

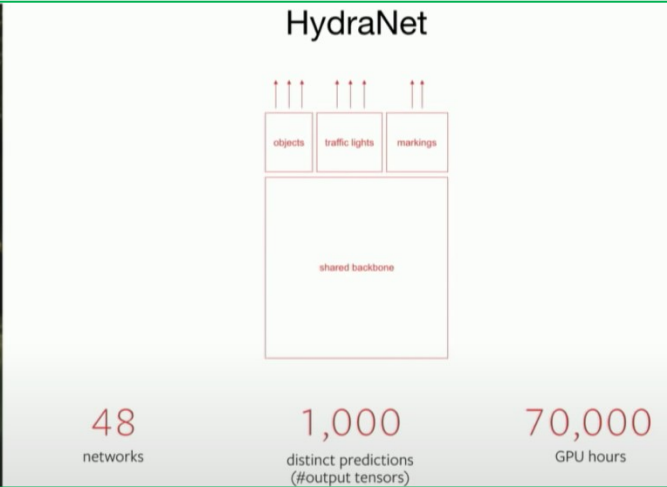
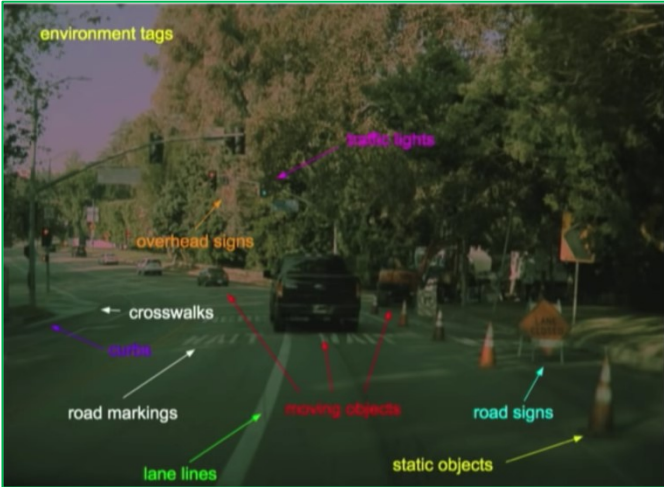
Application of Multi-task Learning at the Injector of European XFEL

