From Hyperons to Hypernuclei Online

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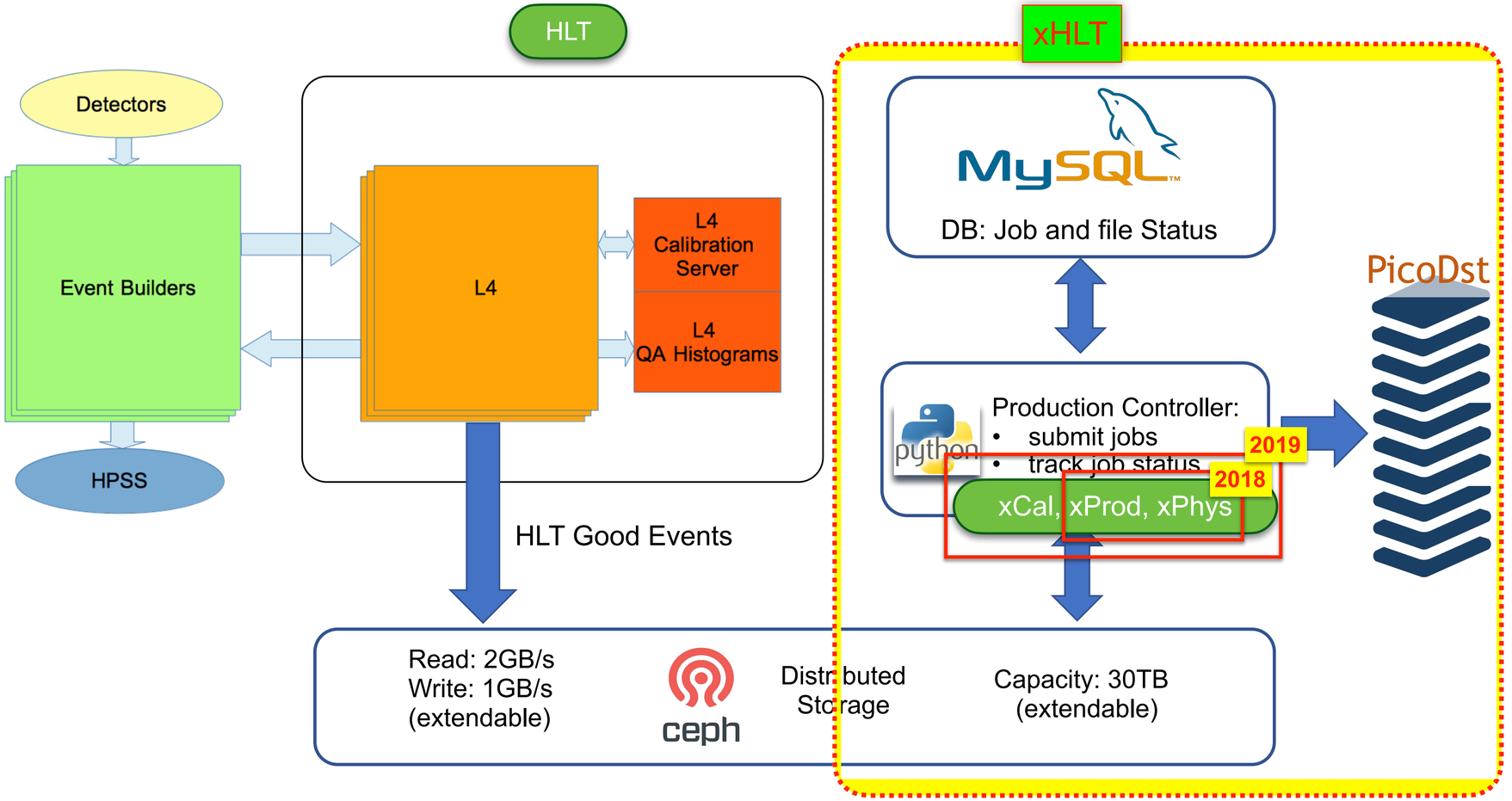
BES-II: HLT+xHLT

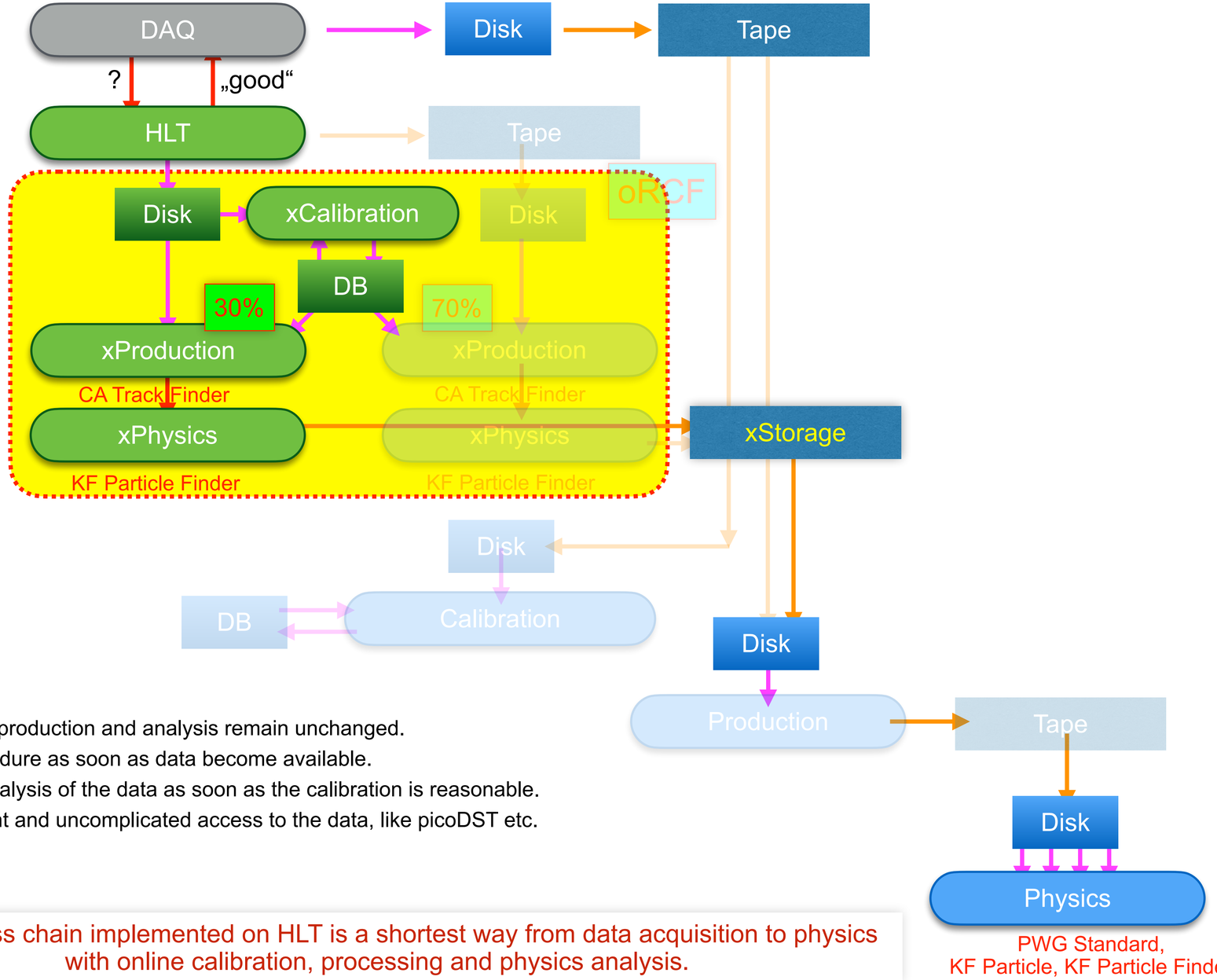
Extend the functionalities of STAR HLT farm with CBM FLES algorithms for express production (xHLT).



