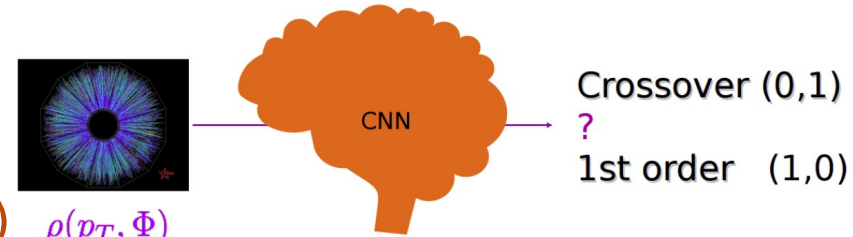


'Deepthinkers' @ FIAS since 08.2017

Third-party funding from Samson AG

BMBF ErUM funding with C.B.M



Dr. Yi-lun Du (heavy-ion collisions EoS meter) $\rho(p_T, \Phi)$

Dr. Olena Linnyk (NA61, data analysis)

Dr. Li-jia Jiang (recognize dynamics in Stochastic motion)

Dr. Nishtha Srivastava (Seismic events prediction)

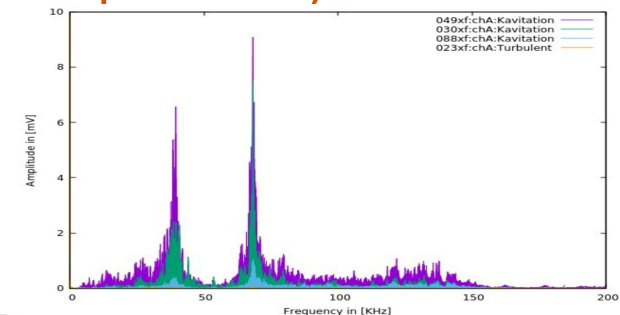
Dr. Kai Zhou (Lattice Field Theory, statistical physics)

Dr. Jan Steinheimer (recognize spinodal decomposition)

Dr. Nan Su (Smart City)

Prof. Stefan Schramm (Smart Valve project)

Prof. Horst Stoecker



Introduction

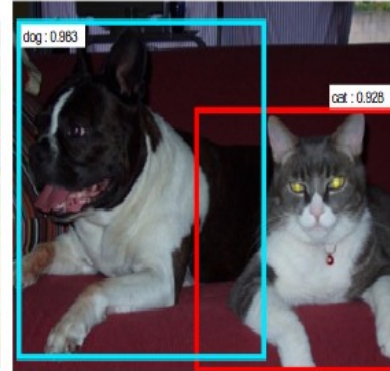
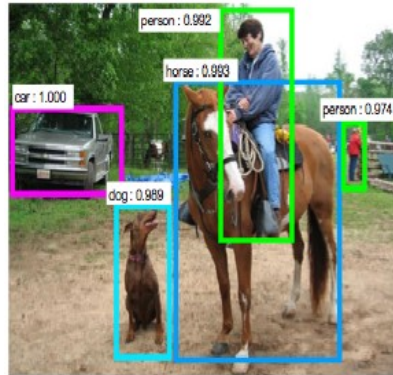
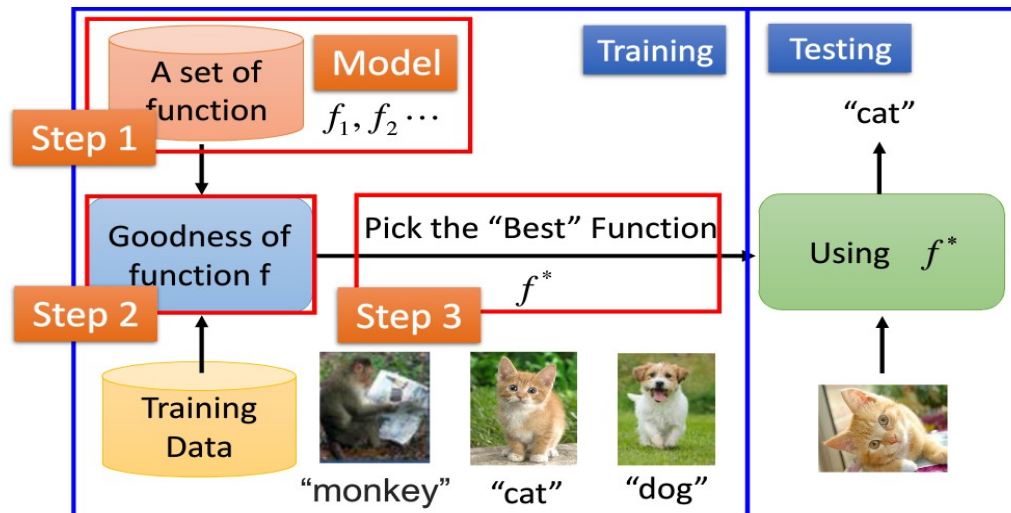


