Probing Charm Production in Cold Nuclear Matter with the CBM Proton Beam Program

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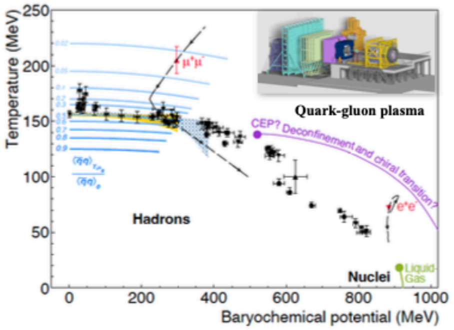
Mapping the phase diagram of strongly interacting matter in the region of high baryon density



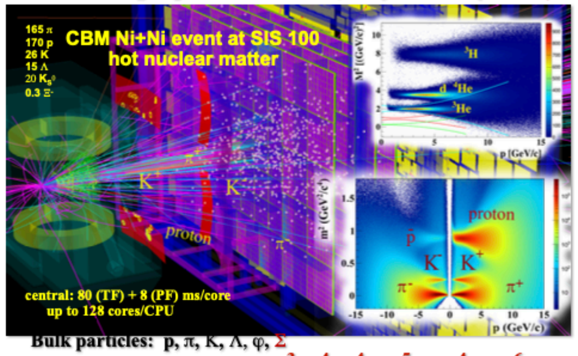
The CBM experiment at FAIR aims to study the properties of dense nuclear matter in the region of the quark-gluon plasma phase transition.

This extreme environment offers a unique opportunity to study hyperon-nucleon and hyperon-hyperon interactions through the production and decay of multi-strange particles and hypernuclei.

Understanding these interactions is critical for describing the nuclear equation of state at high densities and the structure of neutron stars.

Key observables: yields and distributions of particles including
- **Charm, multi-strange hyperons ($\Lambda, \Sigma, \Xi, \Omega$) and Hypernuclei**

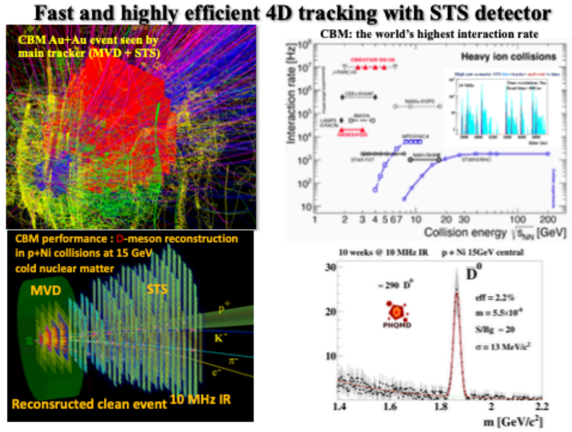
Interaction rates up to 10^7 collisions/sec
700 charged particles/collision, baryon density $\sim 5\rho_0$



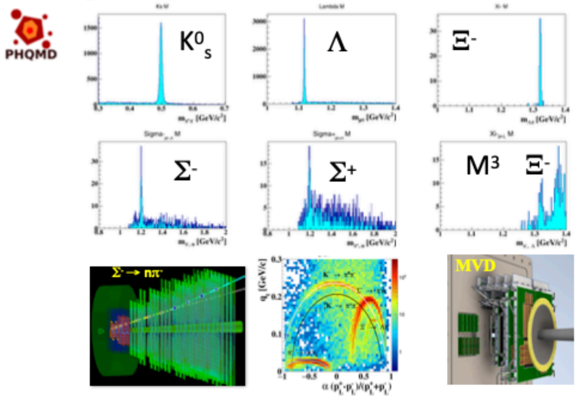
Bulk particles: p, π, K, Λ, φ, Σ

Rare probes: D^0, $D^\pm$, Λ_c; Ξ, Ω; $^3_\Lambda H$, $^4_\Lambda H$, $^4_\Lambda He$, $^5_\Lambda He$; $^4_{\Lambda\Lambda}He$, $^6_{\Lambda\Lambda}He$

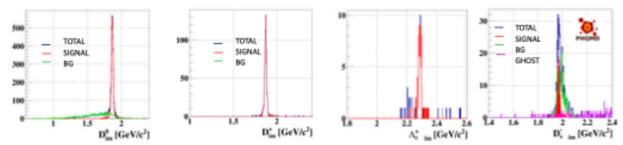
Fast and highly efficient 4D tracking with STS detector



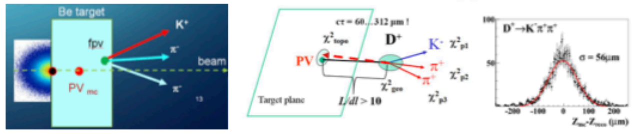
Strangeness: p +Be at 30 GeV (10^6 events 10 sec at day one)



Open charm in CBM at SIS100 with p + Be at 30 GeV



1M simulated PHQMD events with charm trigger: CBM is sensitive to open charm particles within current PHQMD predictions of their multiplicities.