- The „Job status DB“ and „Production Controller“ were started to develop since Run18.
- The ceph distributed disk is completely new of 2020.
- Production with CA and Physics with KF Particle since 2018.
- Full chain with Calibration since 2019.

Full chain of express production and analysis has been running since 2019

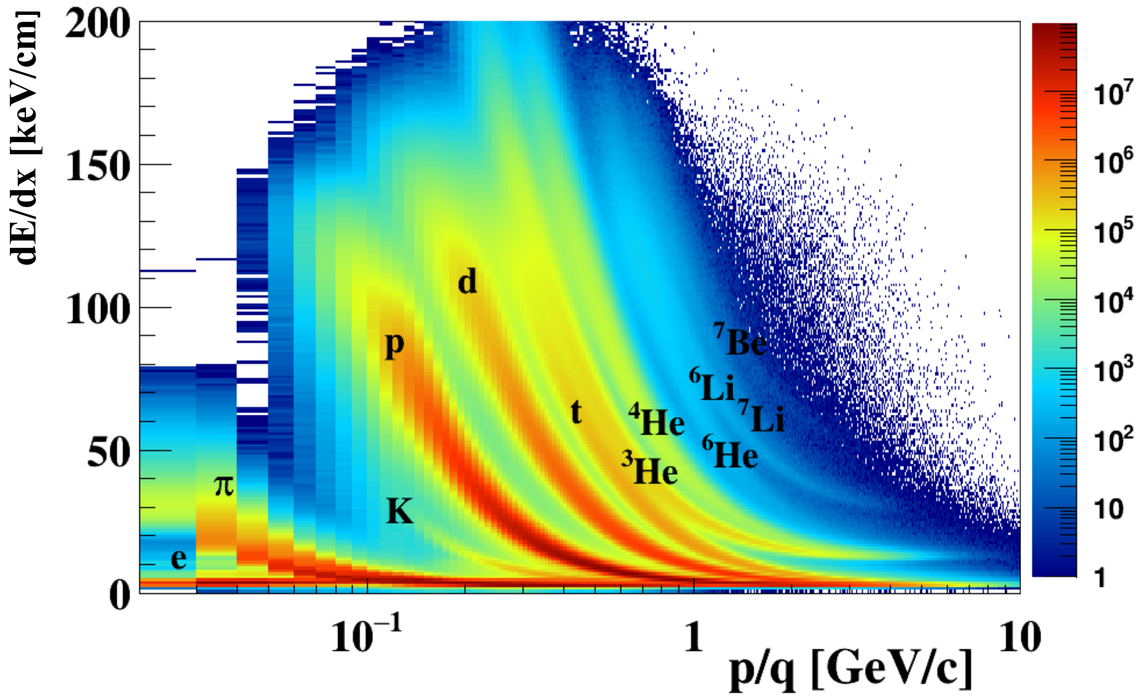
BES-II: Express Production Data Stream

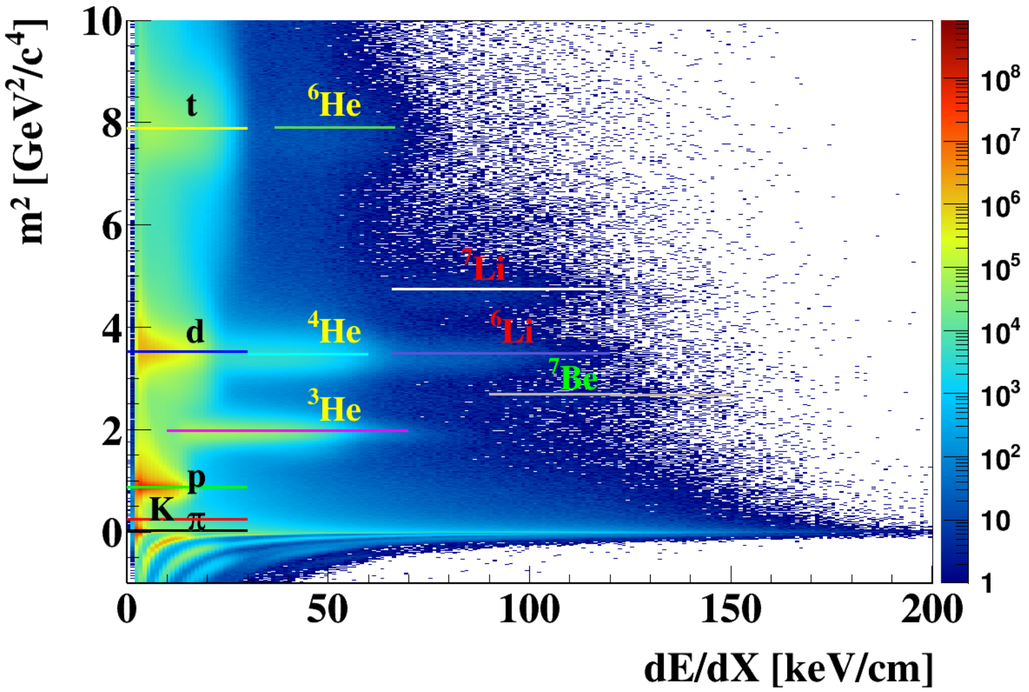


- ☑ The standard calibration, production and analysis remain unchanged.
- ☑ Start the calibration procedure as soon as data become available.
- ☑ Make possible physics analysis of the data as soon as the calibration is reasonable.
- ☑ Provide PWGs with instant and uncomplicated access to the data, like picoDST etc.

The express chain implemented on HLT is a shortest way from data acquisition to physics with online calibration, processing and physics analysis.