Intelligent Process Control Seminar

Jun Zhu

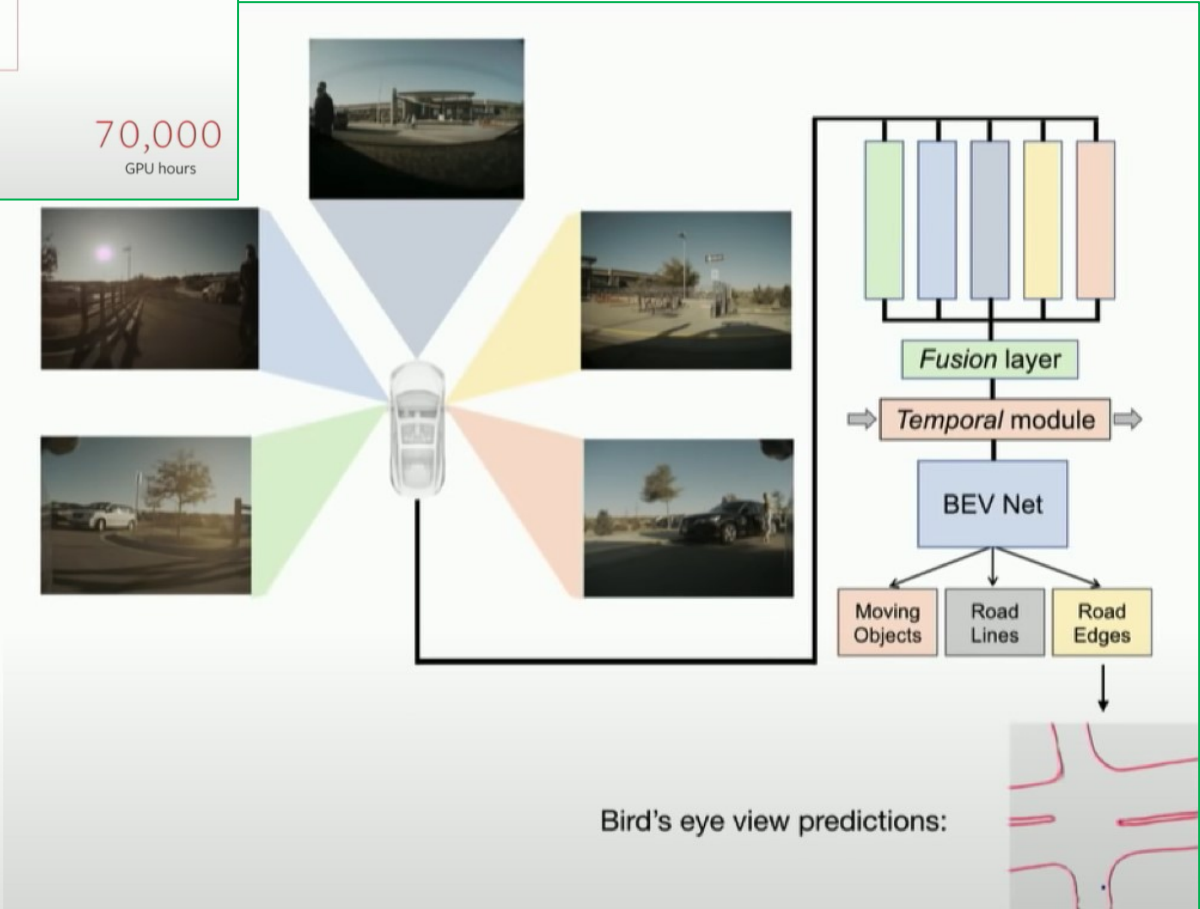
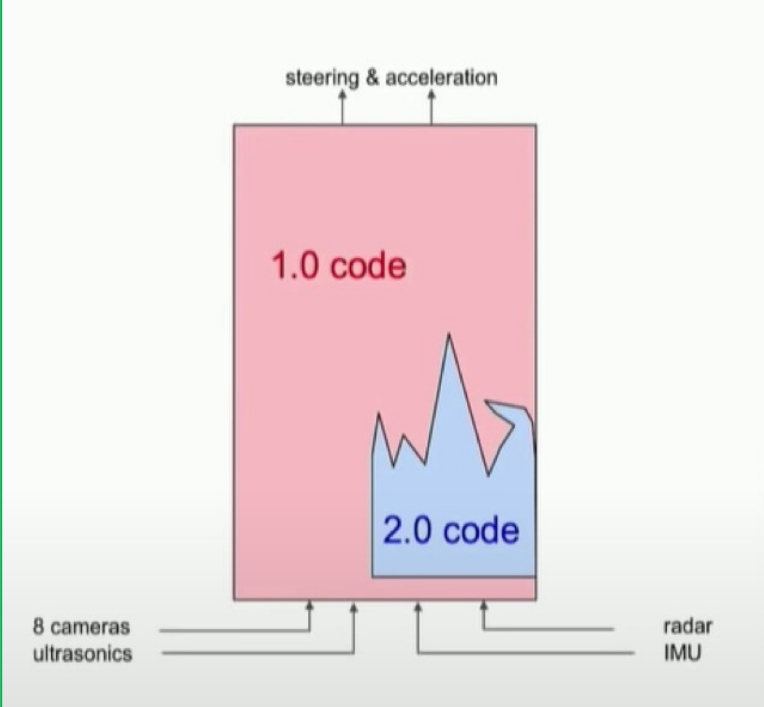
Hamburg, 17.11.2020

Large-scale Multi-task Learning in Production



HydraNet:
shared backbone and multiple heads

A. Karpathy, AI for Full-self Driving at Tesla, 04.2020



Benefits and Challenges of Multi-task Learning

Benefits:

- Improve data efficiency
- Reduce overfitting through shared representation
- Accelerate learning by leveraging auxiliary information
- Speed up test and inference

Challenges:

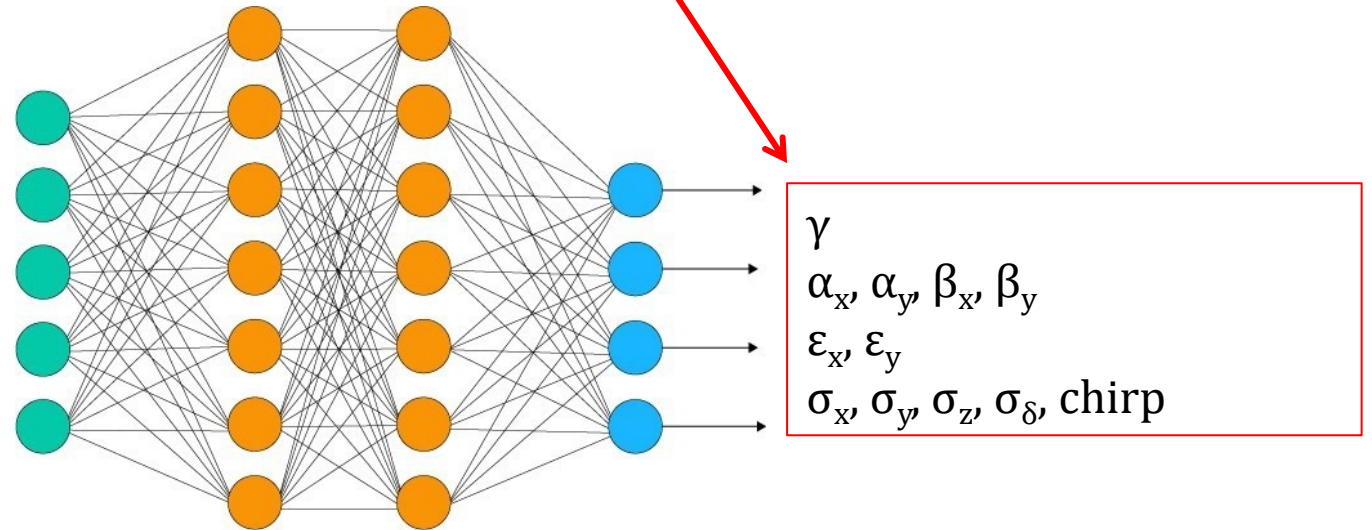
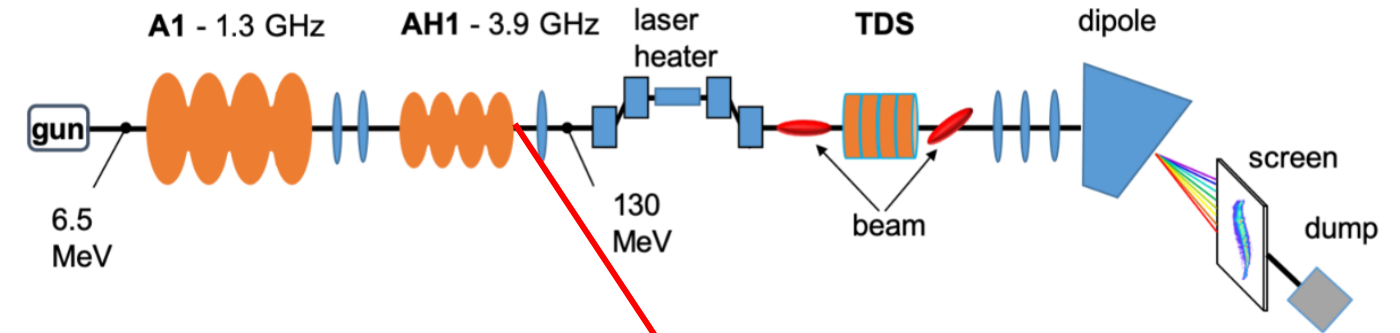
- Neural network architecture design
- Training strategy
 - Loss weighting
 - Regularization
 - Task scheduling
- Task relationship learning

Surrogate model at the injector of European XFEL

ASTRA simulation:

- 20 k particles
- The following highlighted parameters were randomly sampled within the given range.

