Machine Learning Planning Exercise: Theory Applications

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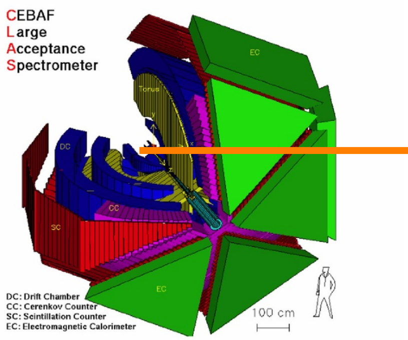
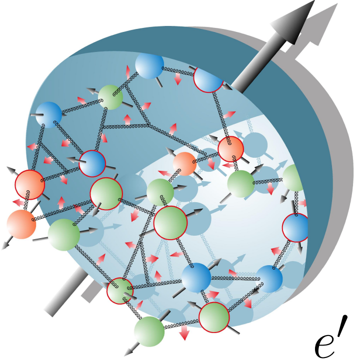
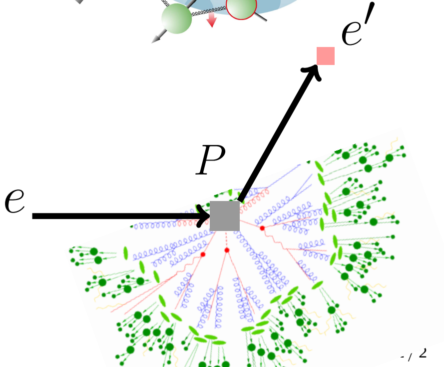
ODU/JLab

Computing Round Table (2019)
JLab, 2019

Zooming in at the femtometer scale using JLab12







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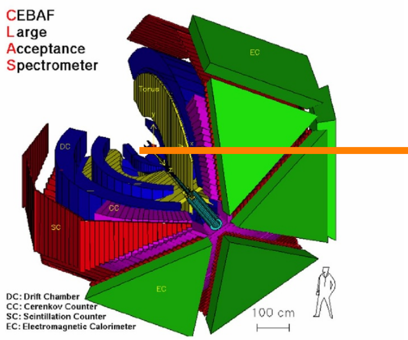
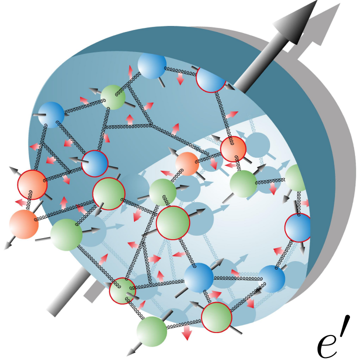
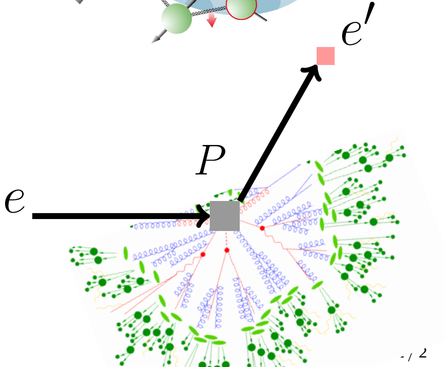


Factorization
(theory)

Inverse problem
(computing)





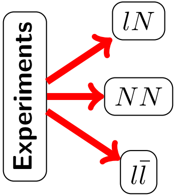
Quantum probability distributions in the nucleon