BES-II: xPID with dE/dx and bTOF





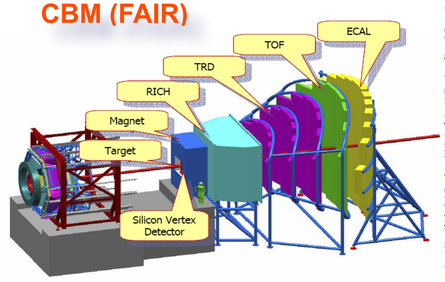
- The first express calibration has included analysis of cosmics data for iTPC alignment and 19 GeV dE/dx calibration which was frozen and put in database.
- The results of this xCalibration have been presented during the final DoE iTPC project review.
- Express production provides high quality of the dE/dx measurement for particles up to ^{7}Be with bTOF and allows us to get clean spectra with high significance.
- The spectra for FXT mode at 3 GeV are shown.

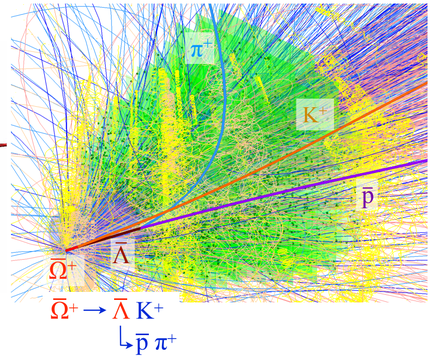
Used for the real time express processing during the BES-II runs (2018-2021)

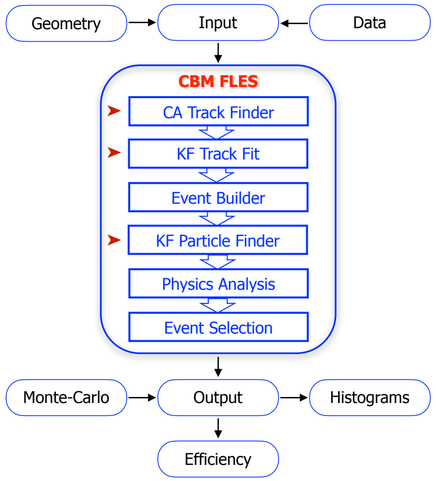
CBM → STAR: Reconstruction and Analysis Software

Within the FAIR Phase-0 program the CBM KF Particle Finder has been adapted to STAR and applied to Au+Au collisions recorded during 2014, 2016, BES-I and BES-II.

CBM (FAIR)

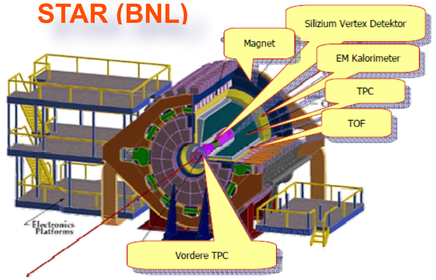


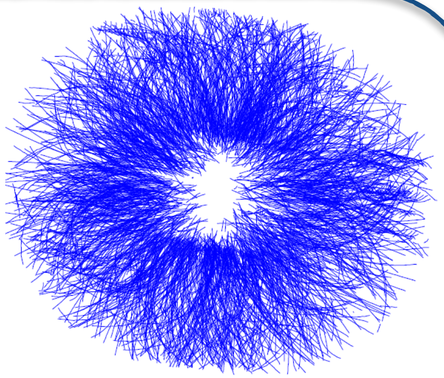


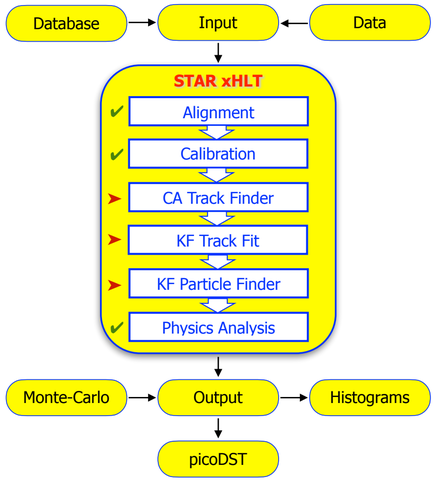


FAIR Phase-0

STAR (BNL)

