2nd COMCHA Workshop

Correction of Bremsstrahlung emissions for electrons at the Run 3 LHCb experiment

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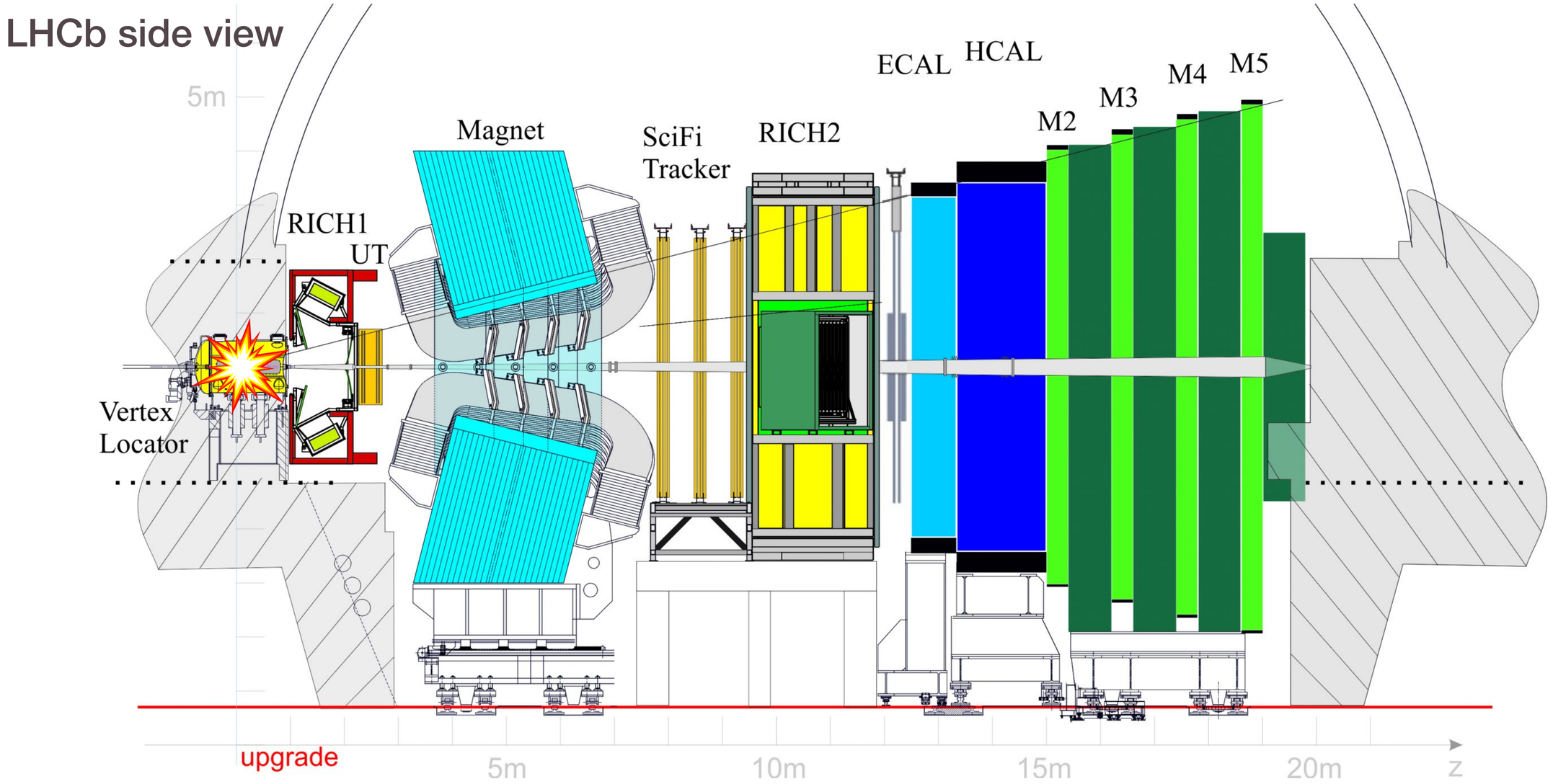
Overview

- Bremsstrahlung emission at LHCb
- Current recovery model
- Machine Learning (ML) recovery approaches
- Future, more complex, models
- Discussion