Image Recognition:

Framework

$$f(\text{cat image}) = \text{"cat"}$$



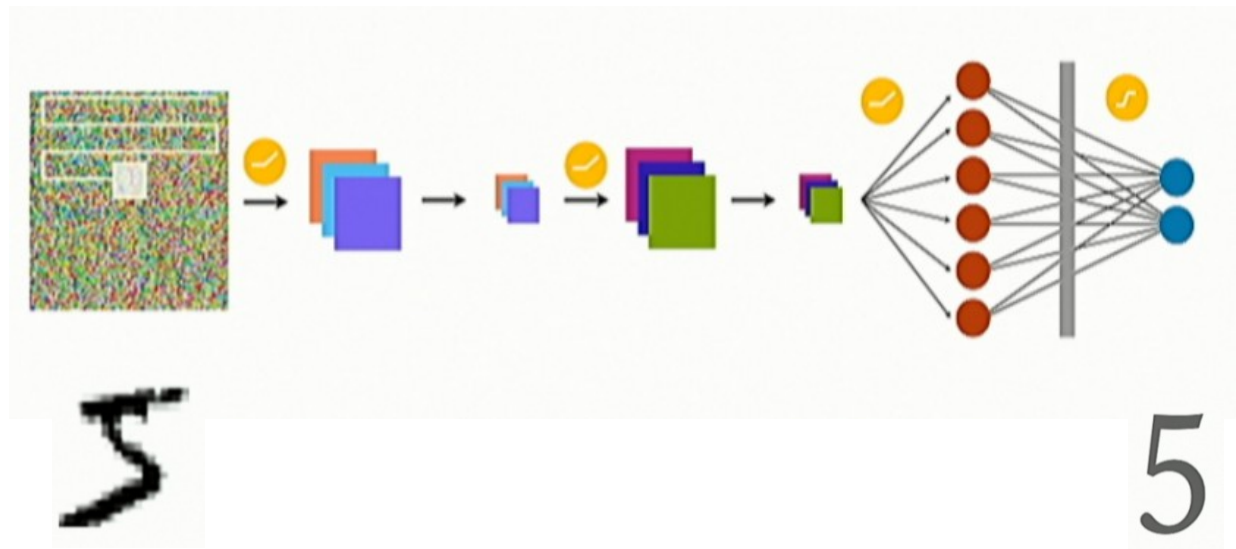
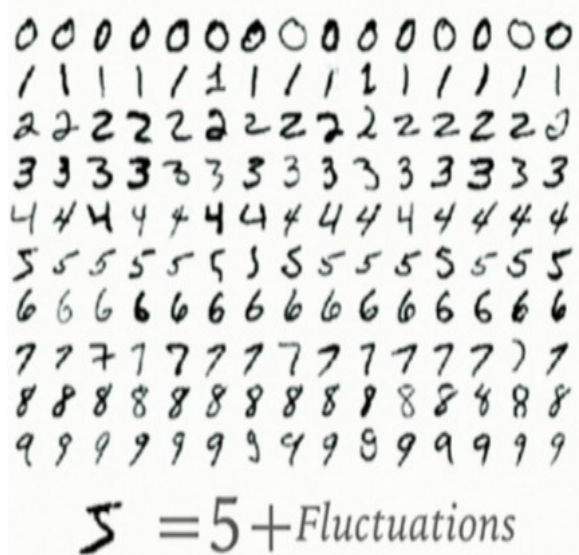
Find and Decode the mapping/representations into
Deep Neural Network

→ **Function approximator**

Universal approximator
(Hastad et al 86 & 91)

