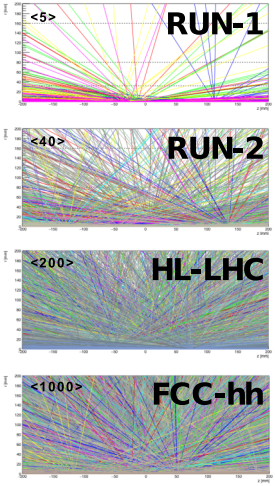
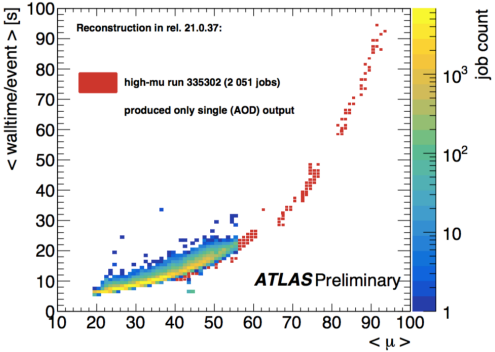
TrackML:
A tracking machine learning challenge

Moritz Kiehn
Université de Genève

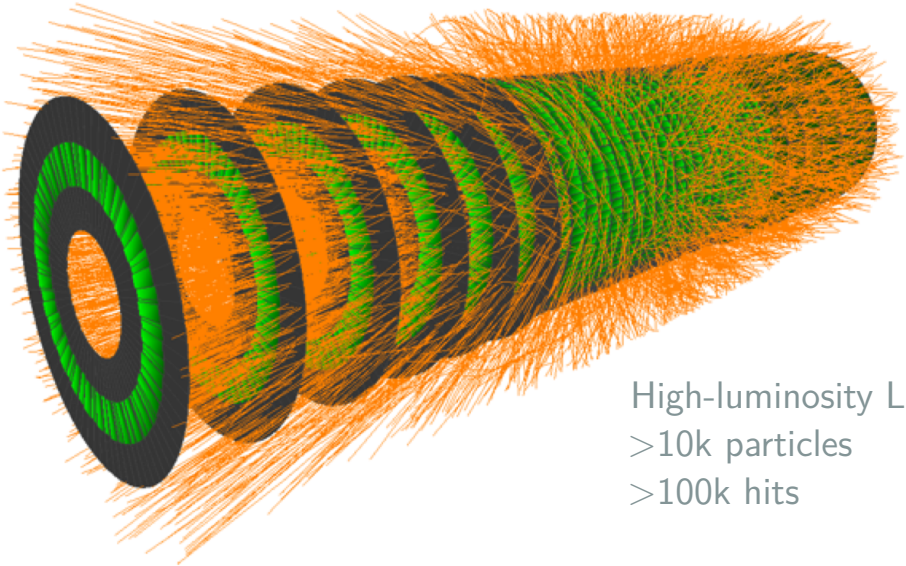
CHEP 2018, Sofia, Bulgaria, 12.07.2018

The tracking problem





Combinatorial nature of current approach.



High-luminosity LHC
>10k particles
>100k hits

Are there better approaches?
How to find them?
Do we have to do it ourselves?