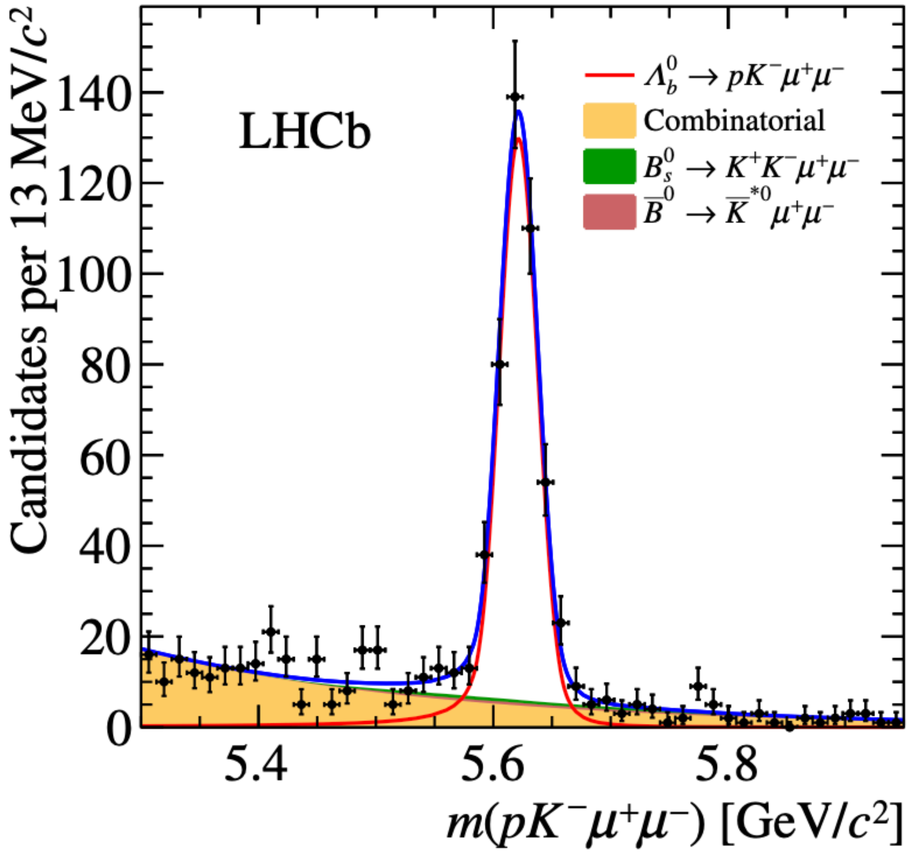
Bremsstrahlung emission at LHCb

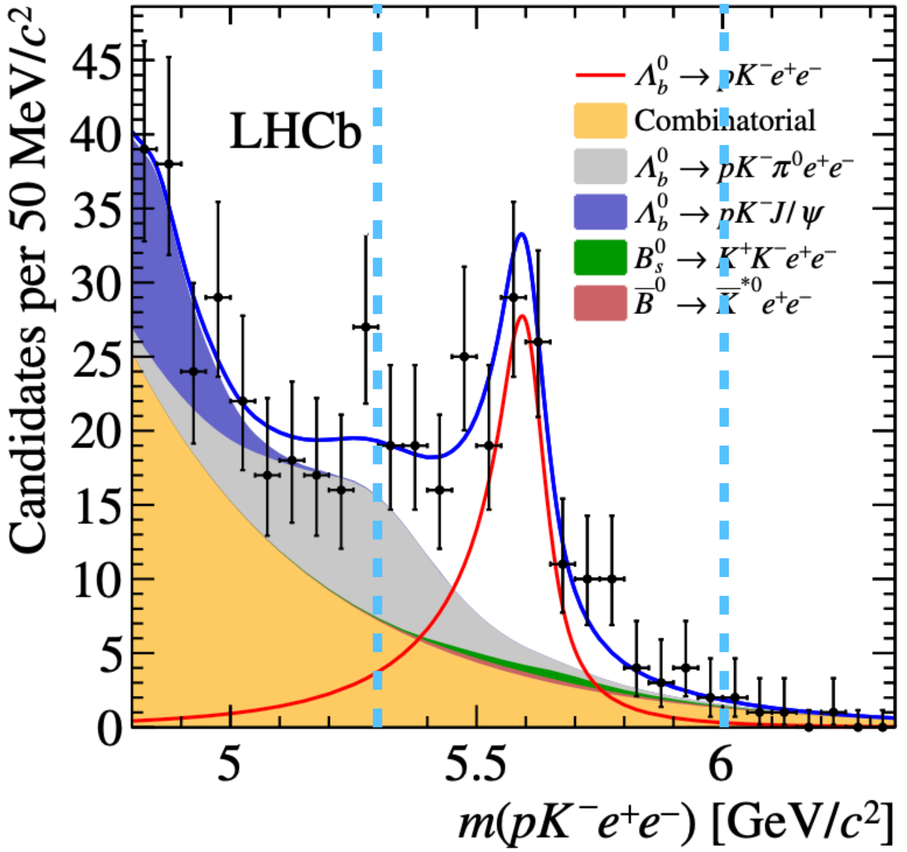


Bremsstrahlung emission at LHCb

We measure electrons with less resolution due to Bremsstrahlung emissions, so more backgrounds are present in analyses with electrons → measurements with more uncertainty

Upgrade of the detector: more pile-up but same ECAL





Bremsstrahlung emission at LHCb

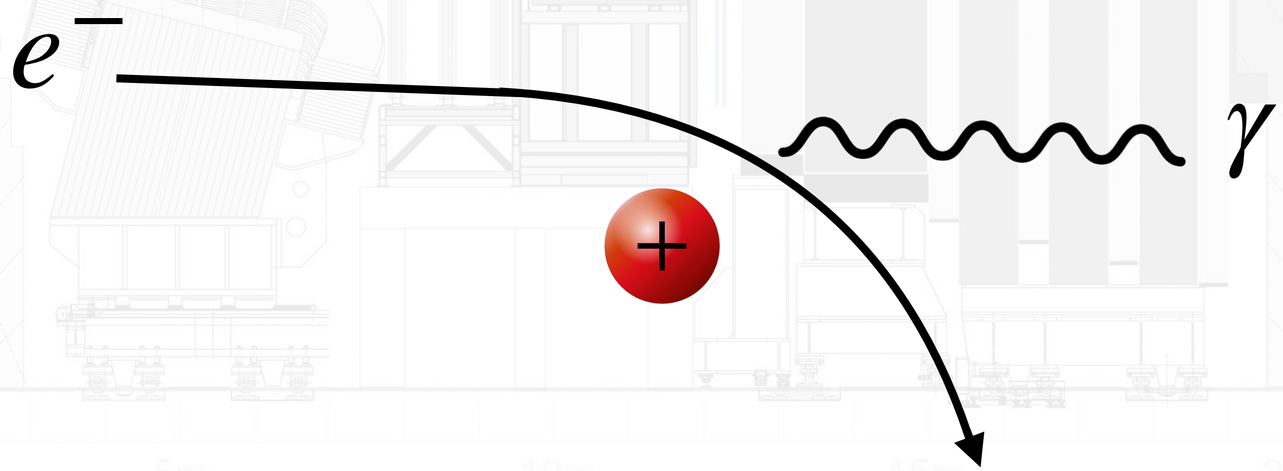
PROBLEM: Electrons interact with the detector material

Charged particles decelerate in the presence of an electric field generated by another charge, emitting a Bremsstrahlung photon and losing a fraction of their energy

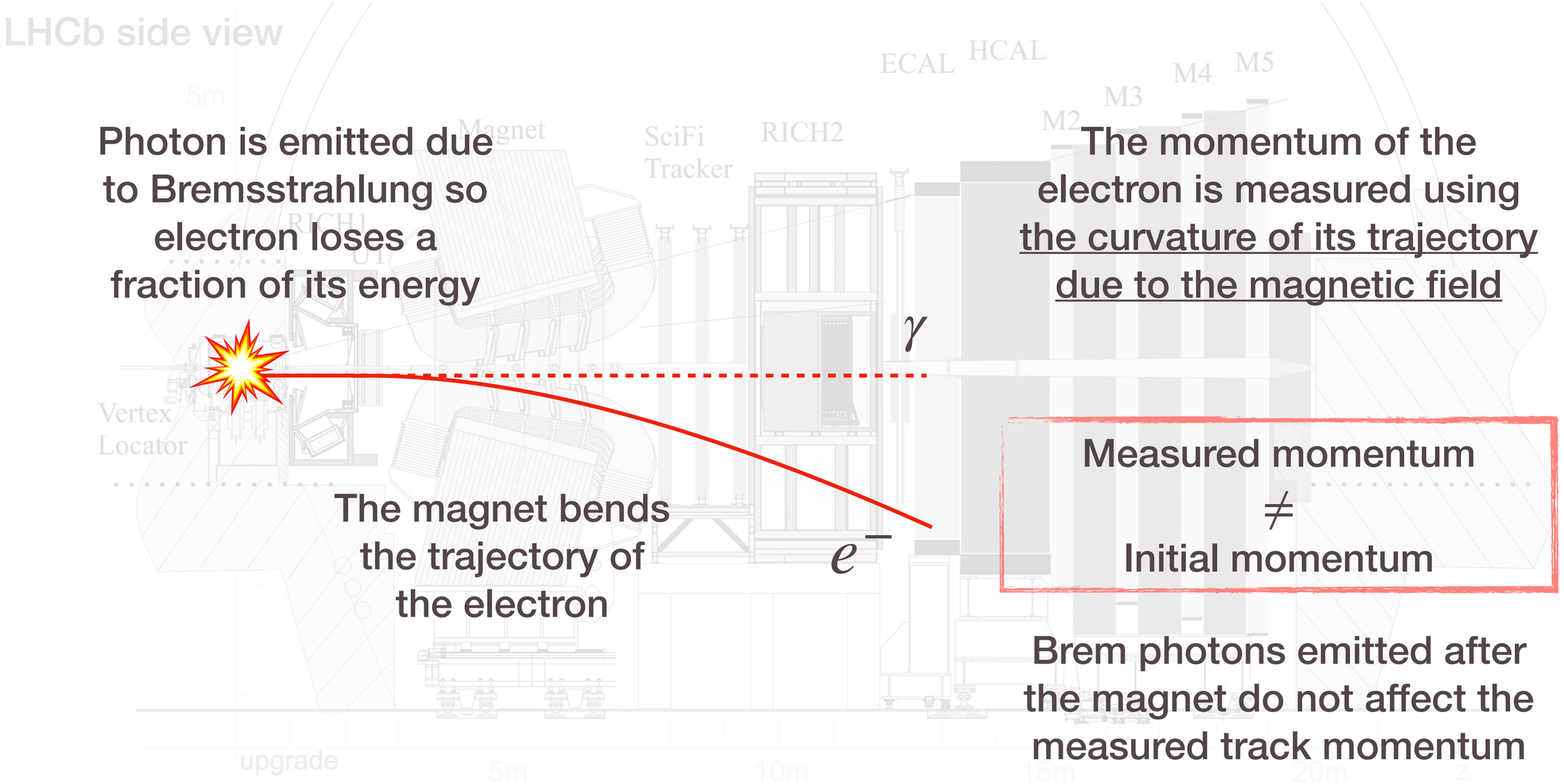
Probability of brem emission $\propto E/m^2$, so it affects mainly <u>electrons</u>