Parameters	Sample range
Charge (pC)	250
Laser pulse duration (ps)	3
Laser spot size (mm)	0.2 ~ 0.3
Gun solenoid (T)	0.2 ~ 0.25
Gun phase (degree)	-10 ~ 10
Gun gradient (MV/m)	50 ~ 60
A1 phase (degree)	-10 ~ 10
A1 gradient (MV/m)	30 ~ 40
AH1 phase (degree)	170 ~ 190
AH1 gradient (MV/m)	0 ~ 20
Q37 gradient (T/m)	-0.2 ~ 0.2
Q38 gradient (T/m)	-0.2 ~ 0.2

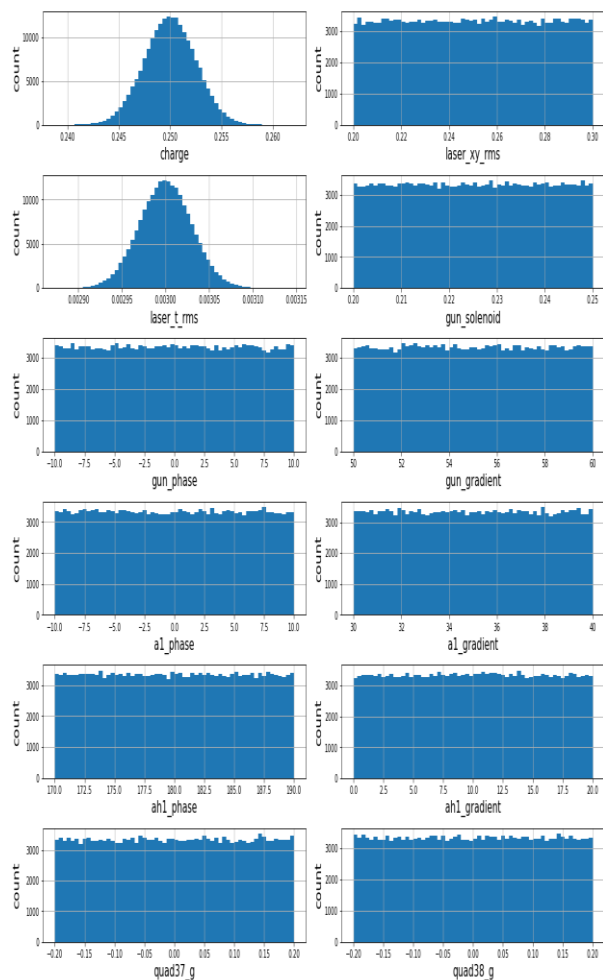


In a sense, this surrogate model is an example of multi-task learning.