F_i	Standard label	β_i
F_1	$F_{UU,T}$	1
F_2	$F_{UU,L}$	ε
F_3	F_{LL}	$S_{\|\|}\lambda_e\sqrt{1-\varepsilon^2}$
F_4	$F_{UT}^{\sin(\phi_h+\phi_S)}$	$\|\vec{S}_\perp\|\varepsilon\sin(\phi_h+\phi_S)$
F_5	$F_{UT,T}^{\sin(\phi_h-\phi_S)}$	$\|\vec{S}_\perp\|\sin(\phi_h-\phi_S)$
F_6	$F_{UT,L}^{\sin(\phi_h-\phi_S)}$	$\|\vec{S}_\perp\|\varepsilon\sin(\phi_h-\phi_S)$
F_7	$F_{UU}^{\cos 2\phi_h}$	$\varepsilon\ \cos(2\phi_h)$
F_8	$F_{UT}^{\sin(3\phi_h-\psi_S)}$	$\|\vec{S}_\perp\|\varepsilon\sin(3\phi_h-\phi_S)$
F_9	$F_{LT}^{\cos(\phi_h-\phi_S)}$	$\|\vec{S}_\perp\|\lambda_e\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S)$
F_{10}	$F_{UL}^{\sin\ 2\phi_h}$	$S_{\|\|}\varepsilon\sin(2\phi_h)$
F_{11}	$F_{LT}^{\cos\phi_S}$	$\|\vec{S}_\perp\|\lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_S$
F_{12}	$F_{LL}^{\cos\phi_h}$	$S_{\|\|}\lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_h$
F_{13}	$F_{LT}^{\cos(2\phi_h-\phi_S)}$	$\|\vec{S}_\perp\|\lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\cos(2\phi_h-\phi_S)$
F_{14}	$F_{UL}^{\sin\phi_h}$	$S_{\|\|}\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_h$
F_{15}	$F_{LU}^{\sin\phi_h}$	$\lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\sin\phi_h$
F_{16}	$F_{UU}^{\cos\phi_h}$	$\sqrt{2\varepsilon(1+\varepsilon)}\ \cos\phi_h$
F_{17}	$F_{UT}^{\sin\phi_S}$	$\|\vec{S}_\perp\|\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_S$
F_{18}	$F_{UT}^{\sin(2\phi_h-\phi_S)}$	$\|\vec{S}_\perp\|\sqrt{2\varepsilon(1+\varepsilon)}\sin(2\phi_h-\phi_S)$

$$\frac{d\sigma}{dx\ dy\ d\Psi\ dz\ d\phi_h\ dP_{hT}^2} \sim \sum_{i=1}^{18} F_i(x,z,Q^2,P_{hT}^2)\beta_i$$

Name	Symbol	meaning
upol. PDF	f_1^q	U. pol. quarks in U. pol. nucleon
pol. PDF	g_1^q	L. pol. quarks in L. pol. nucleon
Transversity	h_1^q	T. pol. quarks in T. pol. nucleon
Sivers	$f_{1T}^{\perp(1)q}$	U. pol. quarks in T. pol. nucleon
Boer-Mulders	$h_1^{\perp(1)q}$	T. pol. quarks in U. pol. nucleon
⋮	⋮	⋮
FF	D_1^q	U. pol. quarks to U. pol. hadron
Collins	$H_1^{\perp(1)q}$	T. pol. quarks to U. pol. hadron
⋮	⋮	⋮

QCD global analysis in a nutshell



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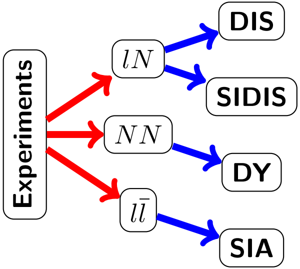

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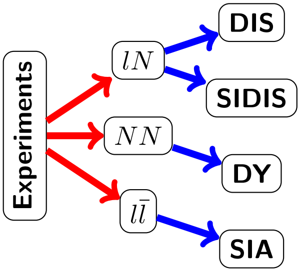