Introduction

- **Convolutional Neural Network** has proved to be extremely powerful in **Pattern Recognition, Image Classification**

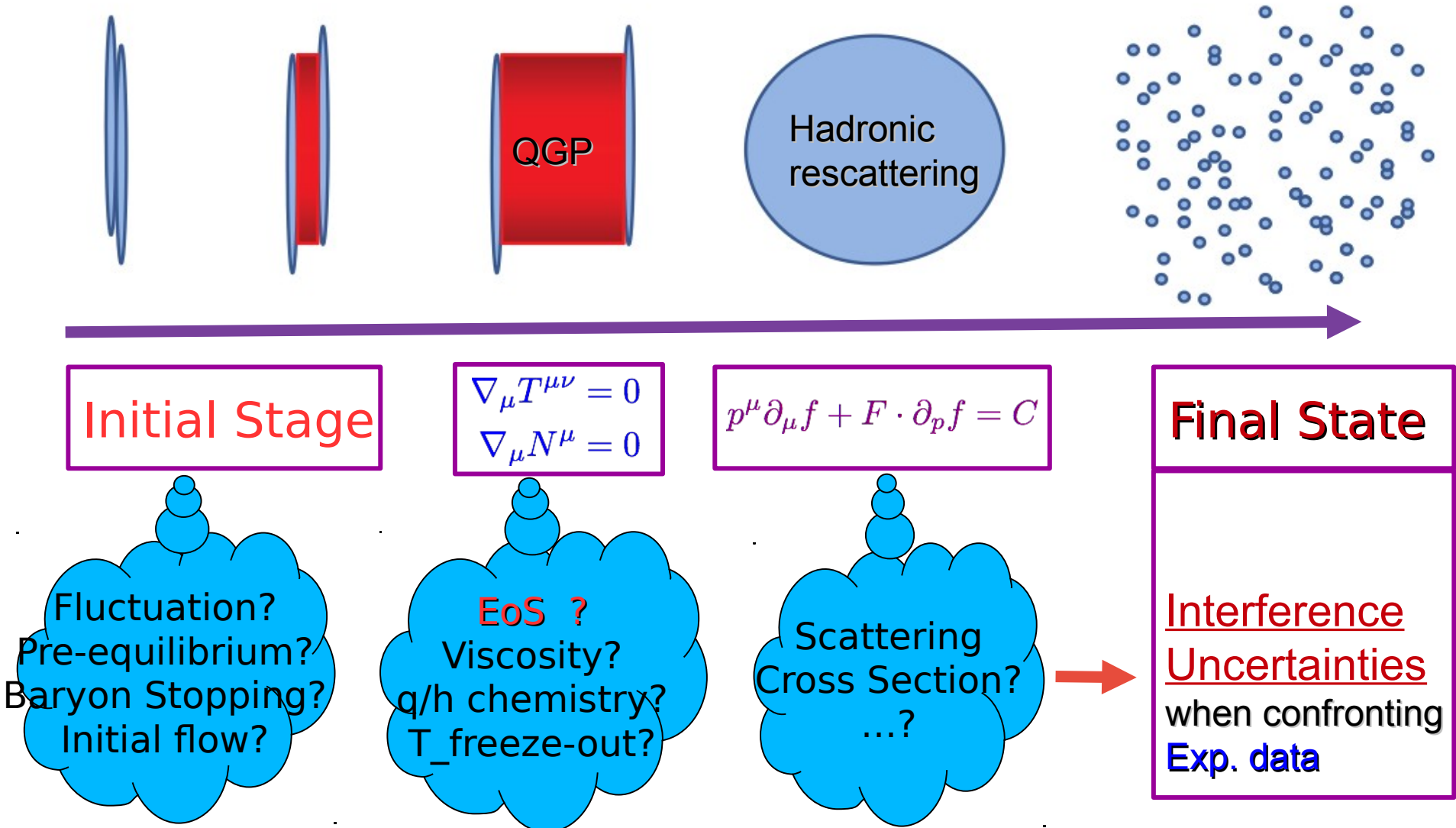


- **Discriminative learning (prediction)** : Classification, Regression
Generative modelling (generation) : RBM, VAE, GAN