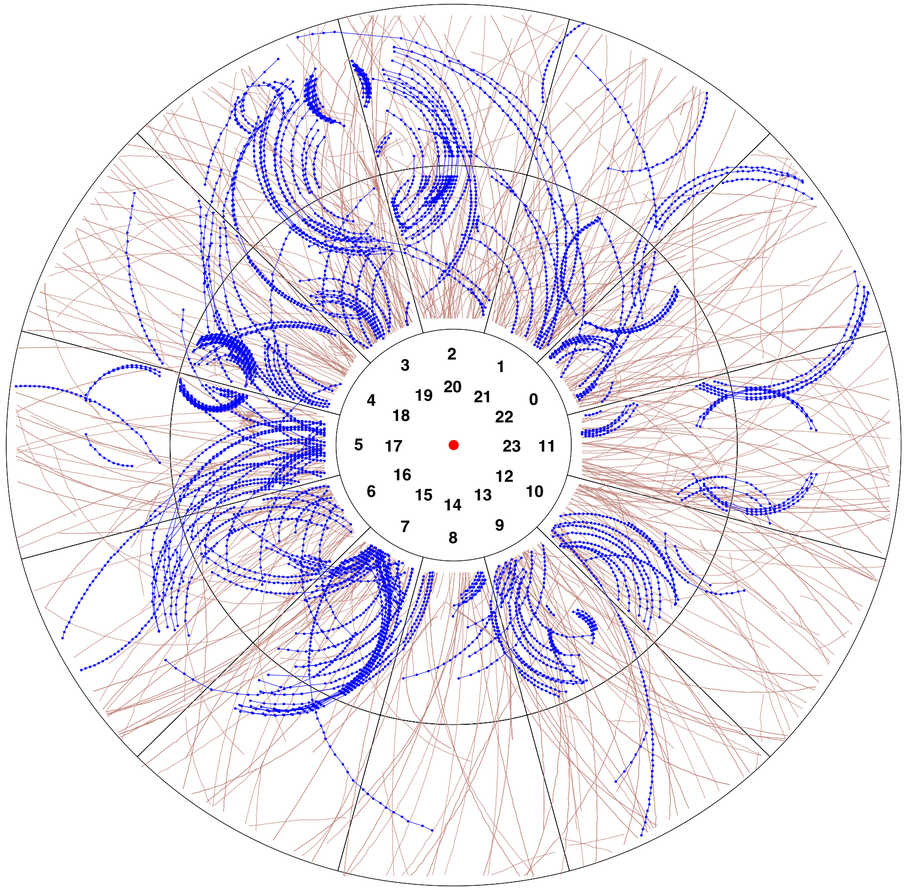


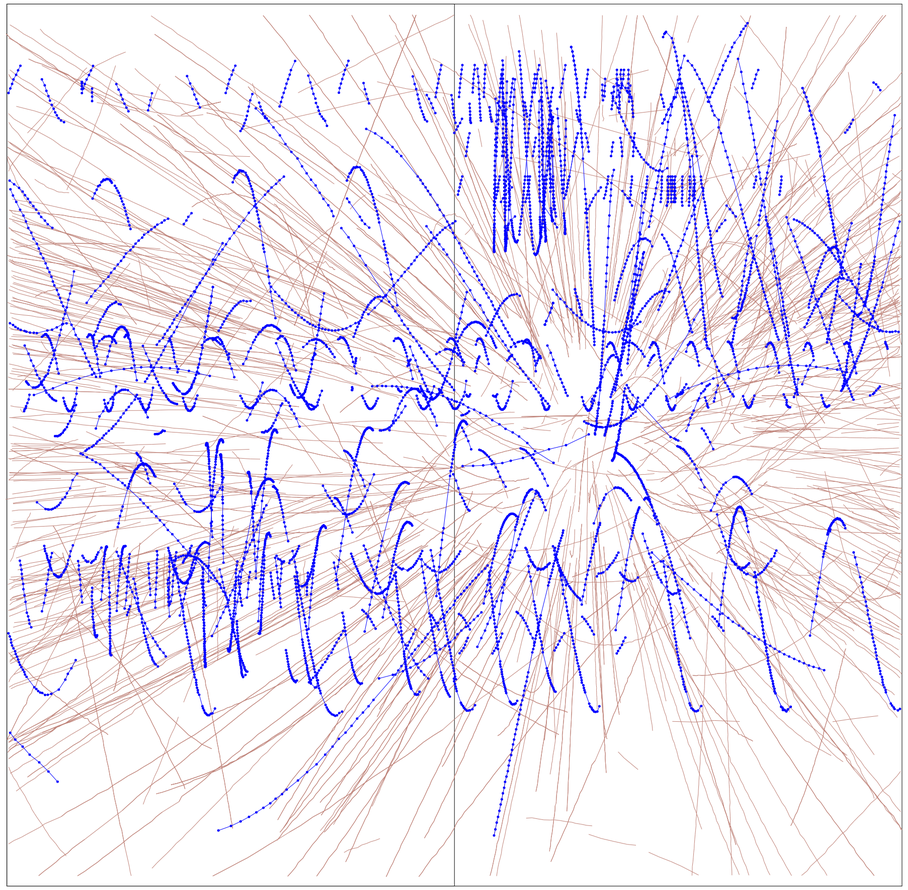




Used for the real time express physics analysis during the BES-II runs (2018-2021)

Loopers found by CA





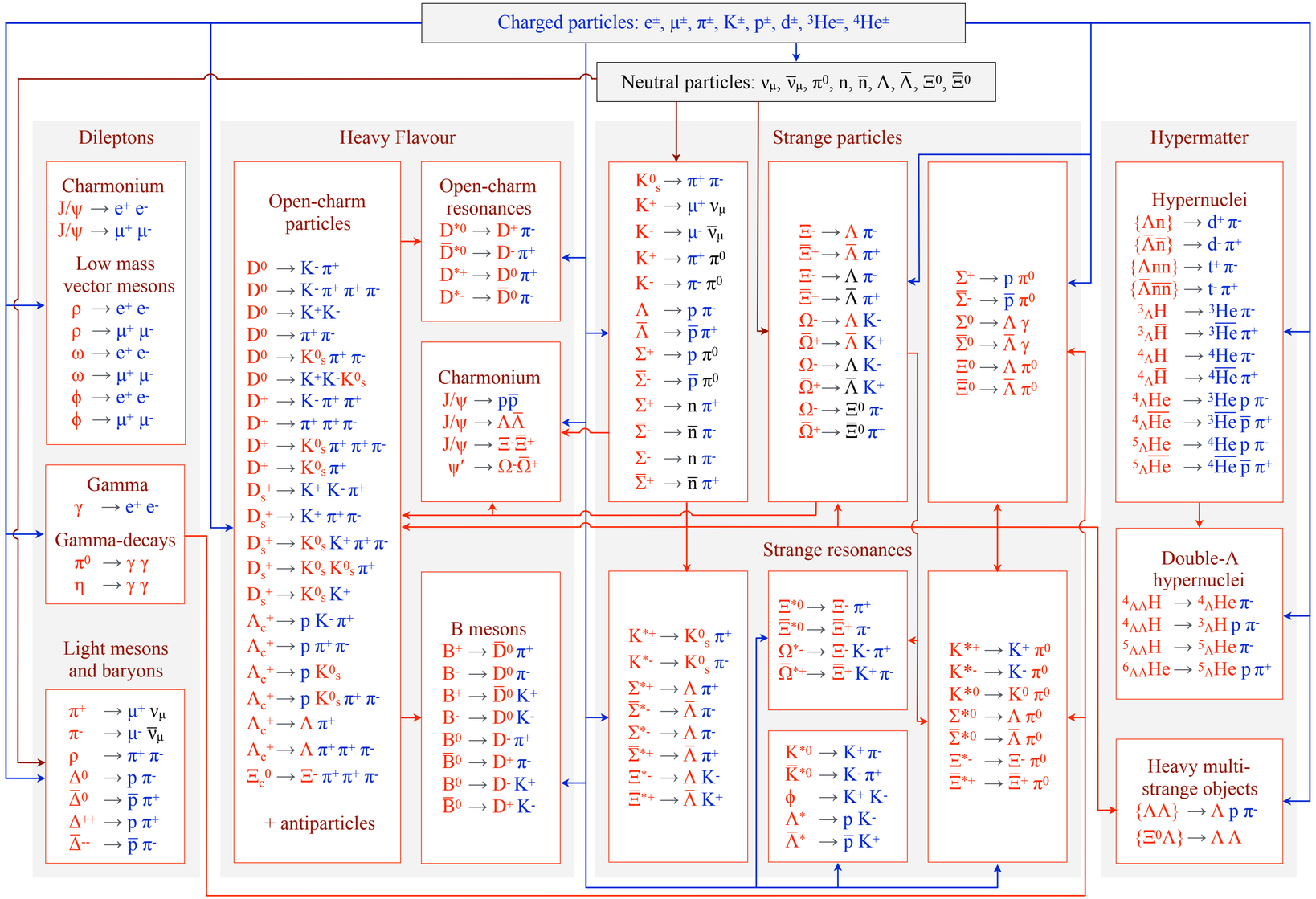
AuAu at 200 GeV

30 loopers / 346 tracks

- The CA track finder has been extended to find loopers of low-momentum particles in iTPC.
- The resolution of the loper problem allows us to increase pseudo rapidity acceptance for track with $p_T < 0.4$ GeV/c.