$\rightarrow$ Use challenge format to look for new solutions

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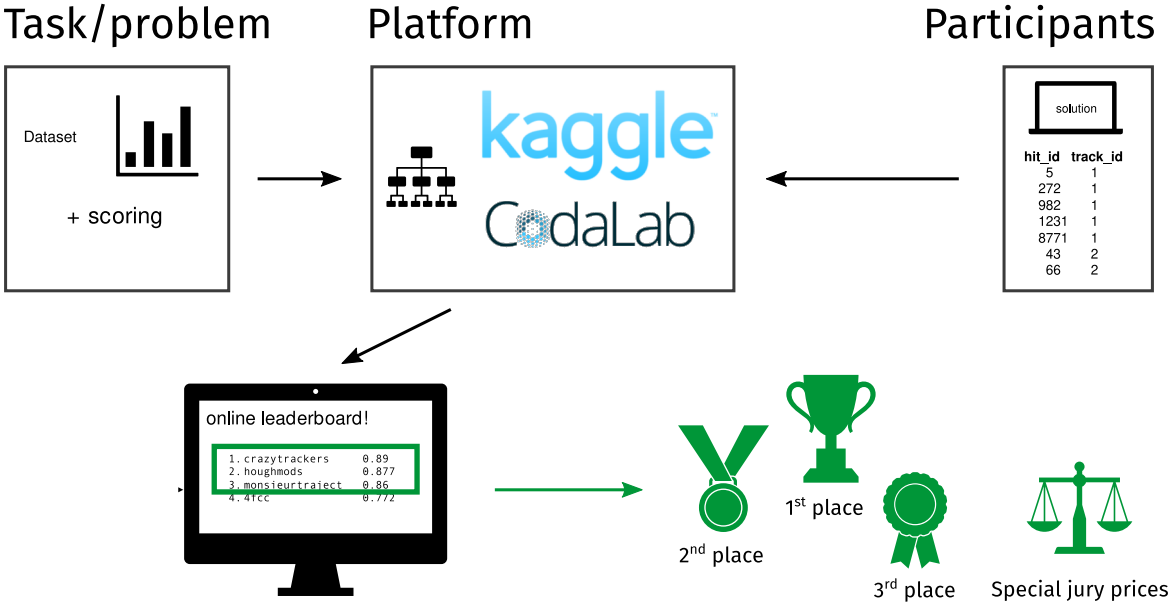
Task/problem
Platform
Participants
Dataset
+ scoring
kaggle
CodaLab
solution
hit_id track_id
5 1
272 1
982 1
1231 1
8771 1
43 2
66 2
online leaderboard!
1. crazytrackers 0.89
2. houghmods 0.877
3. monsieurtraject 0.86
4. 4fcc 0.772
2nd place
1st place
3rd place
Special jury prices

Defining the problem

Real experiment metrics

- Tracking efficiency
- Fake rate vs. purity
- Momentum resolution
- Impact resolution

Simplify and reduce

- No parameter estimation
- No hit merging/splitting/sharing
- Use single metric

Connect the dots

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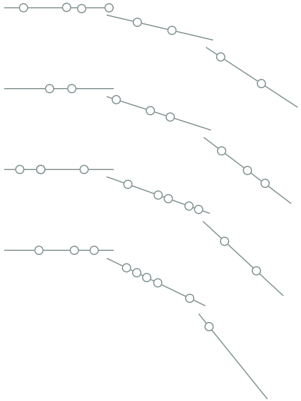

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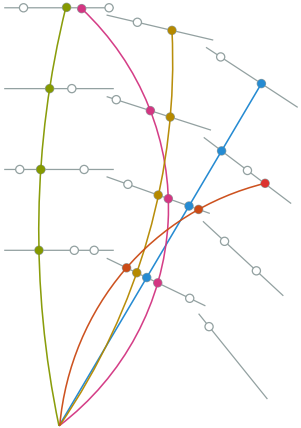


Dataset format

Space points as CSV file

```
hit_id,       x,       y,       z, volume_id, layer_id, module_id
...
      2, -812.8, -631.4,  411.5, ...
      3,  649.4, -785.7, -309.1, ...
...
```

Submission as CSV file

```
event_id, hit_id, track_id
...
       51,      2,       42
       51,      3,       23
...
```

A two-phased challenge

Accuracy phase

kaggle

Currently running until August, 13th

Submit reconstruction result only
Evaluate only accuracy

Leader prizes 12 k$, 8 k$, 5 k$
Special jury prizes (NVIDIA V100 GPU)

Troughput phase

CodaLab

Expected to start in September

Submit reconstruction code
Evaluate accuracy and speed

Expected prizes 7 k$, 5 k$, 3 k$
Special jury prizes

Accuracy phase score

$$\begin{aligned} \text{track} &= \{5, 23, 42, \ldots\} \\ \text{majority particle} &= \{5, 17, 23, 42, \ldots\} \\ \text{good hits} &= \text{track} \cap \text{majority particle} \end{aligned}$$