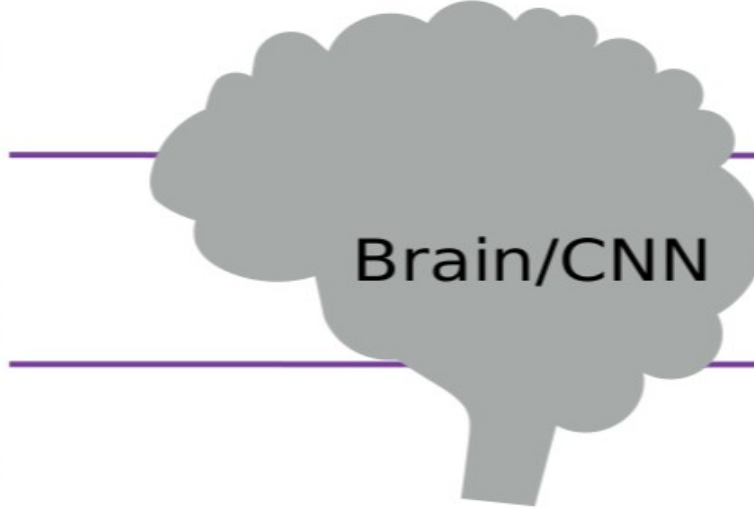
Identifying QCD transition in Heavy-Ion-Collisions

Nature Commun. 9 (2018) no.1, 210

Standard HIC model - uncertainties



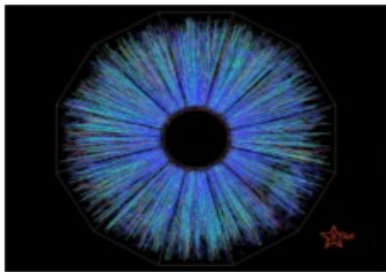
Inspried from Brain/CNN



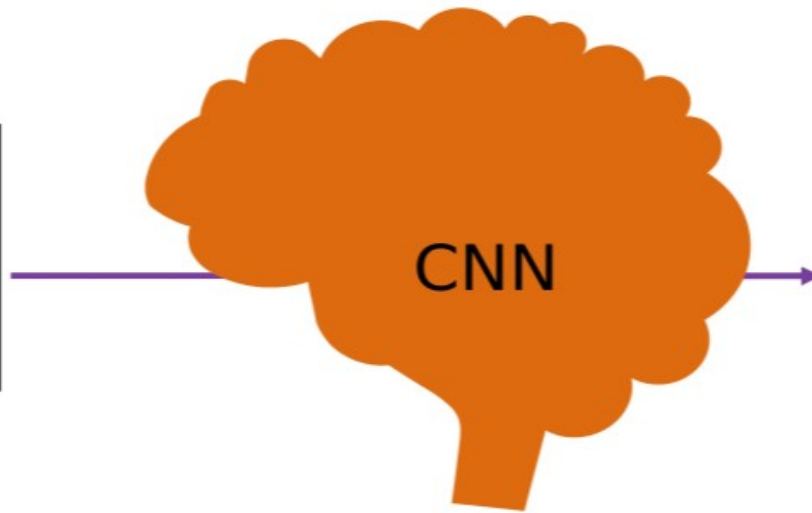
"Dog"



"Cat"



$$\rho(p_T, \Phi)$$



Crossover "(0,1)"

?

1st Order "(1,0)"

Results in testing

TESTING DATA	GROUP 0	GROUP 1	GROUP 2
Number of events	4000	7343	8916
Accuracy	$99.88 \pm 0.04\%$	$93.46 \pm 1.35\%$	$95.12 \pm 3.08\%$

- On average **~95% prediction accuracy**, the trained CNN model identifies the type of QCD transition **solely from the raw spectra**
- The performance is **robust against** : initial conditions, $\eta/s, \tau_0, T_{fo}$
model independent!
- Deep CNNs can help constructing us **EoS-meter** to **directly connect** HIC experiments with QCD properties