Used for the real-time express production during the BES-II runs (2018-2021)

CBM → STAR: KF Particle Finder



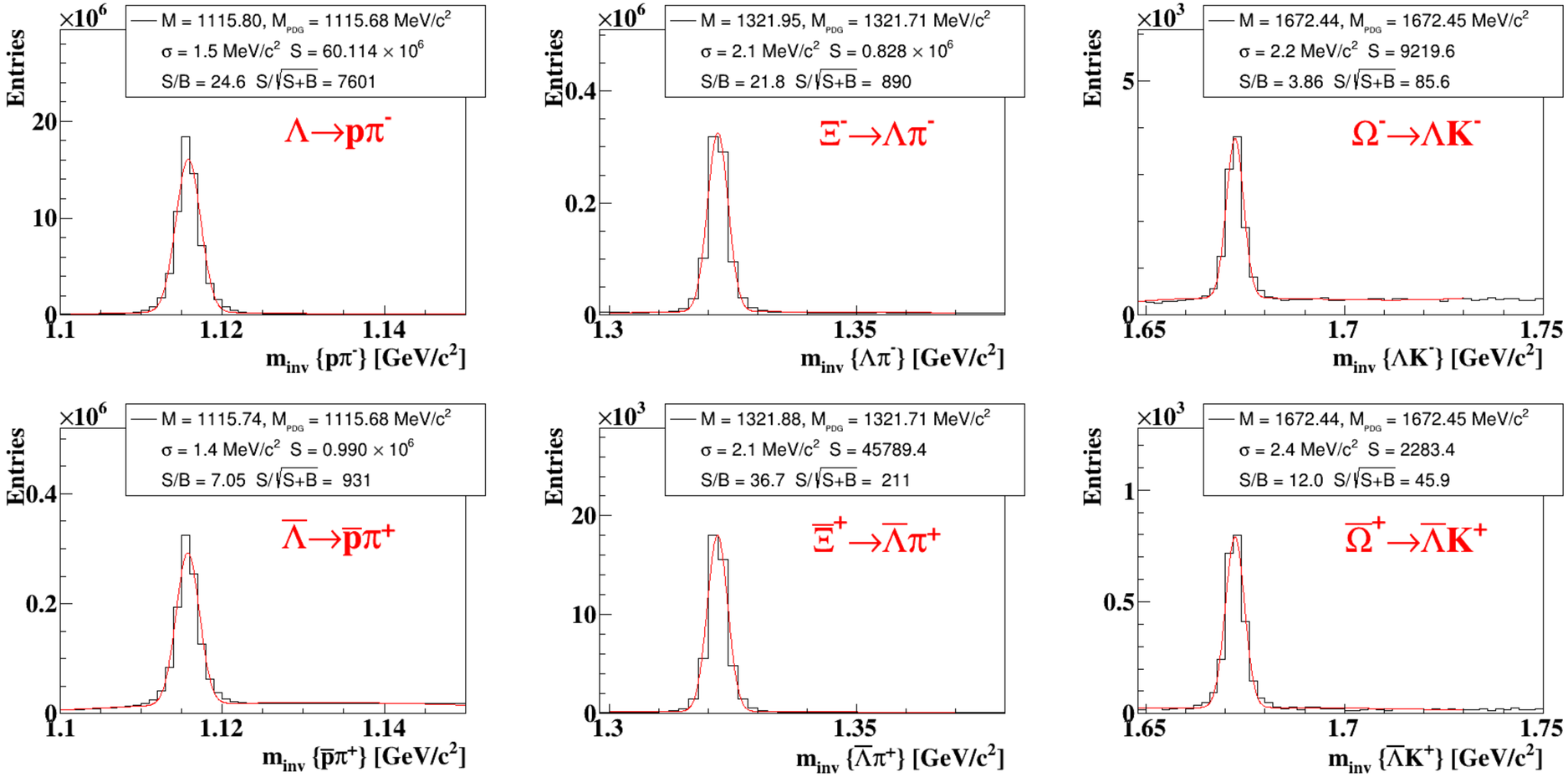
Features:

- KF Particle class describes particles by the state vector and the covariance matrix.
- The method for mathematically correct usage of covariance matrices is provided by the KF Particle package based on the Kalman Filter (KF).
- Heavy mathematics of KF requires fast and vectorised algorithms.
- Mother and daughter particles are treated in the same way.
- The natural and simple interface allows to reconstruct easily complicated decay chains.
- Reconstruction of decays with a neutral daughter by the Missing Mass Method.
- The package is geometry independent and is used in different experiments (CBM, ALICE, STAR).