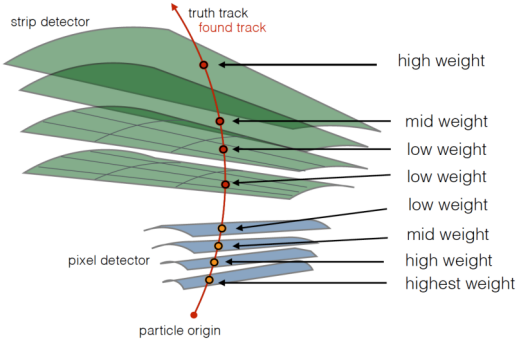
$$S \sim \sum_{\{\text{events}\}} \sum_{\{\text{tracks}\}} \begin{cases} 0 & \#\text{good hits} < 50\,\%, \#\text{hits} < 3 \\ \sum_{\{\text{good hits}\}} w_i & \text{else} \end{cases}$$

$$S_{perfect} = 1$$

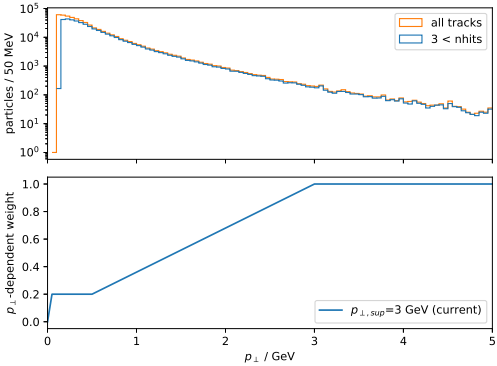
$$w_i = w_i\,(\text{hit order}, \text{particle } p_\perp)$$

Accuracy phase score (cont'd)

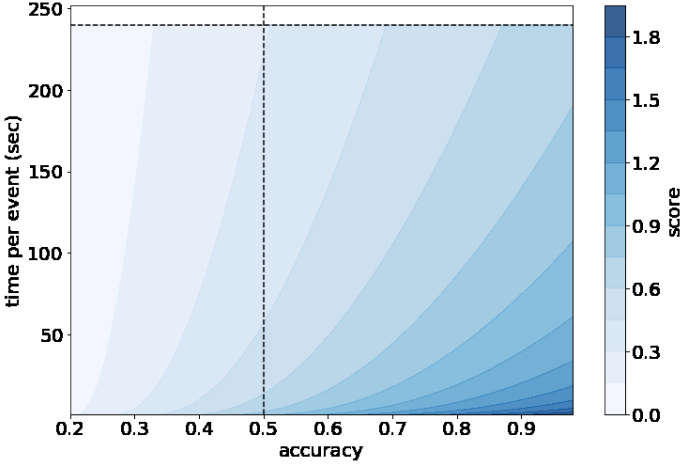
Hit order



Particle $p_\perp$



Throughput phase score (proposal)