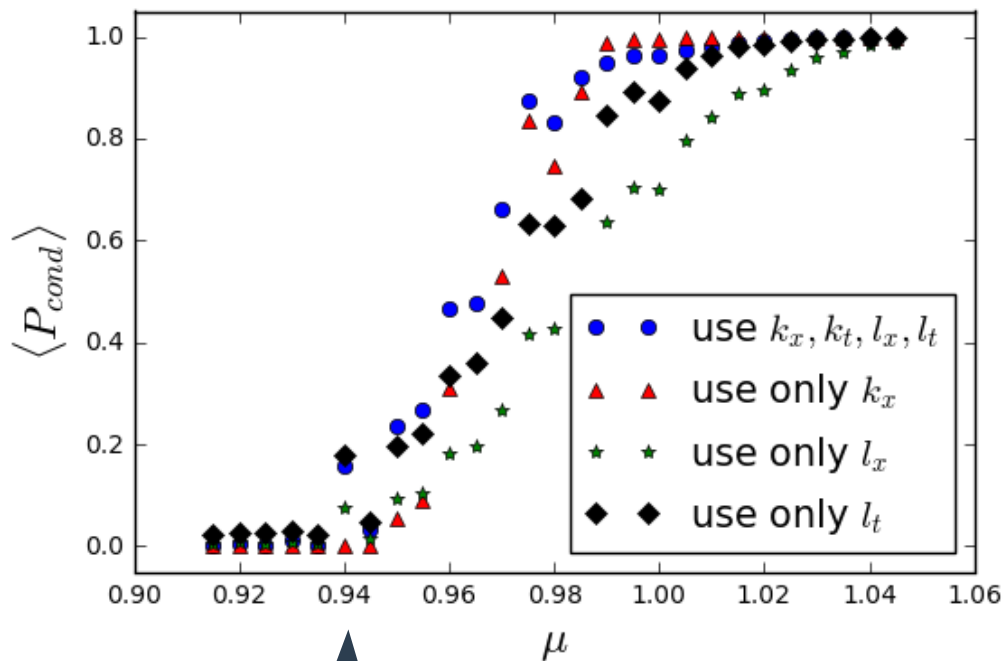
Deep learning in lattice QFT

-- 1+1d scalar field theory

arXiv:1810.12879

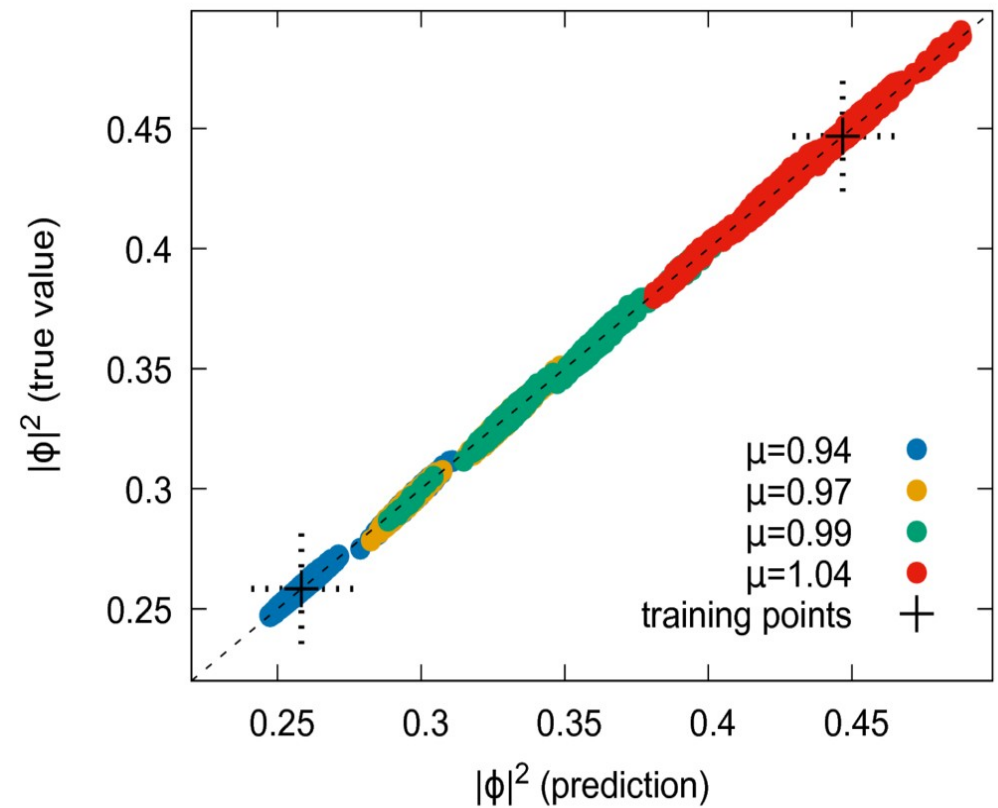
Identify Phase Transition & Physical Observable