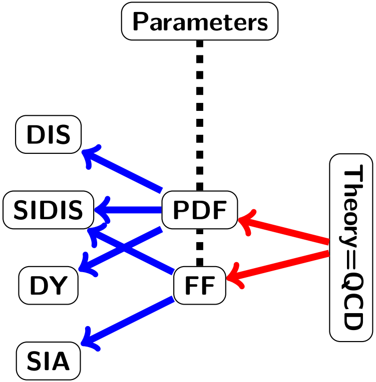

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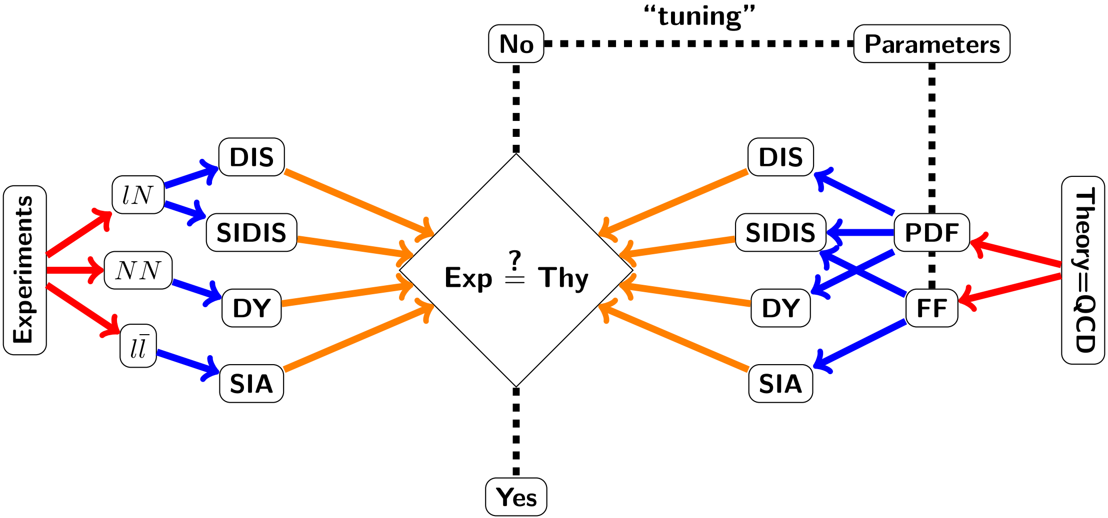

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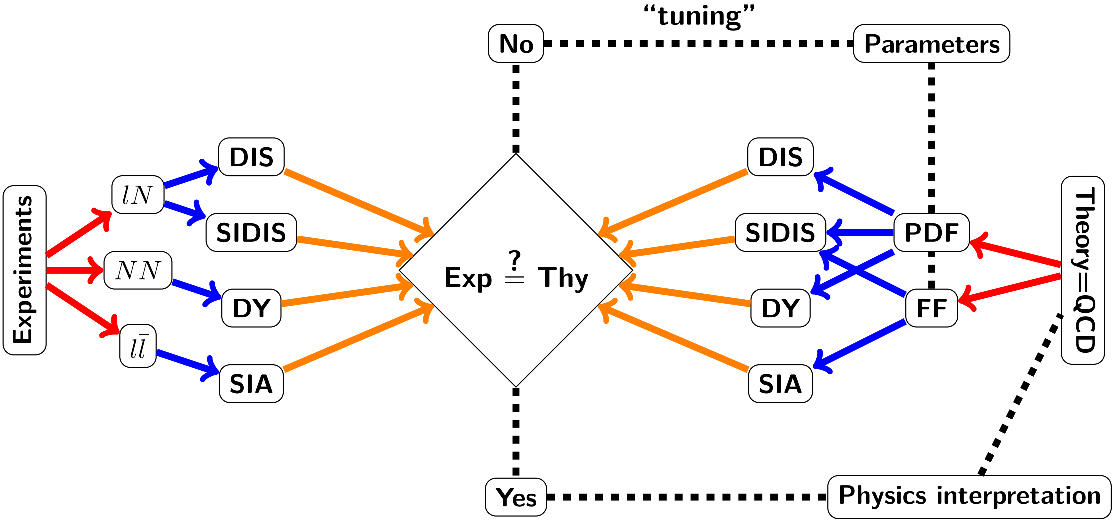