Nonlinear combination of accuracy score and processing time

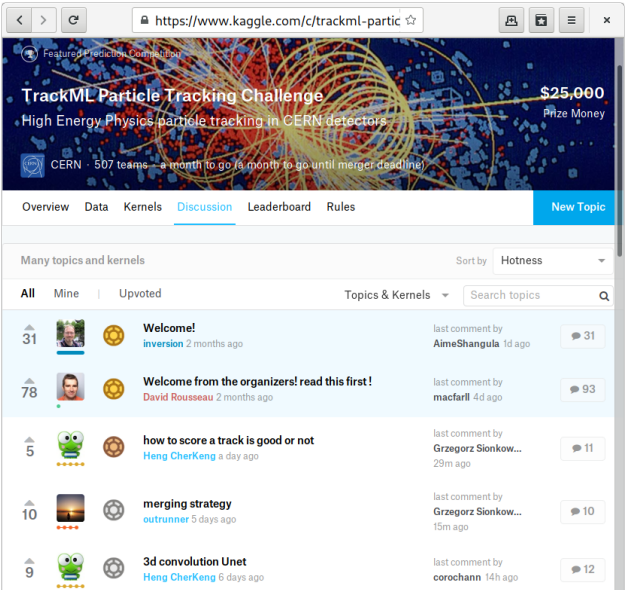
Status accuracy phase challenge

Started in Mai
Ends on August 13th

>500 teams

Best scores are improving

Algorithms known only after finish



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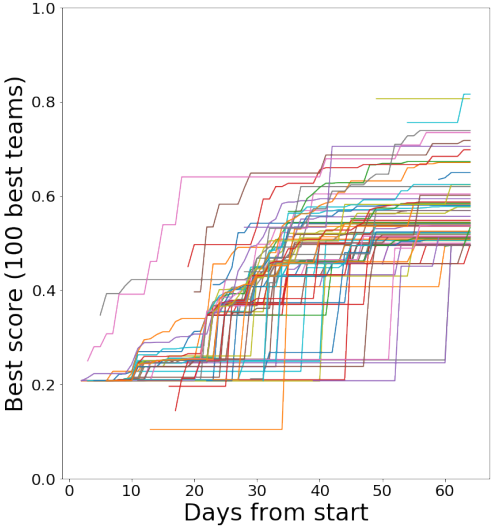

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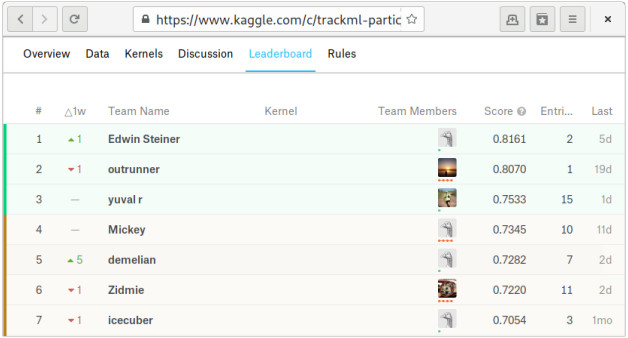

#	△1w	Team Name	Kernel	Team Members	Score	Entri...	Last
1	▲1	Edwin Steiner			0.8161	2	5d
2	▼1	outrunner			0.8070	1	19d
3	—	yuval r			0.7533	15	1d
4	—	Mickey			0.7345	10	11d
5	▲5	demelian			0.7282	7	2d
6	▼1	Zidmie			0.7220	11	2d
7	▼1	icecuber			0.7054	3	1mo

Lessons learned

You need to simplify

A lot of questions on physics and detector details

This is an unusual dataset

Variable # inputs, # outputs, lots of discussions on possible algorithms

You need extensive crosschecks

A few minor dataset features: beam size, electron scattering, sensor thickness

Examples

What you provide might skew the discussion

Organizers

Paolo Calafiura, Steven Farrell, Heather Gray (LBNL Berkeley), Jean-Roch Vlimant (Caltech), Isabelle Guyon (ChaLearn, U Paris Saclay), Cécile Germain (LAL/LRI, U Paris Saclay), David Rousseau, Yetkin Yilnaz (LAL Orsay, U Paris Saclay), Vincenzo Innocente, Andreas Salzburger (CERN), Ilija Vukotic (U of Chicago), Tobias Golling, *Moritz Kiehn*, Sabrina Amrouche (U Genève), Edward Moyse (U of Massachusetts), Vava Gligorov (LPNHE Paris), Mikhail Hushchyn, Andrey Ustyuzhanin (Yandex)

trackML sponsors

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kaggle

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INSTITUTE DATAIA
Data Science, Intelligence & Society

CHALEARN

COMMON GROUND

CERN openlab

Inria
INVENTORS FOR THE DIGITAL WORLD

Caltech

Fermilab

erc

UNIVERSITE PARIS SUD

université PARIS-SACLAY

Summary

A public machine learning challenge to find/evaluate novel tracking approaches.

Website
`https://sites.google.com/site/trackmlparticle/`

Phase I challenge
`https://www.kaggle.com/c/trackml-particle-identification`

Twitter
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Join the challenge!