Pin down 'transition' point without knowledge guidance:

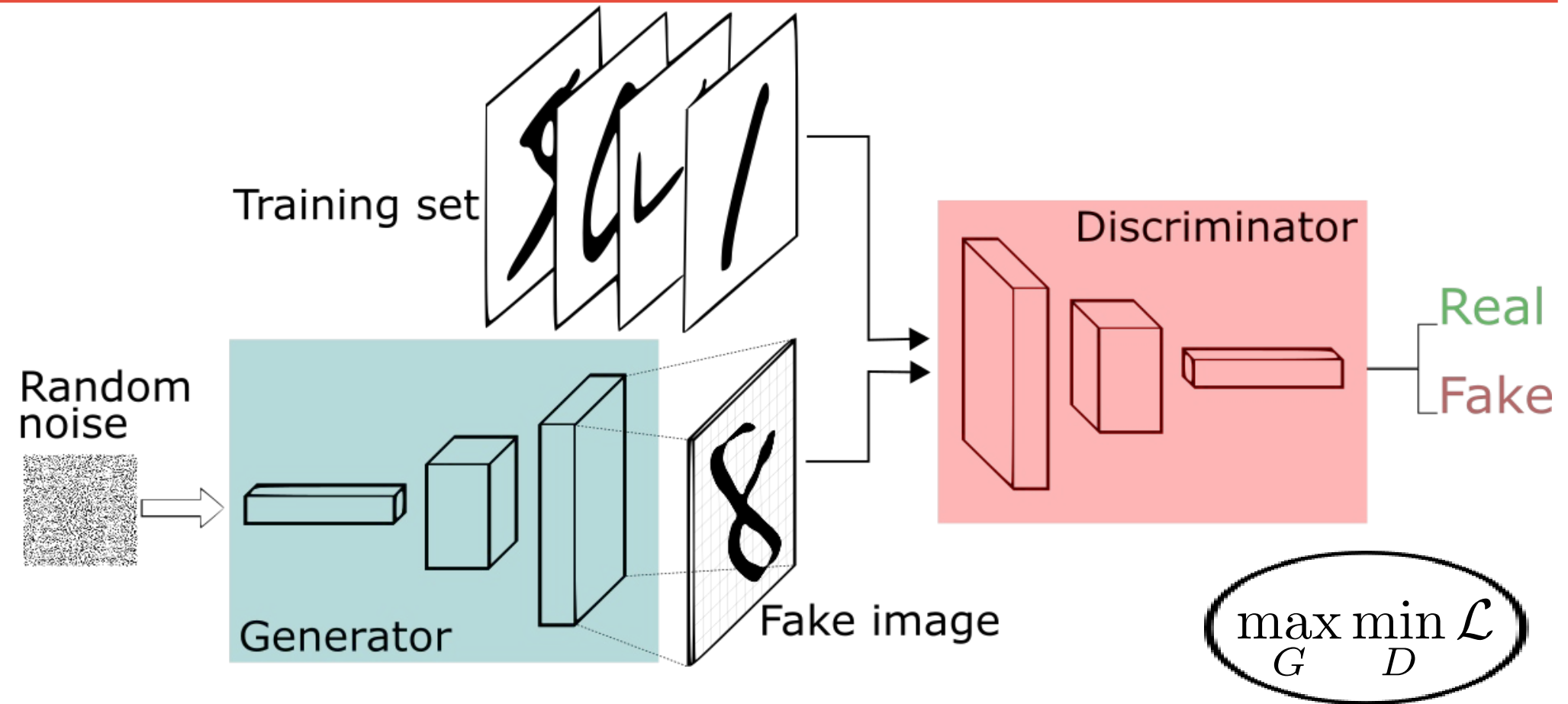


$$\mu_{th}(\langle P_{cond} \rangle > 0) \sim \mu_{th}(\langle n \rangle > 0)$$

Non-linear regression in high-dim space for physical observable:



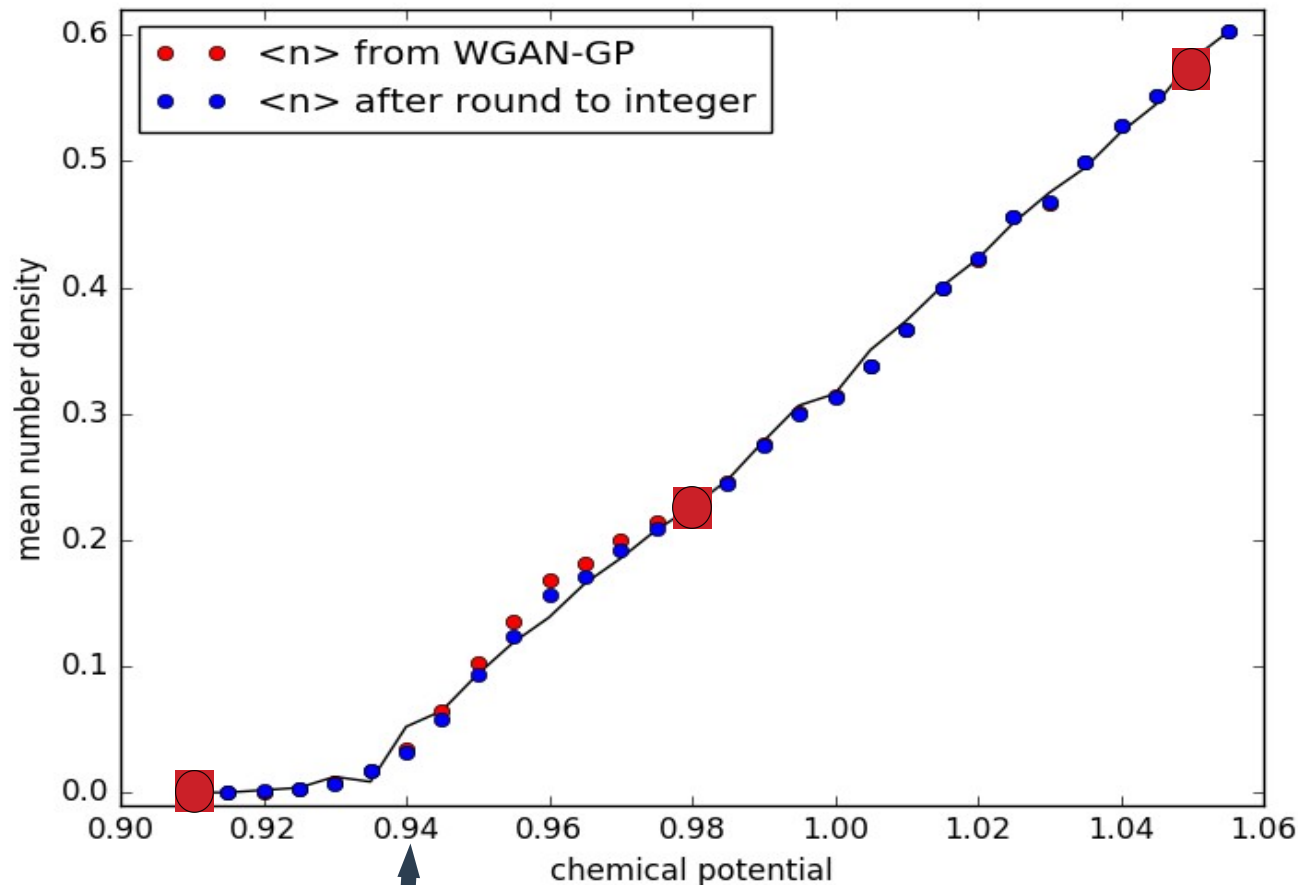
Generative Adversarial Network



$$\mathcal{L} = -\mathbb{E}_{\hat{x} \sim p_r(\hat{x})} [\log(D(\hat{x}))] - \mathbb{E}_{z \sim p(z)} [\log(1 - D(G(z)))]$$

Conditional GAN

phase diagram generated by c-GAN on mu with limited ensemble of training set:



Got the partition sum:

how much can we reconstruct the partition information from several Monte-Carlo generated ensembles of configs ?

Well phase diagram

Well transition point