
Open Obligations	0	0	0	0	0	0	0	0	0	0	0	0
Expenses	0	4	9	0	0	0	0	0	0	0	0	0
Labor	3	4	8	0	0	0	0	0	0	0	0	0
Funding	240	240	240	240	240	240	240	240	240	240	240	240
3-Mo Avg Projection												