Photons are emitted collinearly to the trajectory of e^-

Energy of emitted photons is $\propto E_{e^-}$



Bremsstrahlung emission at LHCb



Photon is emitted due to Bremsstrahlung so electron loses a fraction of its energy

γ

e^-

The magnet bends the trajectory of the electron

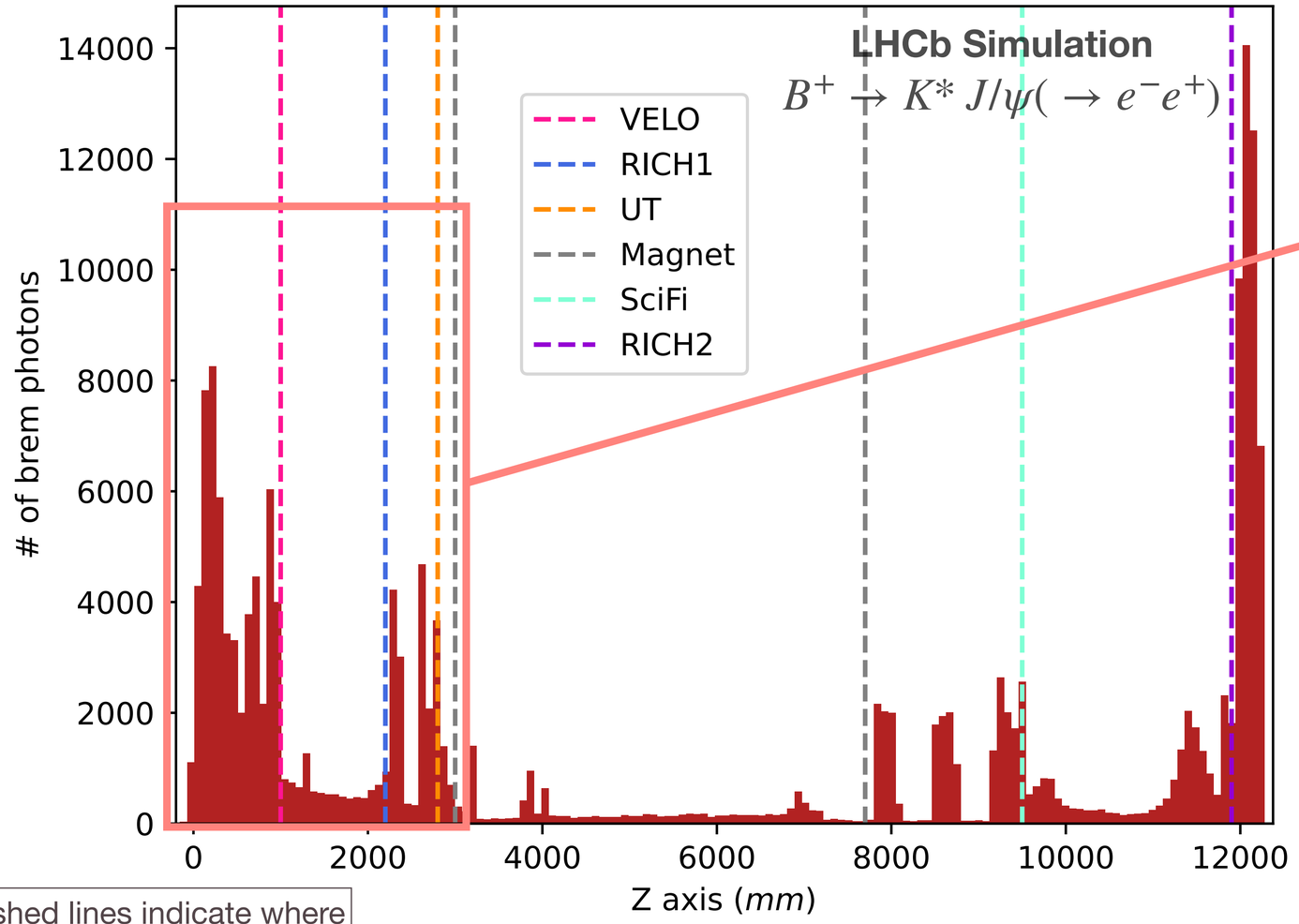
The momentum of the electron is measured using the curvature of its trajectory due to the magnetic field

Measured momentum
$\neq$
Initial momentum

Brem photons emitted after the magnet do not affect the measured track momentum

Bremsstrahlung emission at LHCb

Where are Bremsstrahlung photons emitted?



Dashed lines indicate where each subdetector ends!