The search for up to 200 decay channels is implemented in the KF Particle Finder

xBES-II: Hyperons

Signal utilizing 140M AuAu events at 7.7 GeV, 2021 BES-II (x)production

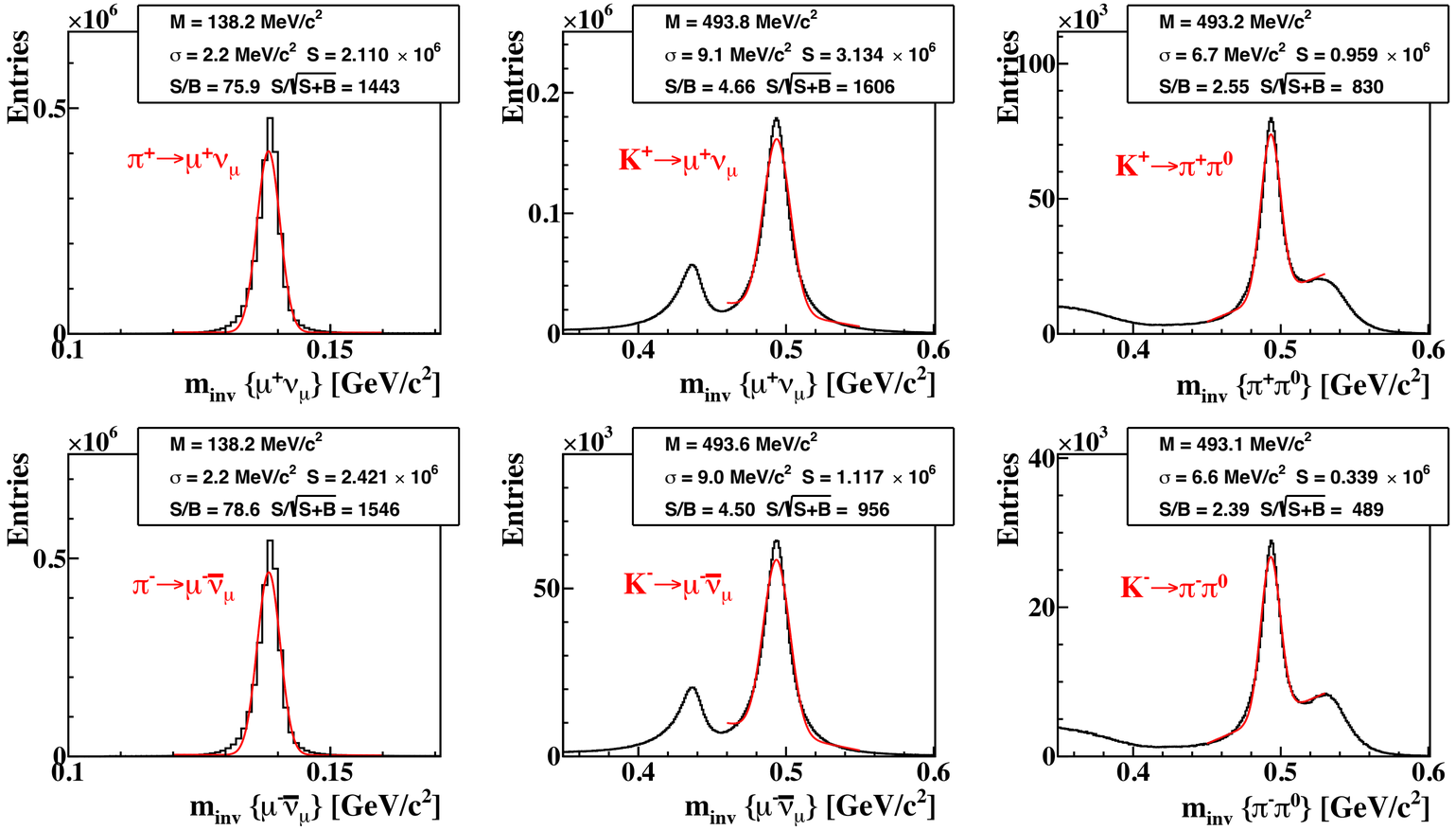


- Recently STAR has upgraded the inner part of TPC that together with an improved CA track finder have increased efficiency.
- New data give a possibility to study lower p_t region.

With express calibration and production we observe all hyperons with high significance and S/B ratio

xBES-II: Missing Mass Method

Signal utilizing 32.5M AuAu events at 7.7 GeV, 2021 BES-II (x)production

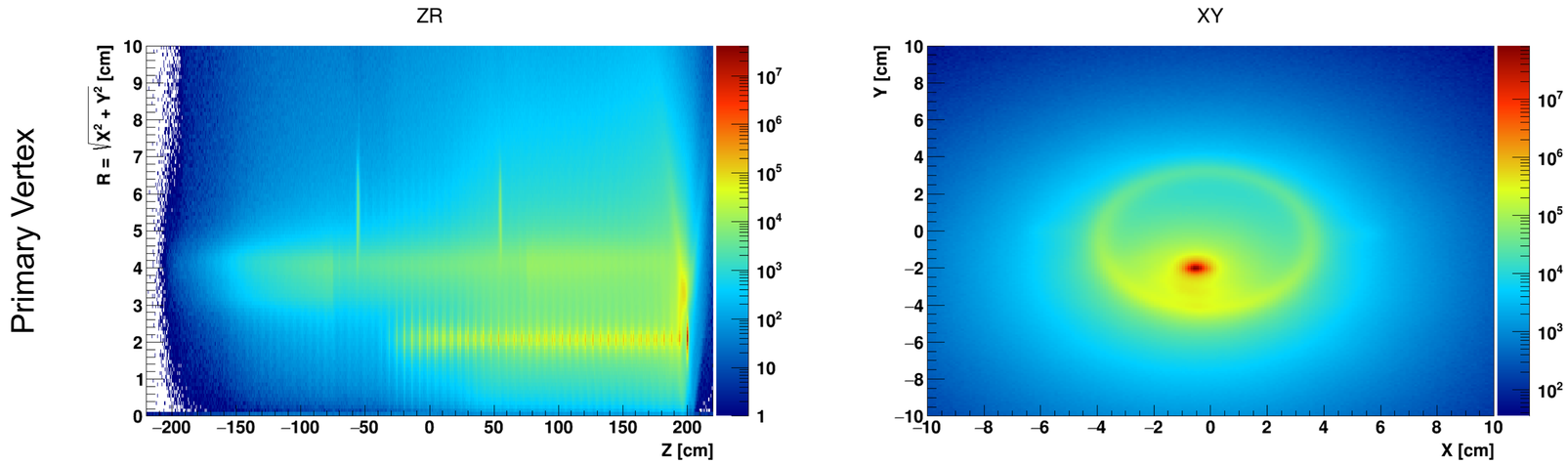


Second peak is due to (μ/π) particle misidentification.

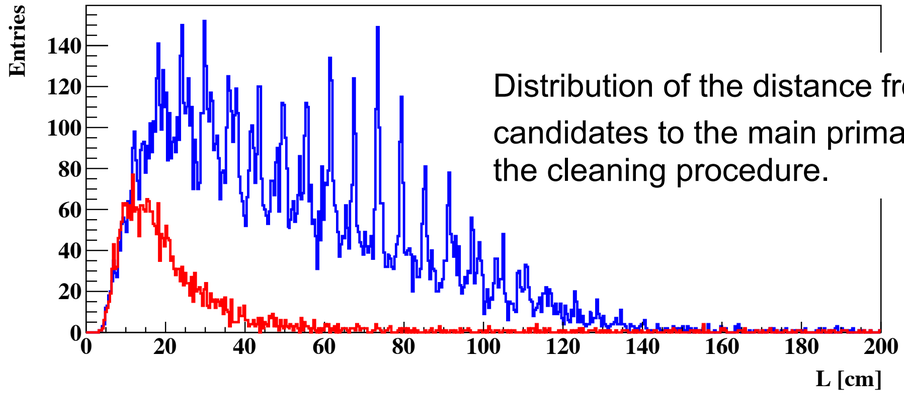
- Kaons can also be found using the Missing Mass Method.

The missing mass method provides additional opportunities in the study of decay channels

Fixed Target xBES-II: Pileup



- To increase statistics the beam interaction intensity was increased.
- This resulted in more than a half of events with at least two reconstructed primary vertices.
- A structure at R = 2 cm is formed by pileup.
- Interactions with the beam pipe material and support structures are also visible.