Surrogate model at the injector of European XFEL

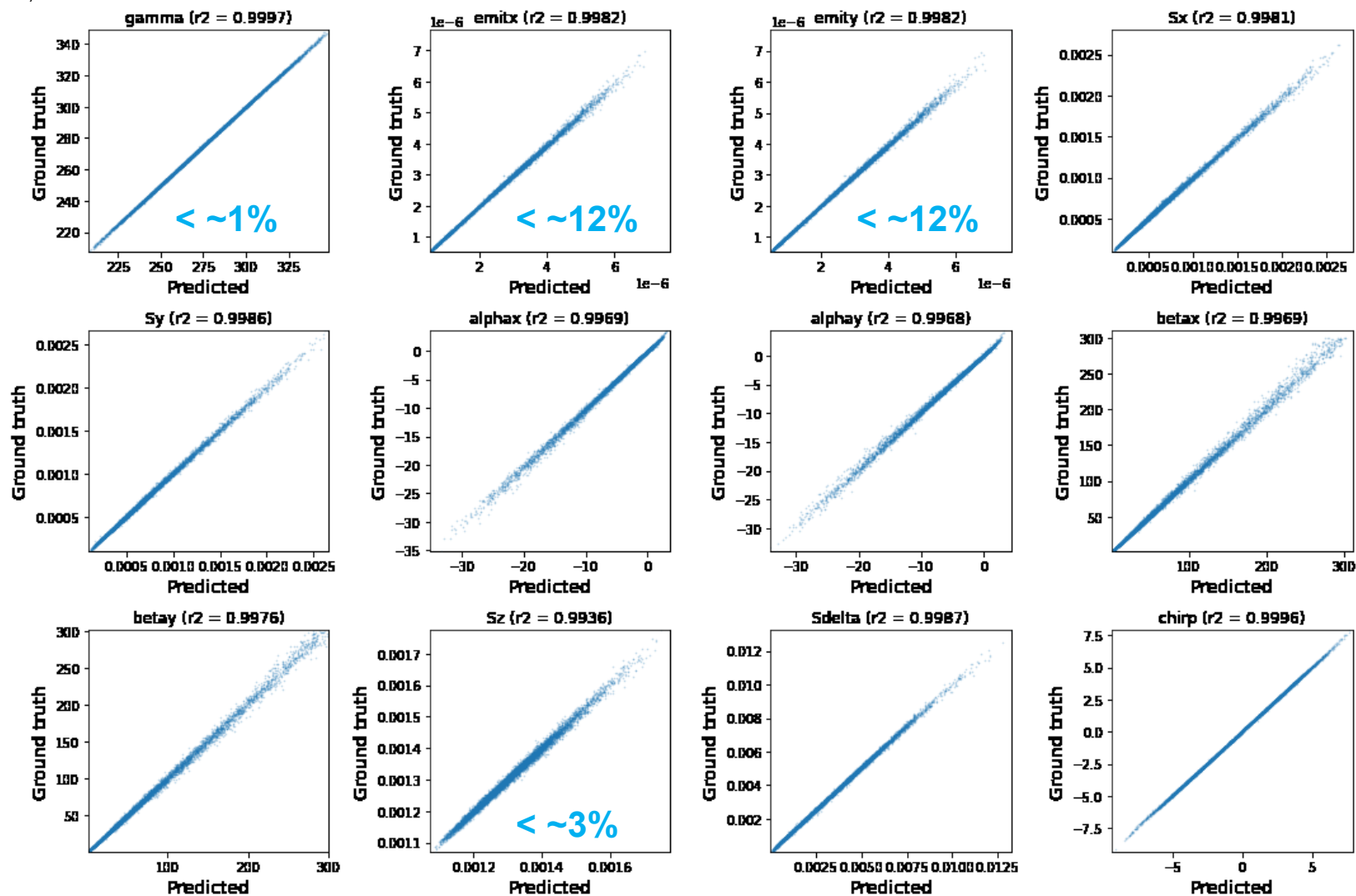
200,000 simulations in total

37,516 simulations (no particle loss, $\beta_x < 300$ m, $\beta_y < 300$ m)



Distribution of input parameters

Prediction with the test data set (20%)