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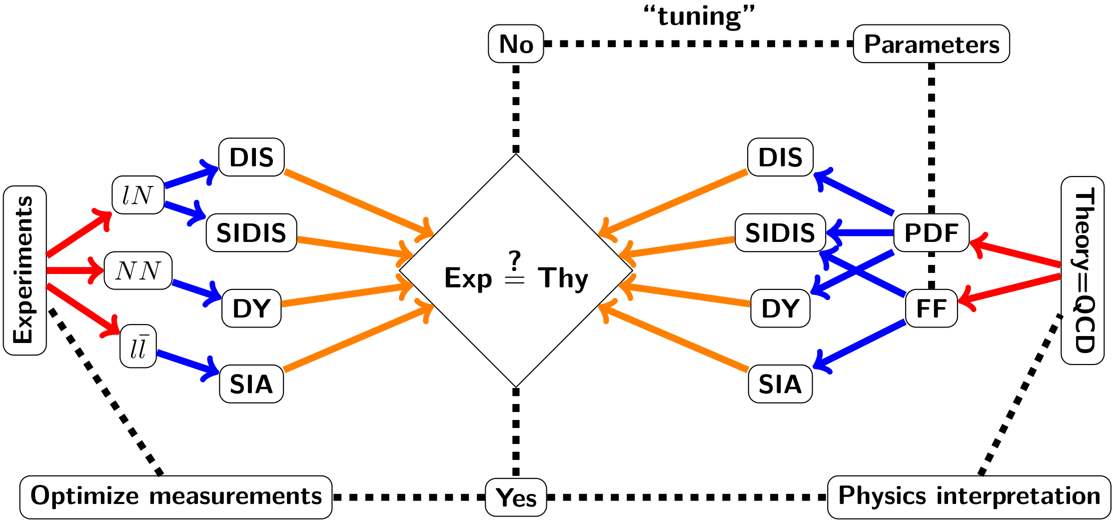
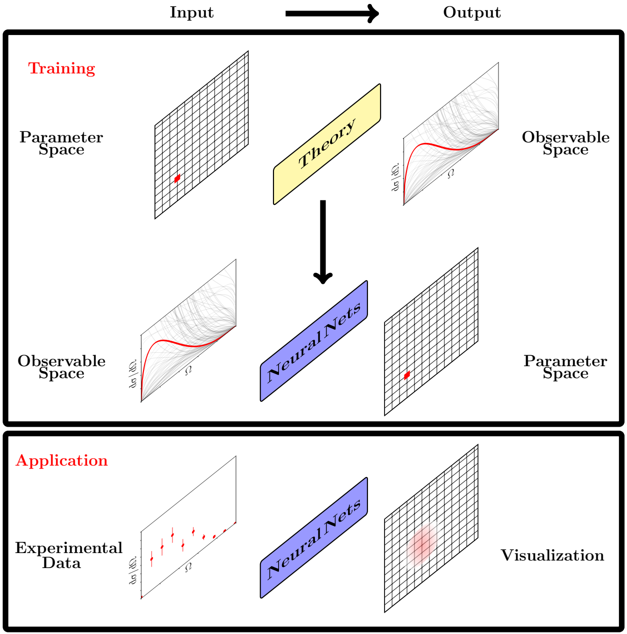


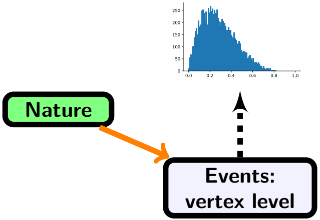
ML for global analysis

- **Theory**: PDFs, FFs, TMDs, GPDs, GTMDs, Wigner distributions
- **ML**: parameter space $\rightarrow$ observable space
- **Multi-disciplinary**:
  - QCD scientists: JLab, Argonne, Temple
  - Comp. scientists: ODU, Davidson College

Proposal for CNF



Empirically Trained Hadronic Event Regenerator (ETHER)



LDRD19:
JLab/ODU/Davidson

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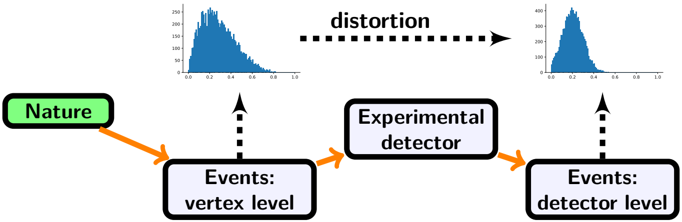