Very large amount of Bremsstrahlung photons are emitted before the magnet

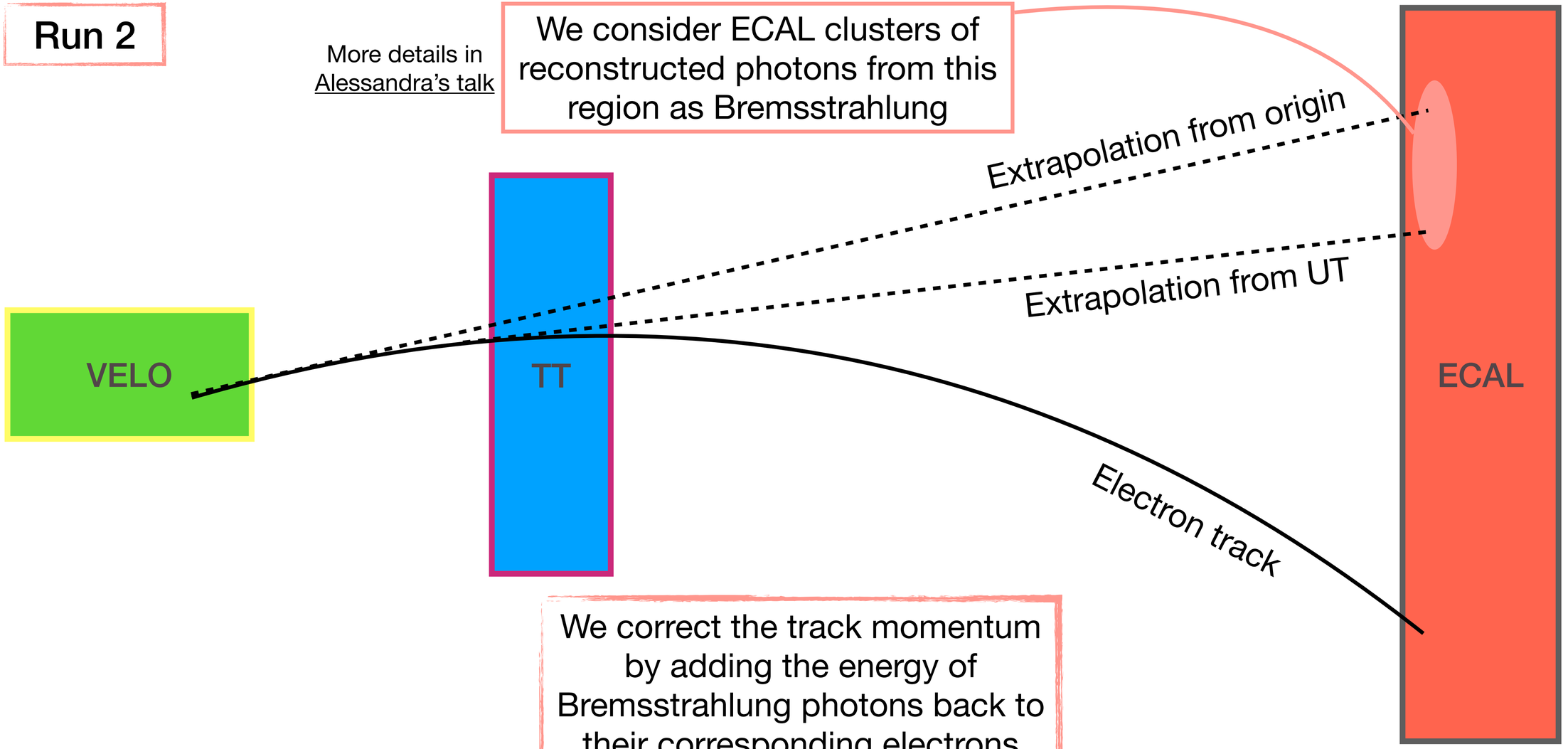
We must recover this energy loss

Current recovery model

Run 2

More details in Alessandra's talk

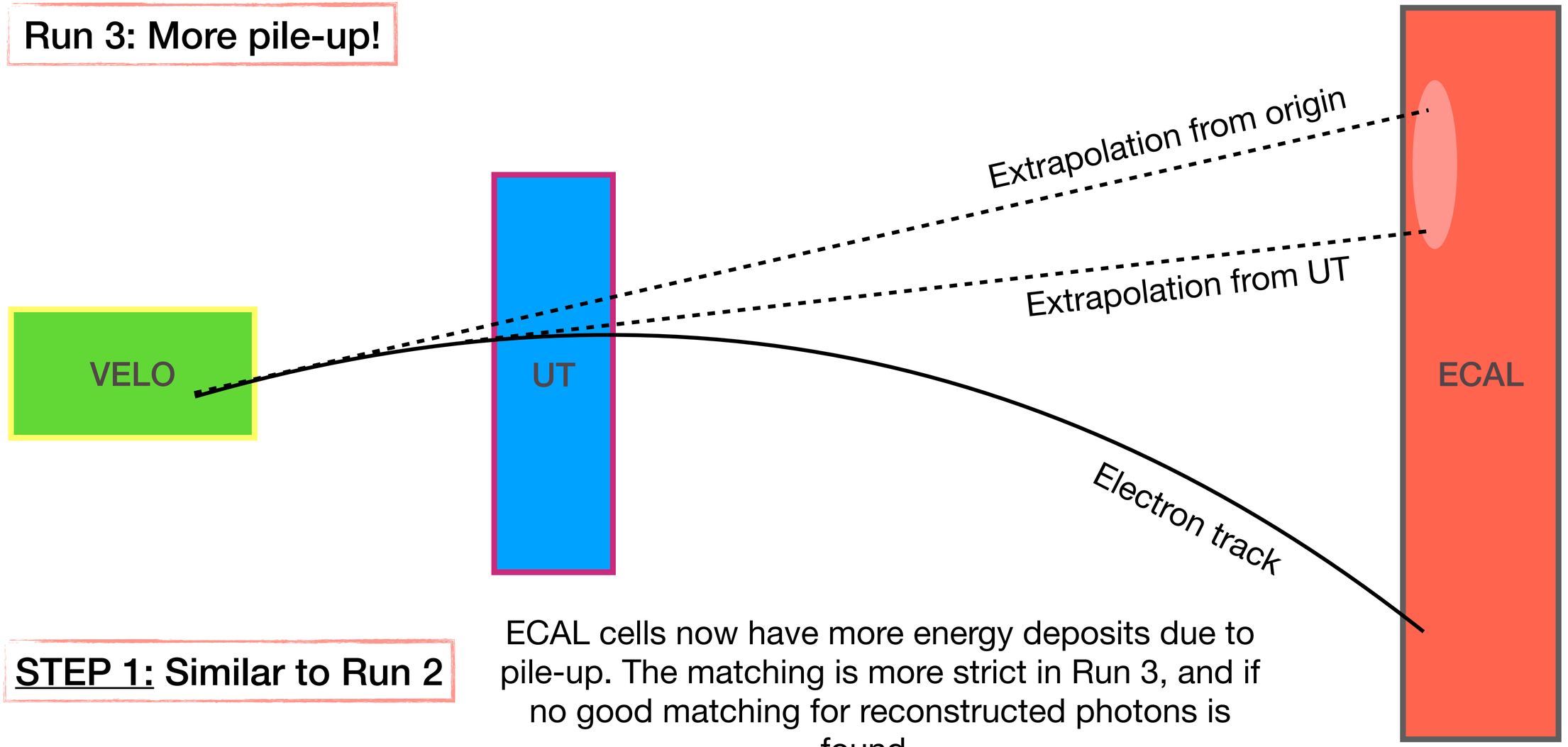
We consider ECAL clusters of reconstructed photons from this region as Bremsstrahlung



We correct the track momentum by adding the energy of Bremsstrahlung photons back to their corresponding electrons

Current recovery model

Run 3: More pile-up!