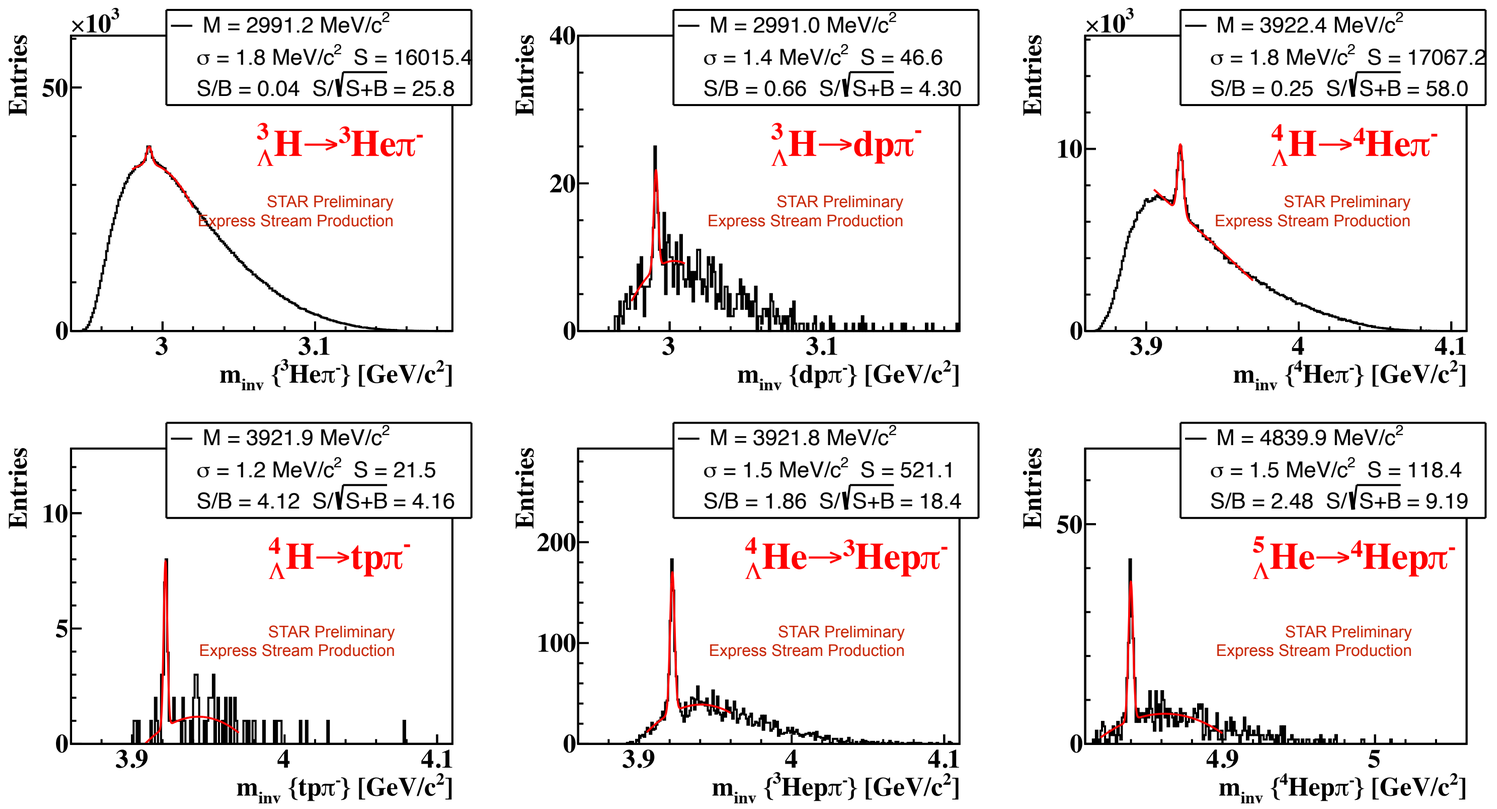
Distribution of the distance from $^{4}_{\Lambda}\mathrm{He} \rightarrow {}^{3}\mathrm{He}+\mathrm{p}+\pi^{-}$ candidates to the main primary vertex without and with the cleaning procedure.

- The cleaning procedure: reconstruct primary vertices from pileup and interaction with the beam pipe, then discard these primary tracks.

The cleaning procedure significantly reduces background, especially in 3-body channels

xBES-II: Hypernuclei

Signal utilizing 437M AuAu HLT triggered events at $\sqrt{s_{NN}}$ = 3.0 GeV Fixed Target, 2021 BES-II (x)production



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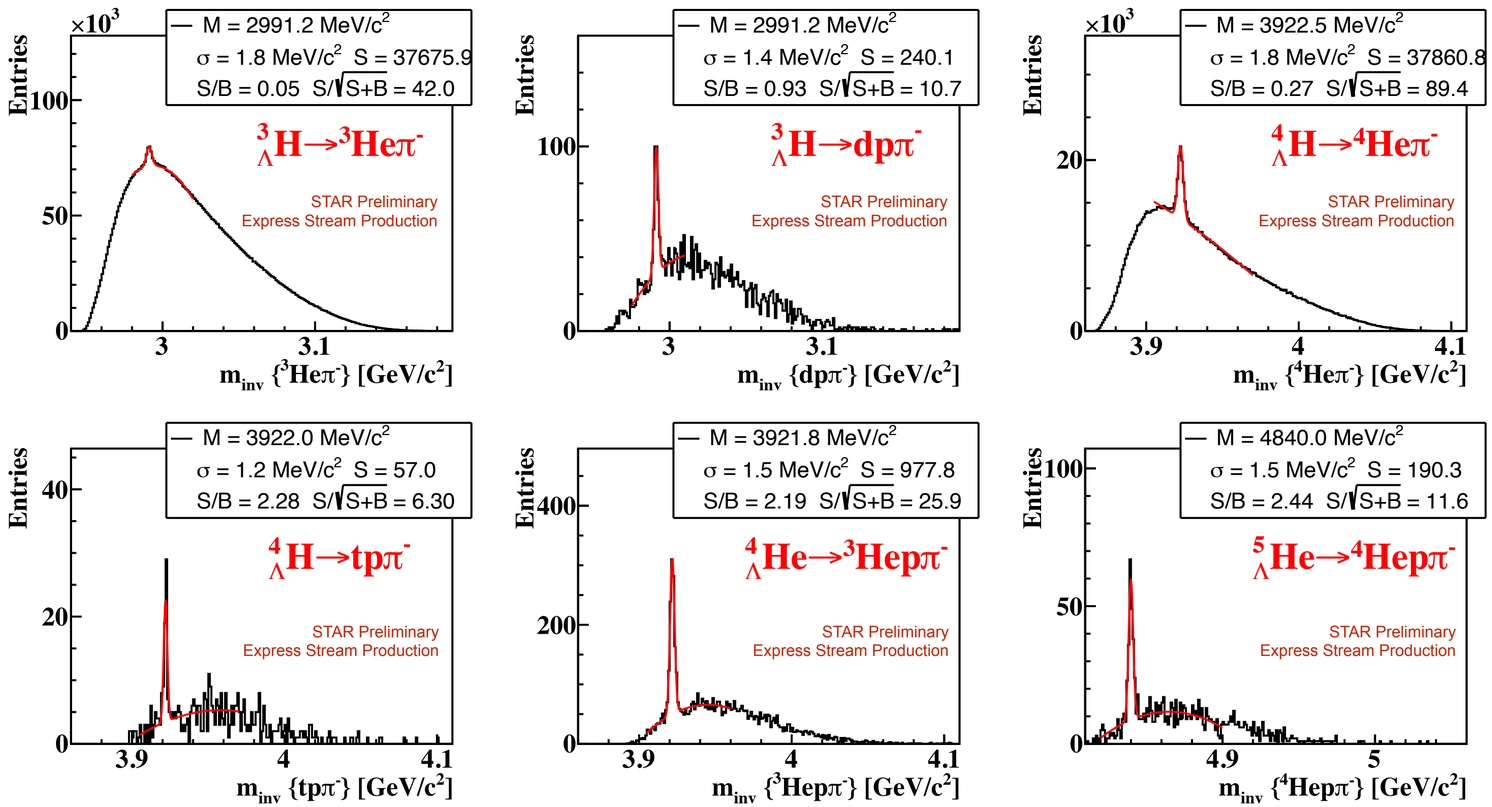
- With increased beam collision intensity in the Fixed Target mode HLT farm had not enough capacities to process all collected data online.
- Therefore a trigger on He has been introduced to enhance hypernuclei.