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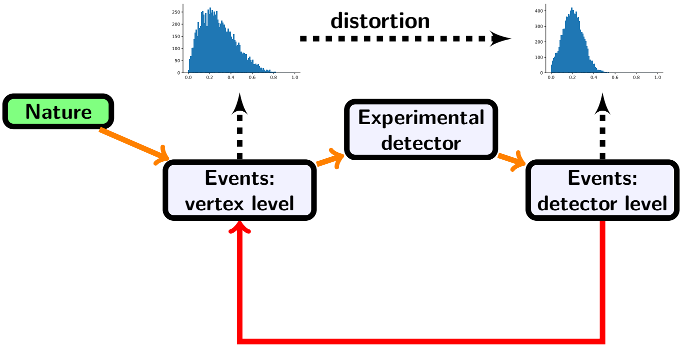

Inverse problem → solutions are not unique

→ model dependent

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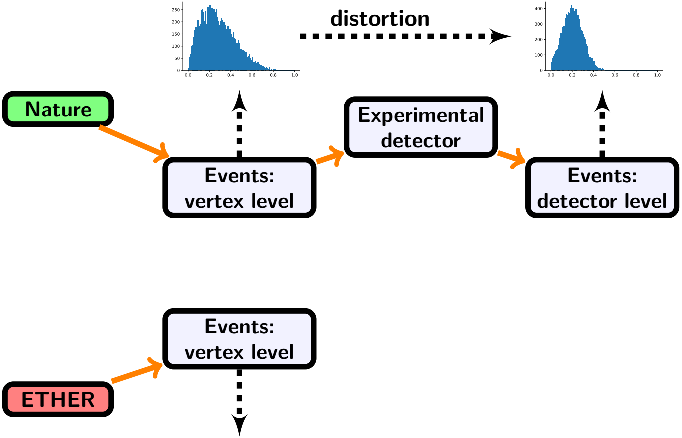

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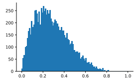

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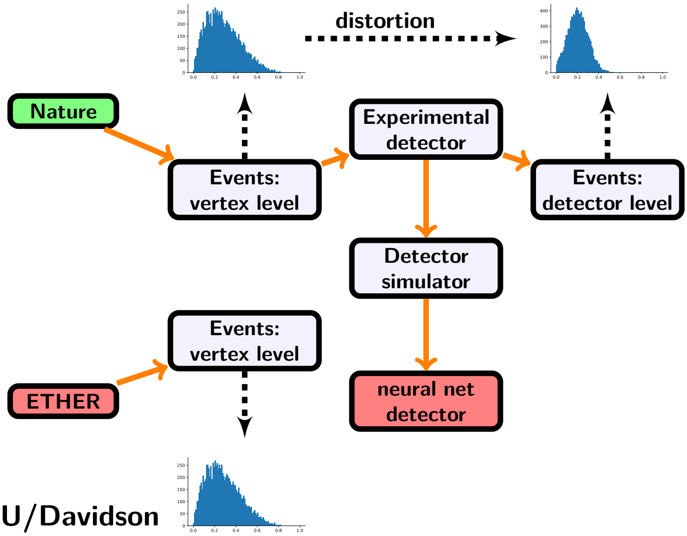

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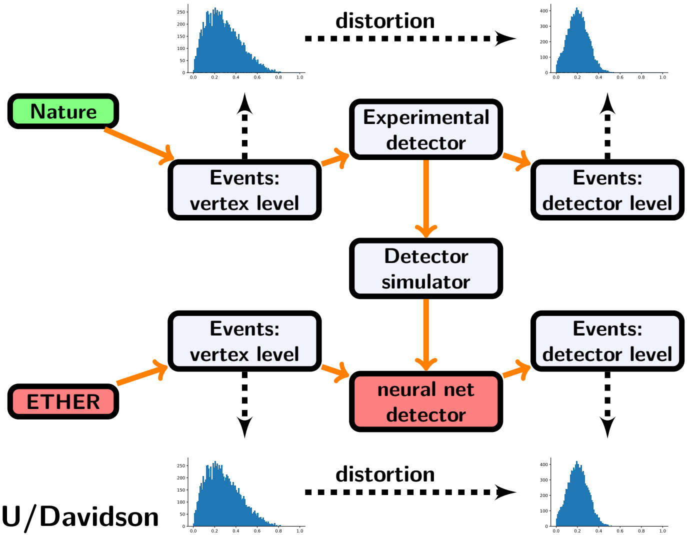