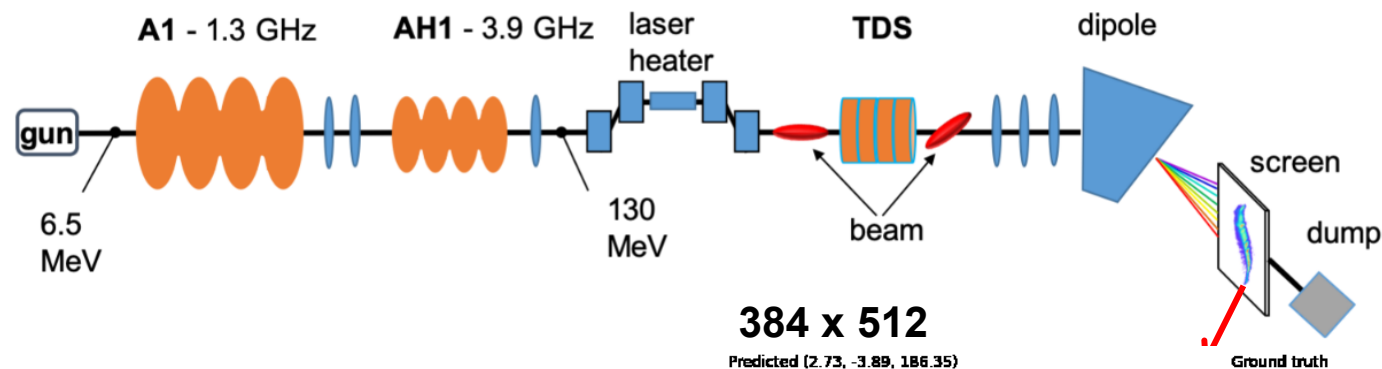


Longitudinal Phase Space Prediction

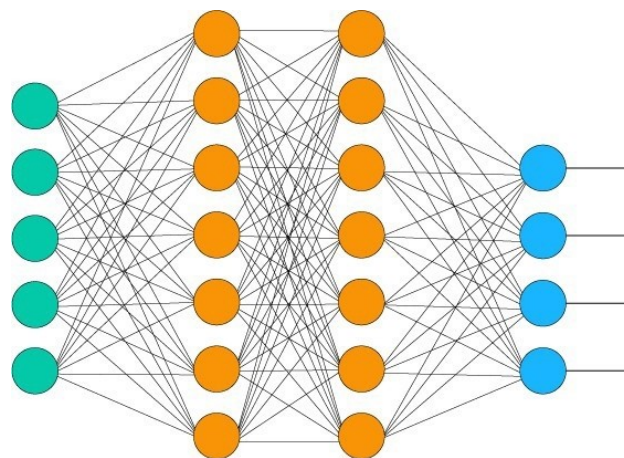
ASTRA + ELEGANT simulation:

- 20 k particles
- The following highlighted parameters were randomly sampled within the given range.

Parameters	Sample range
Charge (pC)	250
Laser pulse duration (ps)	3
Laser spot size (mm)	0.25
Gun solenoid (T)	0.216
Gun phase (degree)	-6 ~ 6
Gun gradient (MV/m)	56.3
A1 phase (degree)	-6 ~ 6
A1 gradient (MV/m)	33.3
AH1 phase (degree)	182 ~ 188
AH1 gradient (MV/m)	14
Q37 gradient (T/m)	-1.156
Q38 gradient (T/m)	1.093

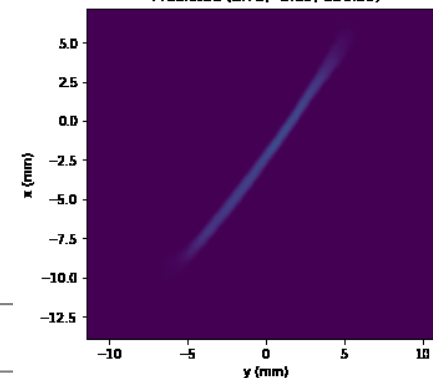


2000 data points

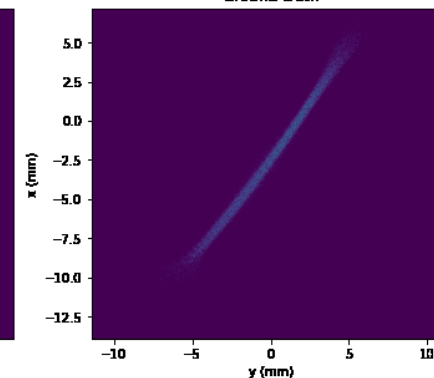


384 x 512

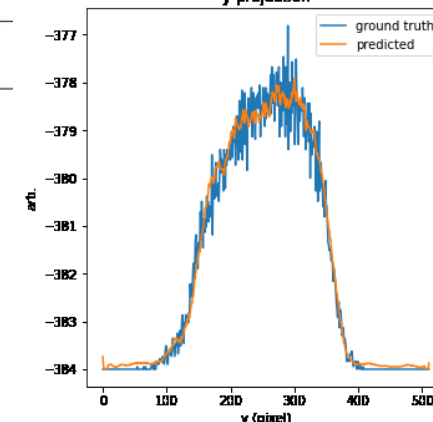
Predicted (2.73, -3.89, 186.35)