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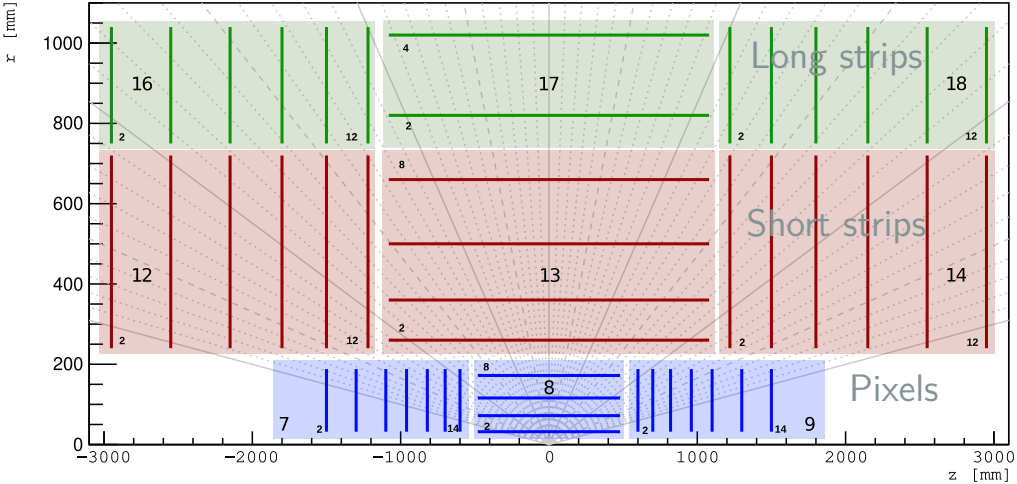
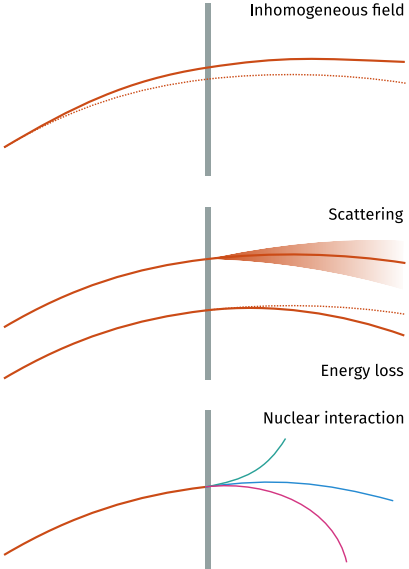
Appendix

The TrackML silicon tracker

A1



Simulation setup



Generator

- Pythia8 $t\bar{t}$ as signal
- Pythia8 minimum bias as pile up, $\mu = 200$
- Luminous region $\sigma_z = 5\,\mathrm{mm}$

ACTS fast simulation

- ATLAS-like field
- Parameterized interaction effects
- 15 % random hits

Ground truth (only for training dataset) A3

event...-particles.csv

```
      particle_id,      vx,    vy,   vz,     px,    py,    pz,  q
...
4503805785800704, -0.0083, 0.013, 0.30,  0.182, 0.064,  0.18,  1
4503943224754176, -0.0083, 0.013, 0.30, -0.051, 0.167, -0.12, -1
...
```

event...-truth.csv

```
hit_id,         particle_id,    tx,    ty     tz,   tpx,   tpy,   tpz
...
      2,   4513289073590272, -813., -630.,  378., -0.74, -0.19,  0.27
      3, 117094208786923520,  648., -786., -352.,  0.12, -0.63, -0.21
...
```

Scoring metric: example

Truth

particle 1 = $\{2, 4, 8, 16, 32\}$ weights 1 = $\{25, 15, 10, 10, 15\}$

particle 2 = $\{3, 5, 9, 17, 33\}$ weights 2 = $\{7, 5, 5, 3, 5\}$

Reconstruction

track a = $\{3, 4, 8, 16, 32\}$ good hits a = $\{4, 8, 16, 32\}$

track b = $\{\_, 5, 9, 17, 33\}$ good hits b = $\{5, 9, 17, 33\}$

Score

score a = 50 score b = 18

score total = 68