The collected statistics is enough to measure yields, lifetimes and spectra of these hypernuclei

BES-II: Hypernuclei

2018, 2019, 2020, 2021x FXT and 2021x collider at 7.7 GeV



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- With the same procedure all FXT data from 2018, 2019 and 2020 were analyzed.
- In all (standard and express) production data $^{5}_{\Lambda}$He is visible with significance **11.6 σ**.

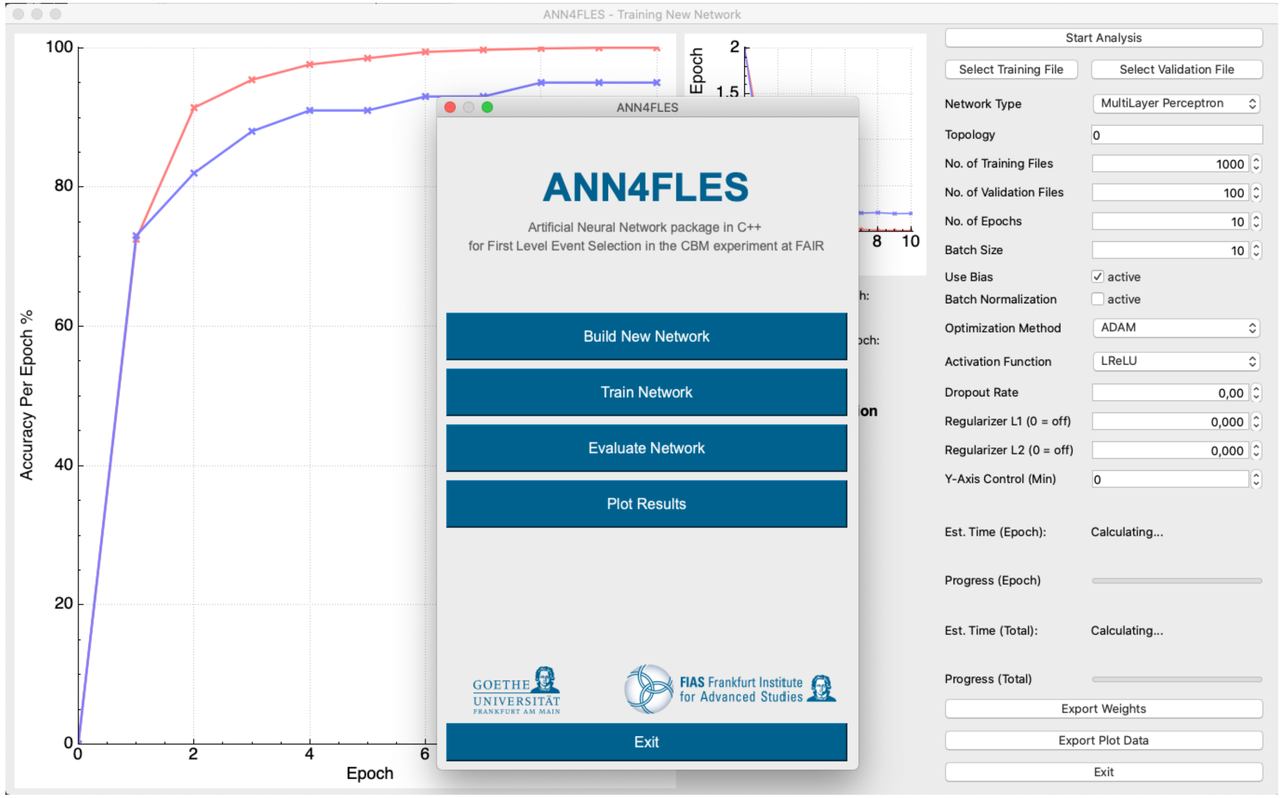
The collected statistics is enough to study Dalitz plots of 3-body channels

ANN4FLES: ANN Package for First Level Event Selection

ANN4FLES is a C++ package of Artificial Neural Networks developed for online event reconstruction and selection in the CBM experiment at FAIR

Currently implemented Networks:

- MLP - Multi-Layer Perceptron
- CNN - Convolutional
- RNN - Recurrent
- GNN - Graph
- ENN - Elastic
- BNN - Bayesian



An ANN4FLES package of Artificial Neural Networks for online event reconstruction is under development

Summary

- The fast algorithms for data reconstruction and analysis of the FLES package of the CBM experiment were successfully adapted to work on the High-Level Trigger of the STAR experiment in real time.
- On the STAR HLT, a so-called express data stream was created, which provided full processing and analysis of the experimental data in real time.
- Practically all collider data and 30% of fixed target data collected in 2019-2021 by the Beam Energy Scan (BES-II) program down to low energies of 3 GeV were processed on the free resources of the HLT computer farm.
- Hyperons and hypernuclei up to ${}^{5}_{\Lambda}\mathrm{He}$ with a significance of $11.6\cdot\sigma$ have been searched and analyzed in real time, both in collider mode and in fixed-target mode, as part of the express data processing, including online calibration, track reconstruction and search for short-lived particles.
- The collected statistics of the hypernuclei are sufficient to measure their yield, lifetime, and spectra, as well as to study Dalitz plots in the three-body channels.
- The high quality of the express data enabled preliminary analysis results in several physics measurements.
- We are currently working on the development of the ANN4FLES package of algorithms based on Artificial Neural Networks in order to further improve the efficiency and reliability of data processing and analysis in real time.