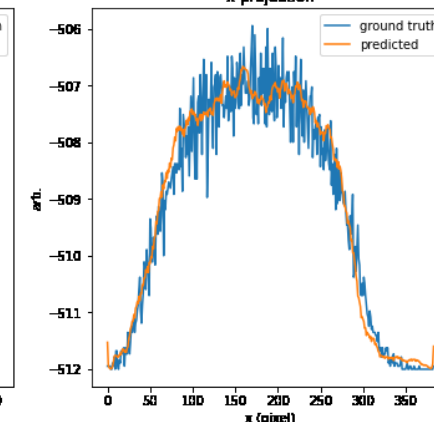
Ground truth



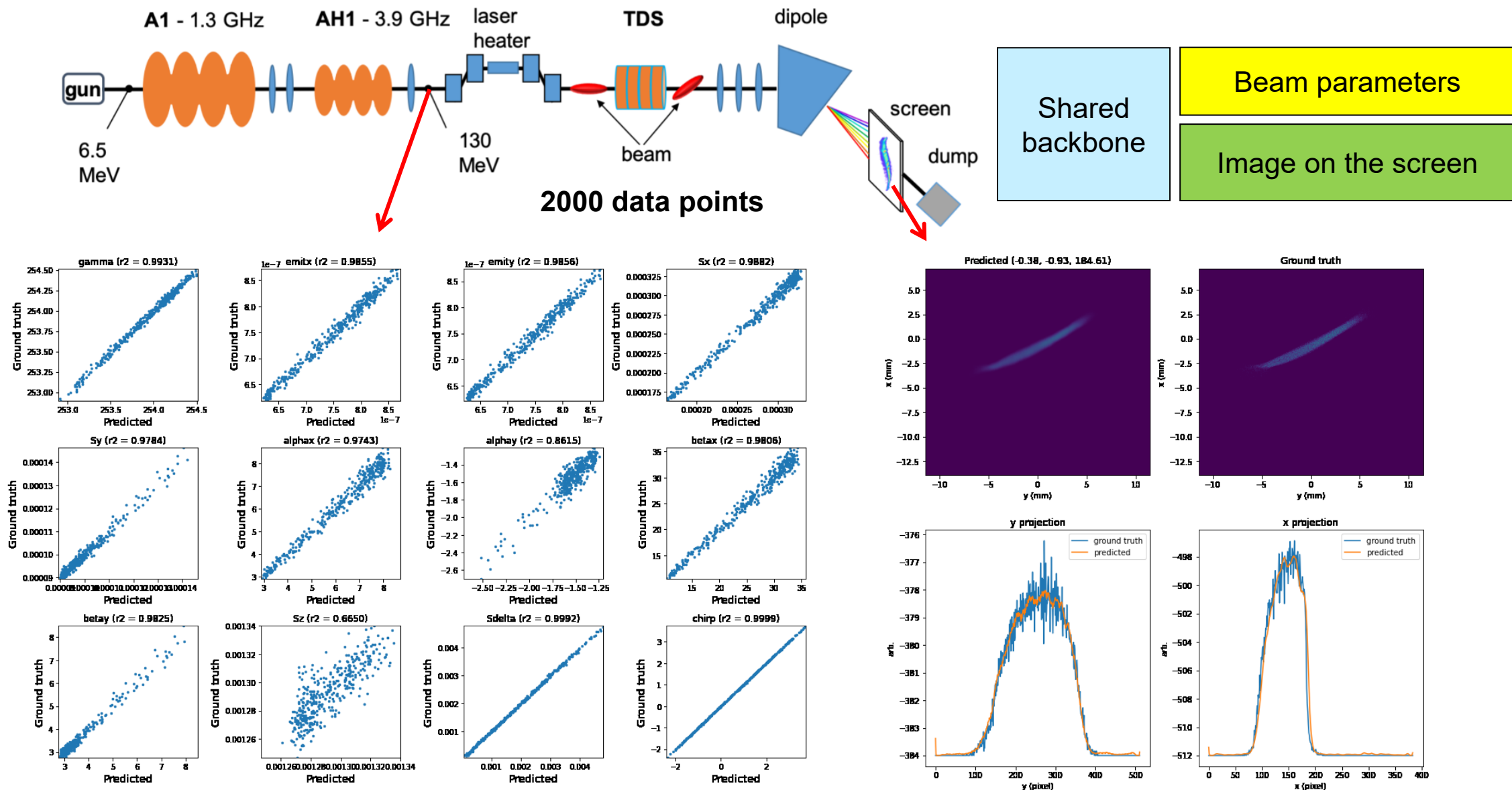
y projection



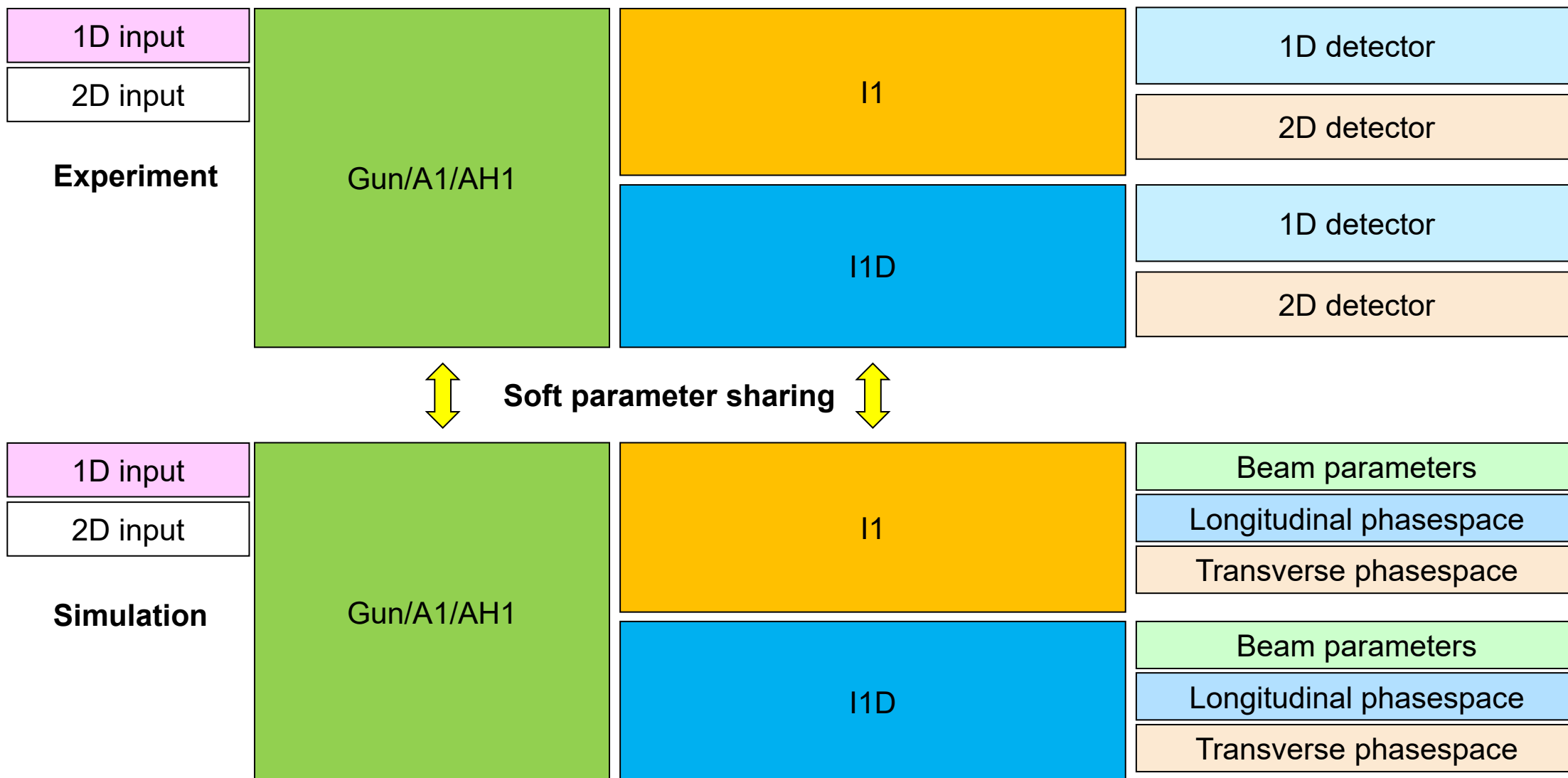
x projection



Surrogate Model with Longitudinal Phase Space Prediction



“HydraNets” for the Injector



**Thank you
for your attention!**