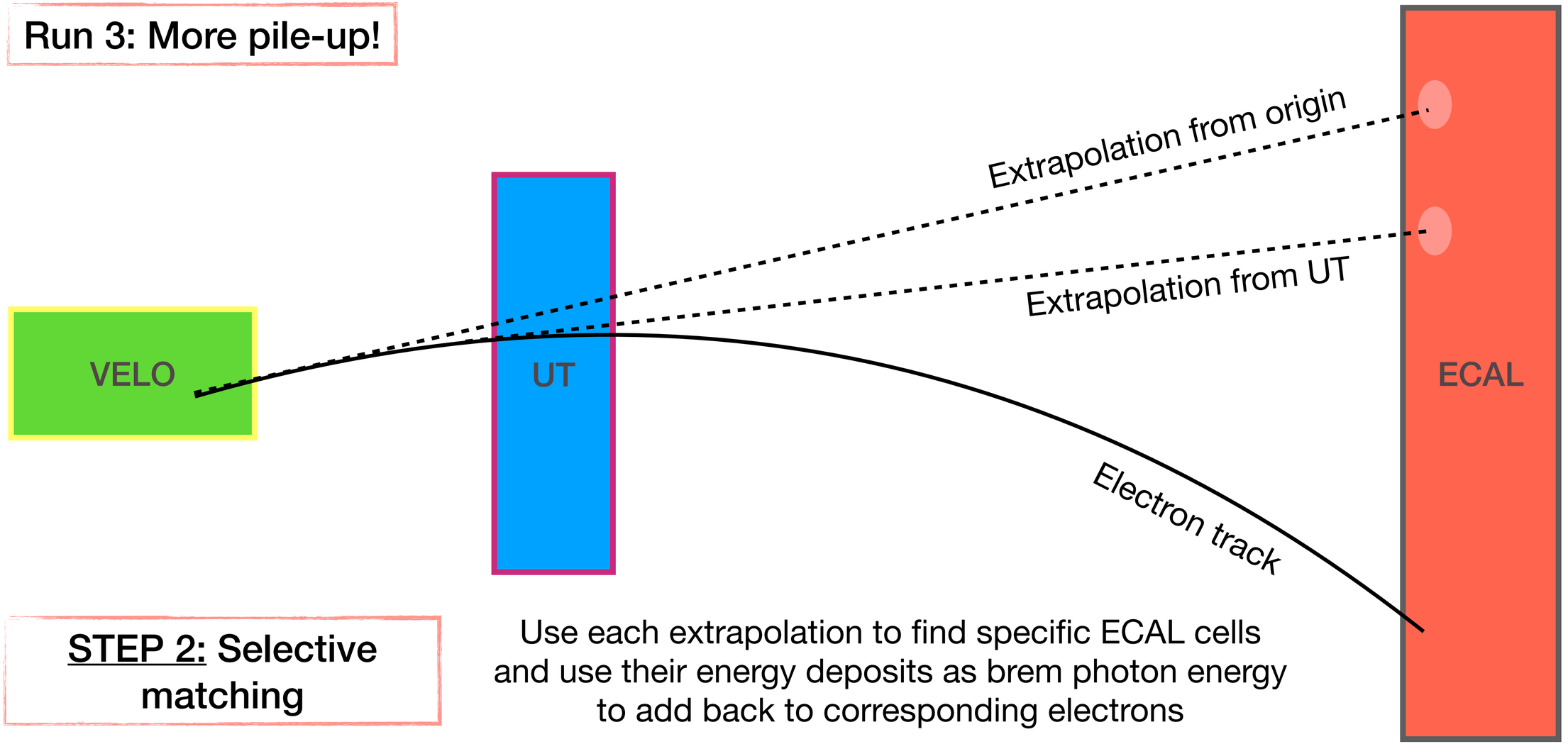


<u>STEP 1:</u> Similar to Run 2

ECAL cells now have more energy deposits due to pile-up. The matching is more strict in Run 3, and if no good matching for reconstructed photons is found…

Current recovery model

Run 3: More pile-up!

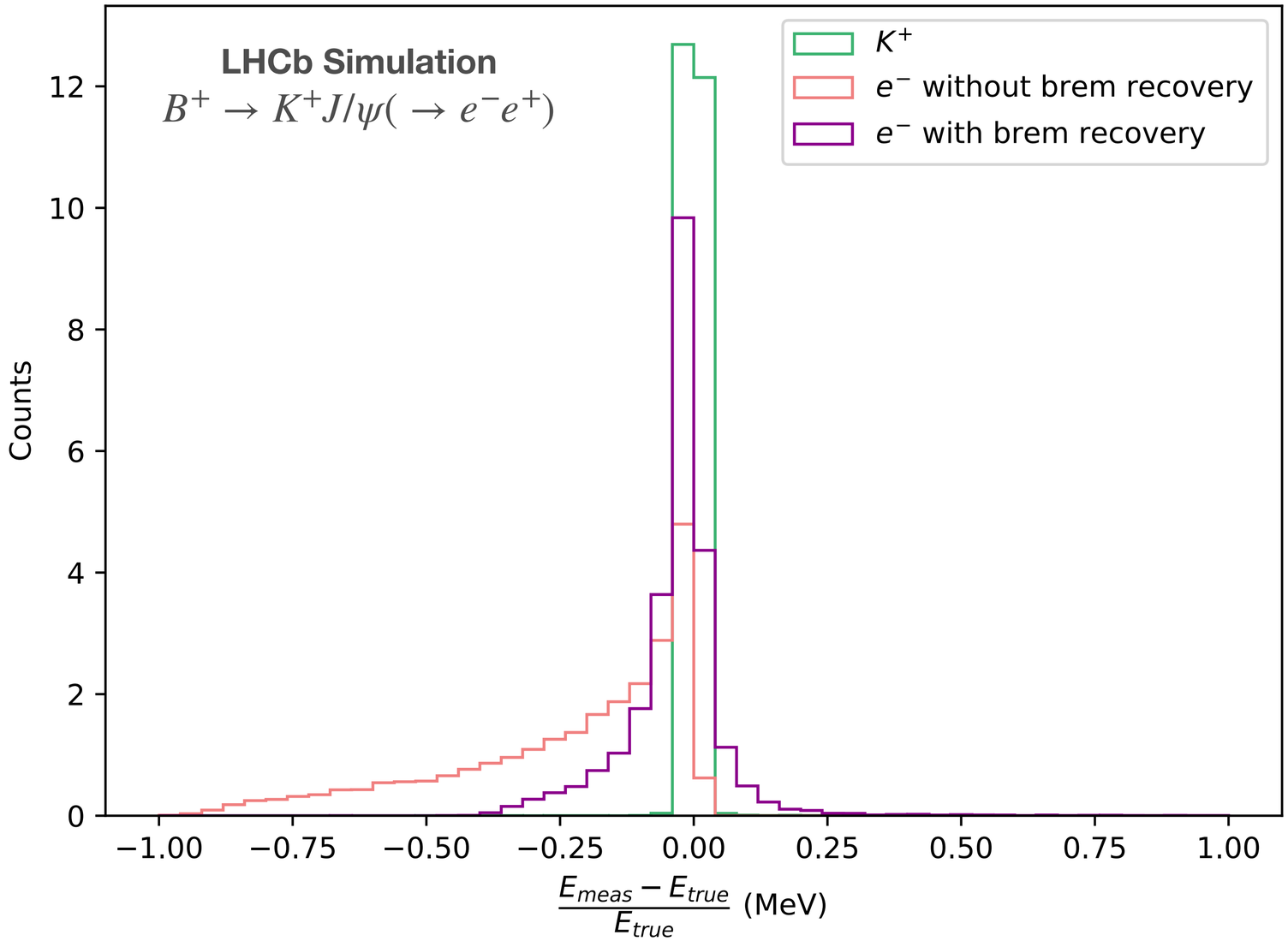


<u>STEP 2:</u> Selective matching

Use each extrapolation to find specific ECAL cells and use their energy deposits as brem photon energy to add back to corresponding electrons

Current recovery model

Good correction, but can we improve it?