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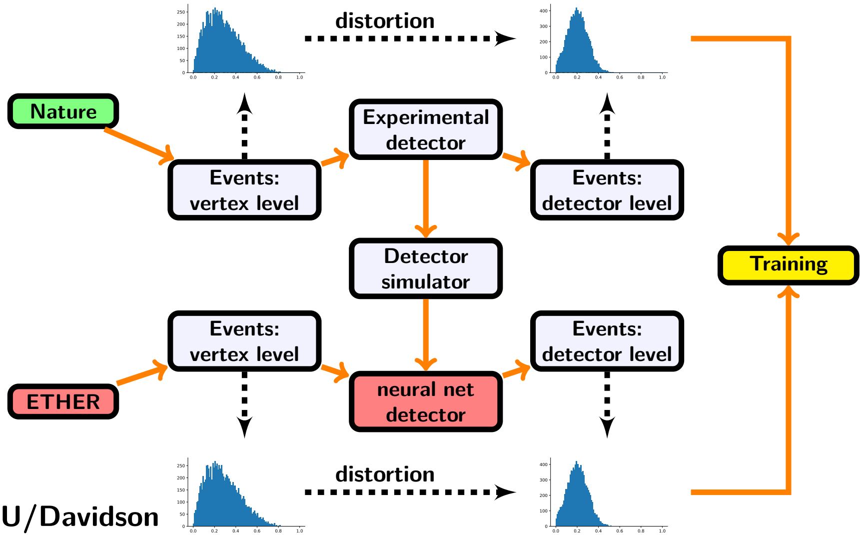

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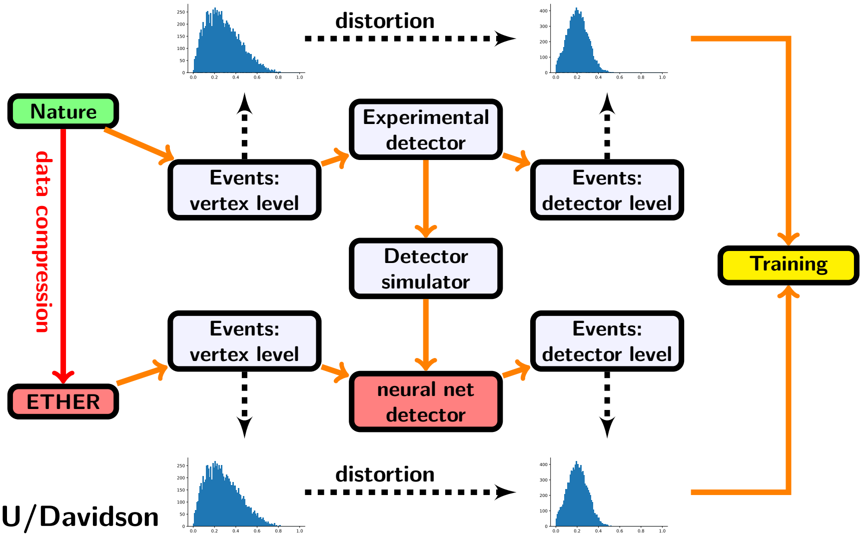

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Summary and outlook

- **ML for QCD global analysis - proposal for CNF**
  - Multi-disciplinary $\rightarrow$ QCD scientists, computer scientists
  - Next generation of QCD analysis tools $\rightarrow$ boost scientific research
- **ML based MCEG (ETHER) - LDRD19**
  - Data compactification tool
  - MCEG free of theory assumptions at the femtometer scale