Machine Learning recovery approaches

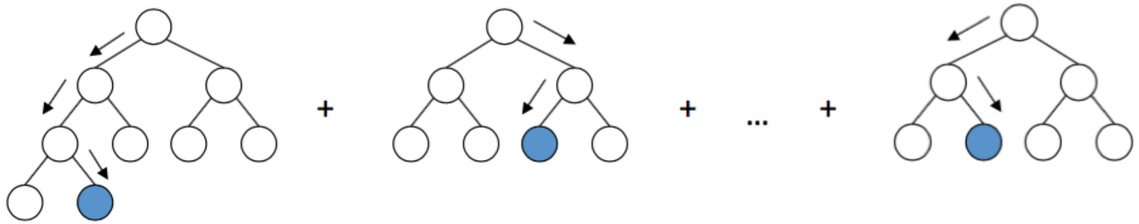
Ultimately the goal is to create a model with the power to estimate the amount of lost energy of each electron due to Bremsstrahlung emissions: it's a **regression** task.

Available information on electrons not being used by the current recovery algorithm:

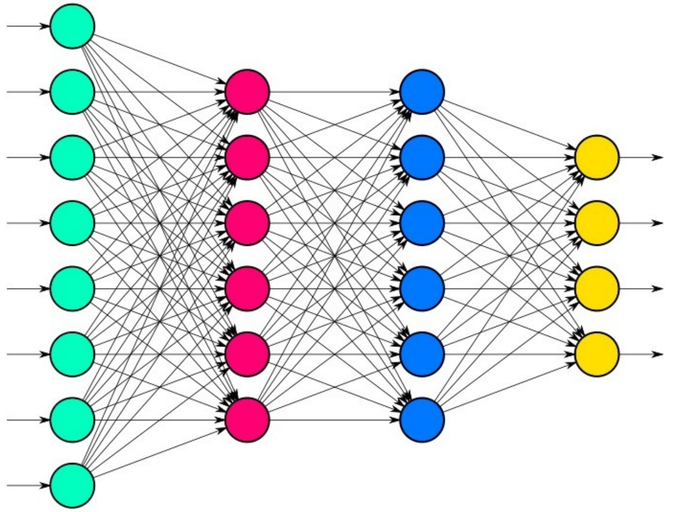
- Kinematic information of electrons such as measured p_T
- Geometric information of electrons and parent particles: position of origin vertices, η , ϕ
- Information about the interaction between electrons and the detector:
  - Number of times they hit sensitive material in the detector
  - Position (x, y, z) of the hits

Current prototype models

BOOSTED DECISION TREES



DENSE NEURAL NETWORKS



Current prototype models

BOOSTED DECISION TREES

- GradientBoostingRegressor from scikit-learn
- MeanSquaredError loss
- 600 estimators

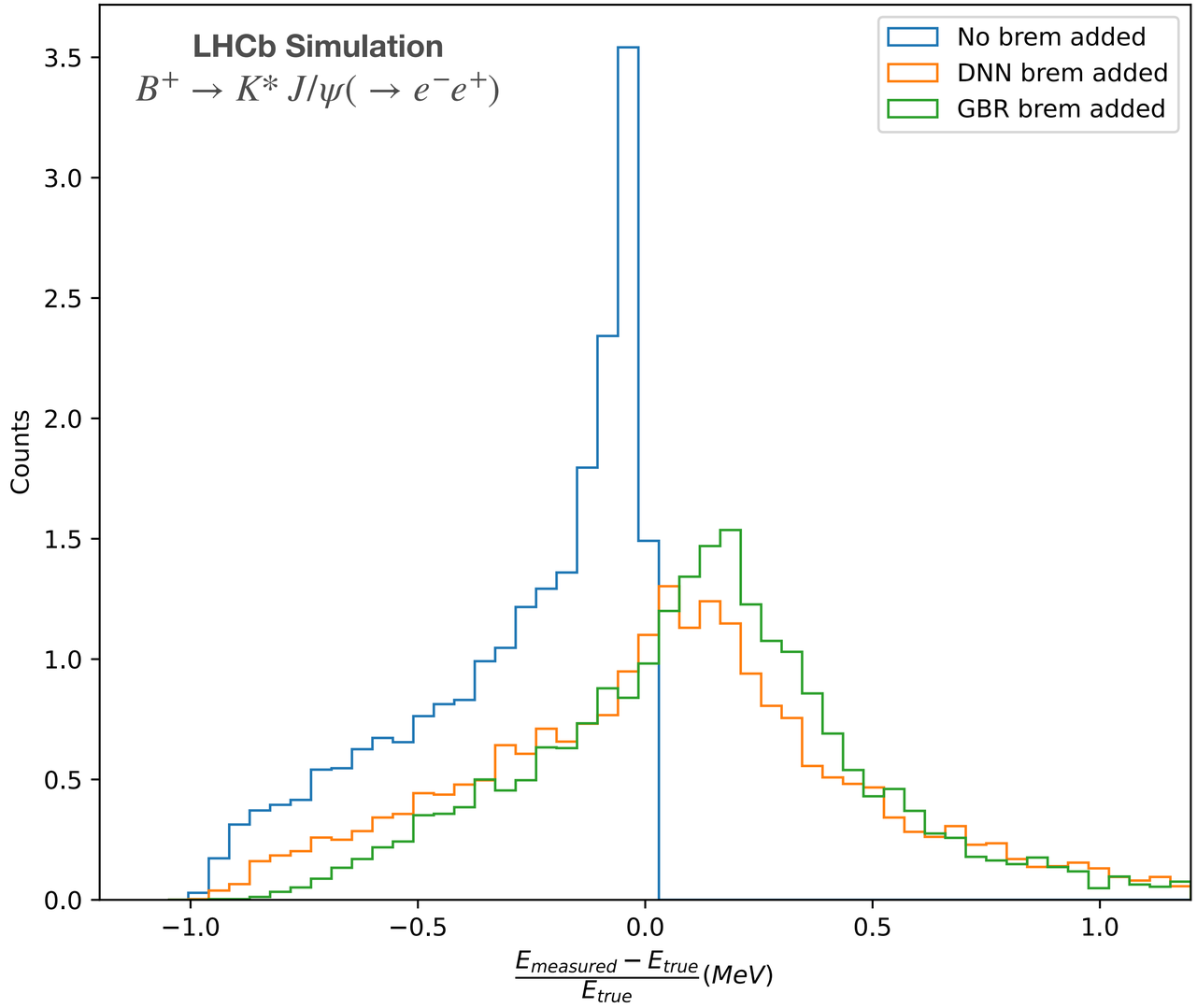
DENSE NEURAL NETWORKS

- Keras from Tensorflow
- MeanSquaredError loss
- Two layers with 200 and 100 neurons, respectively
- Regularization term

Variables used: z coordinate of origin of B meson, z coordinate of origin of electron, measured E of electron, measured p_T of electron, η , ϕ , # hits in VELO, # hits in UT

Current prototype models

Very preliminary results!



Current prototype models

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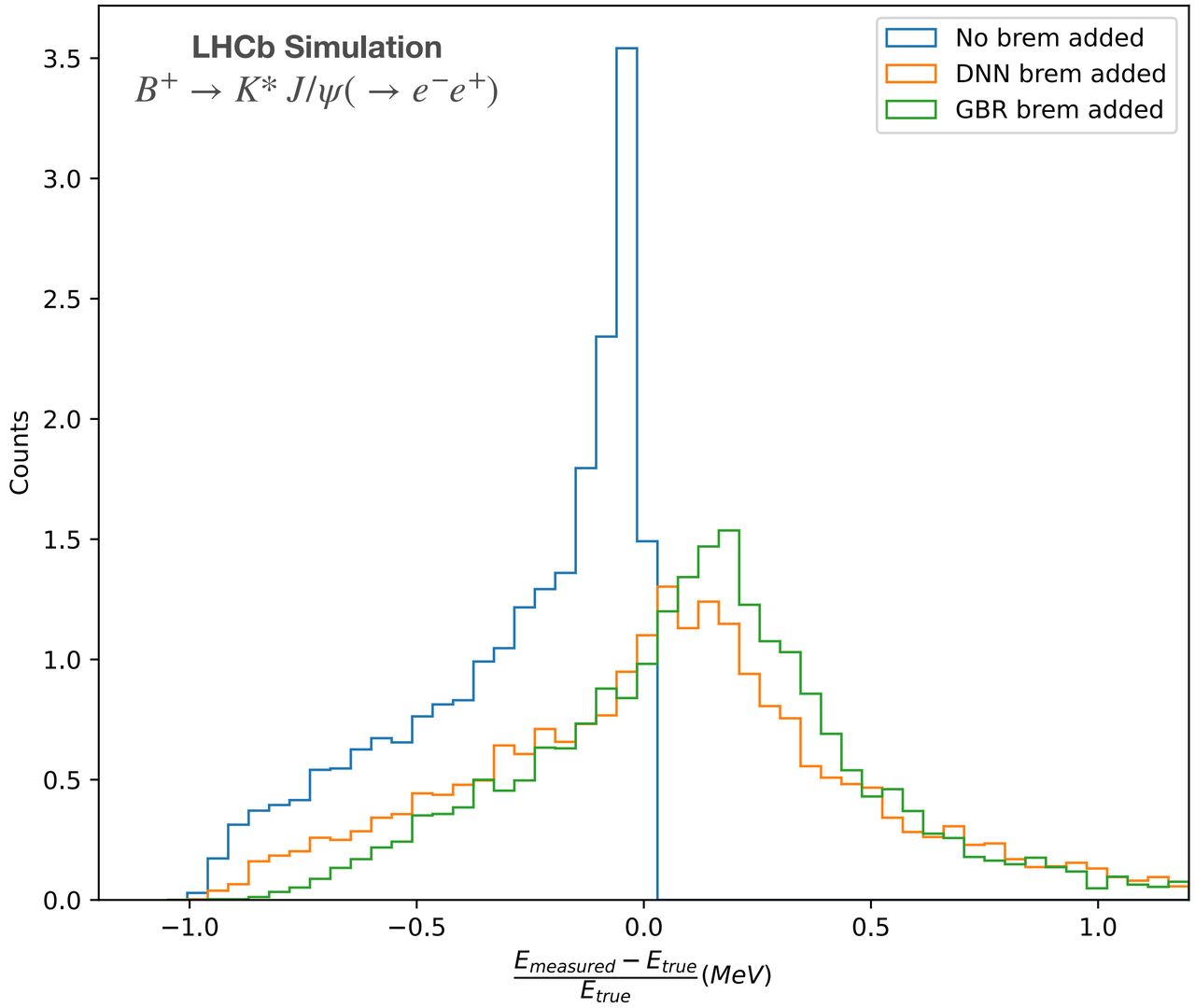

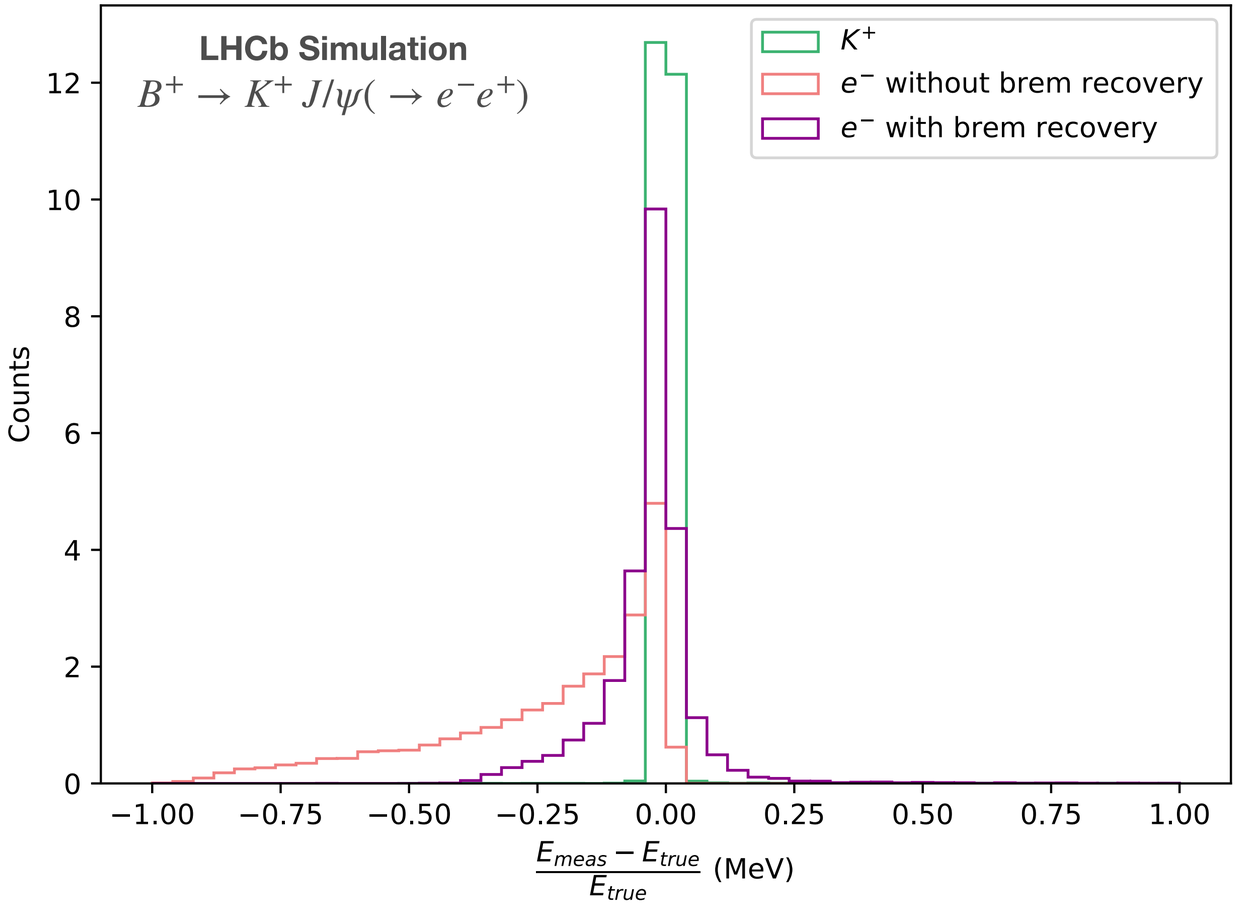

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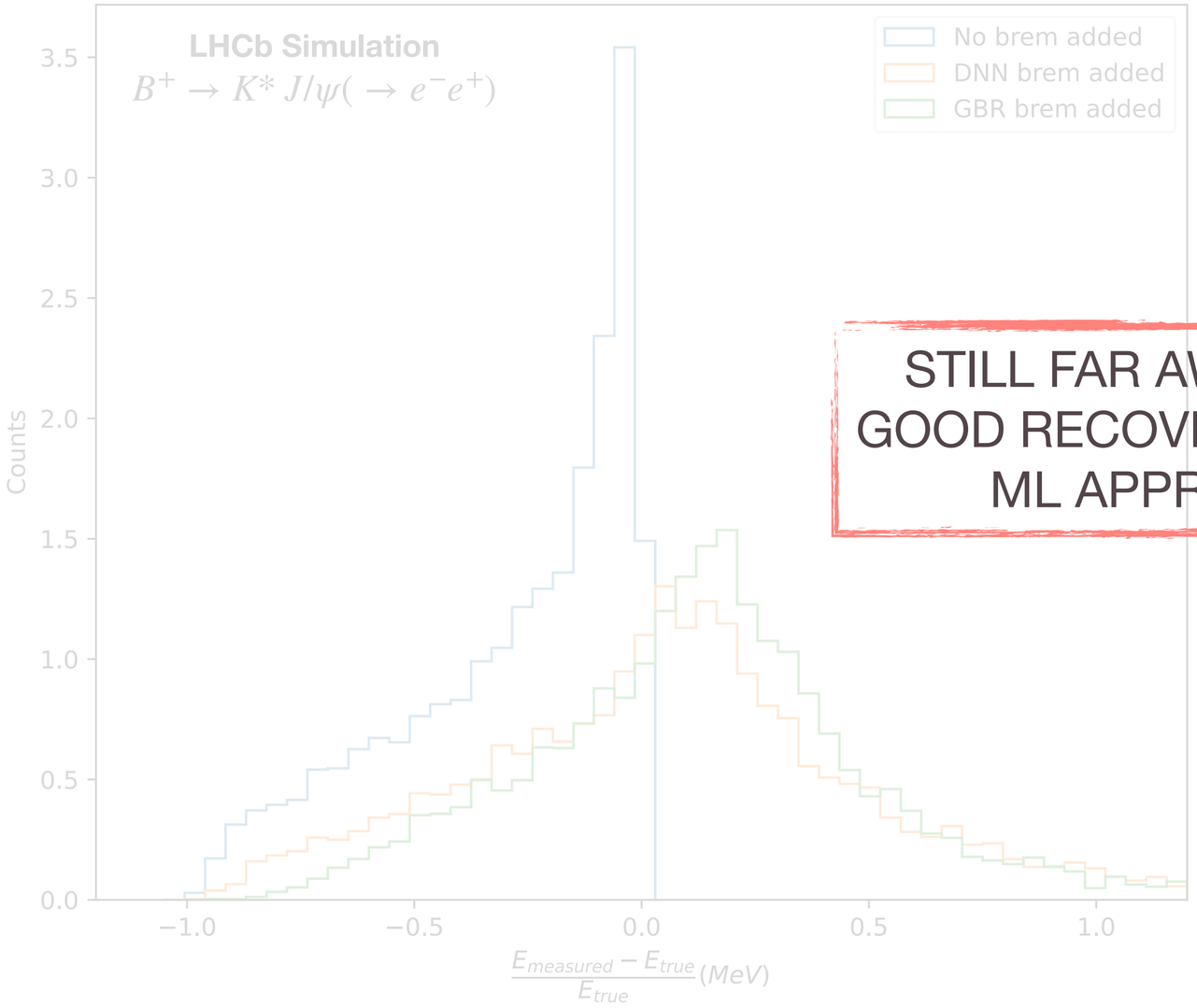
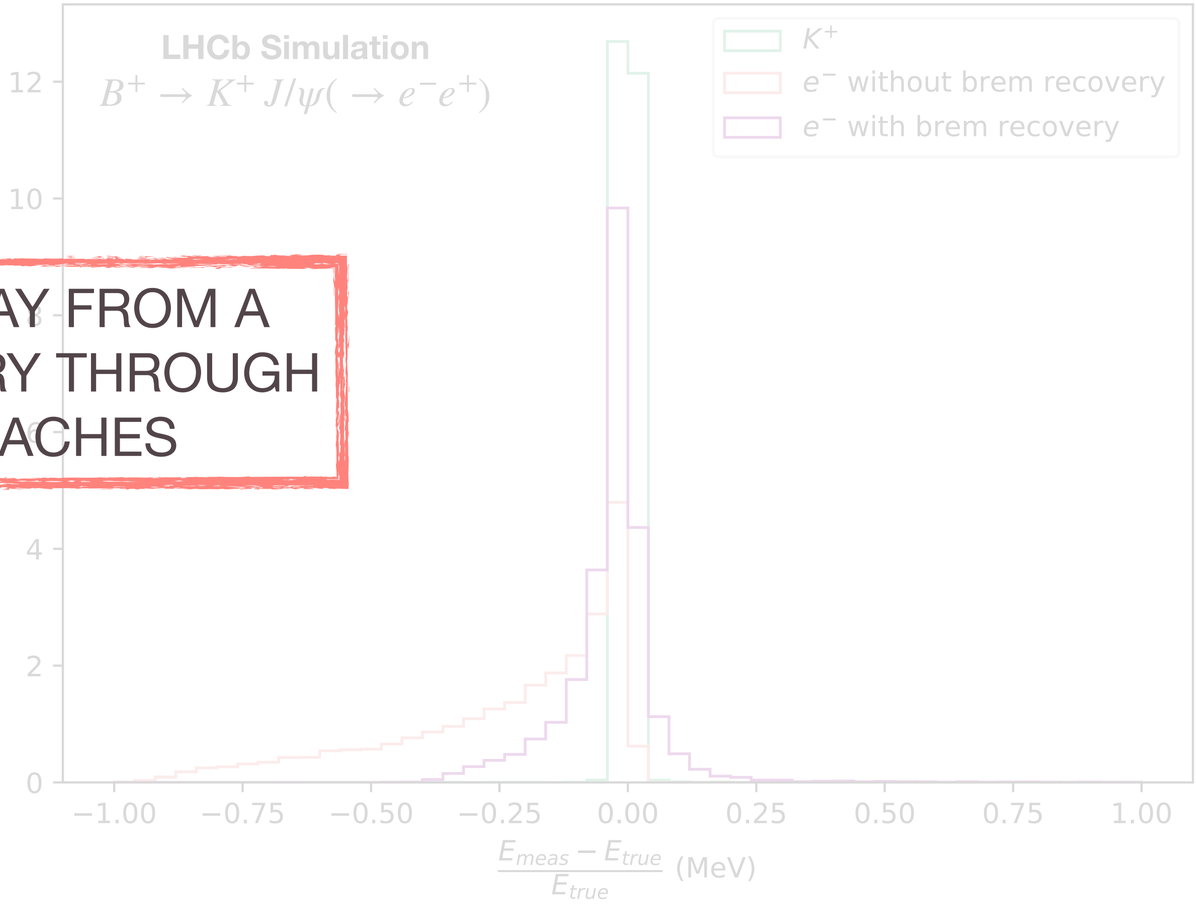


STILL FAR AWAY FROM A GOOD RECOVERY THROUGH ML APPROACHES



Future, more complex, models

- More data, bigger models, better models?
- Other types of architectures that use different information: geometric coordinates of the electron hits for a Convolutional Neural Network
- Current model gives better results than ML models, can we combine both?
- Suggestions, comments, ideas super welcome!

Thanks for your attention!