Excellent open charm decay vertex resolution with KFParticle Finder package

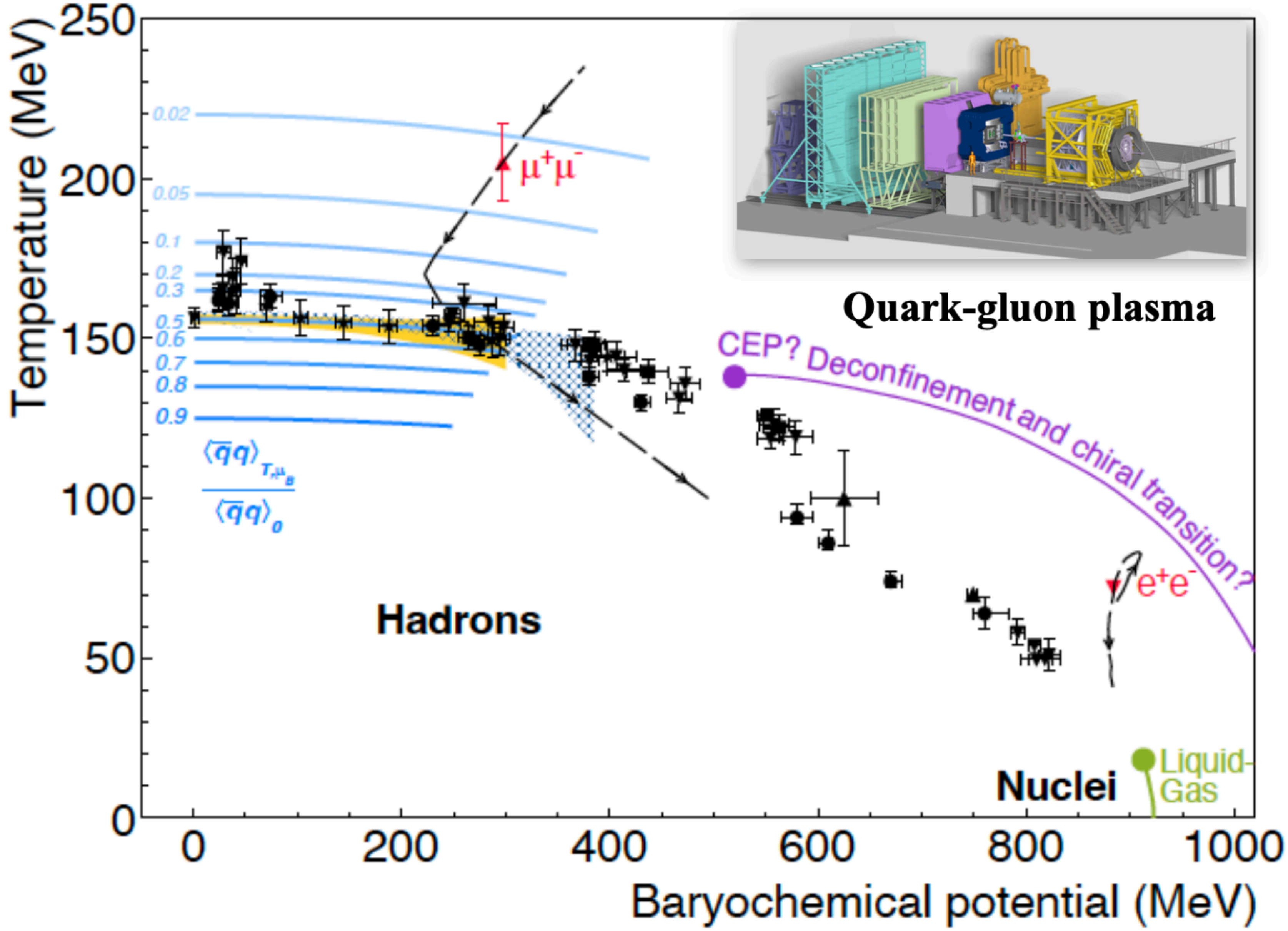
Summary

CBM@SIS100: Open charm production at threshold

Proton beams up to 30 GeV
- Excitation function of charm (production mechanism)
- Charm propagation in cold nuclear matter

Light nuclei (Ni) beams up to 15 GeV
- Charm production & propagation in hot nuclear matter

Mapping the phase diagram of strongly interacting matter in the region of high baryon density



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Key observables: yields and distributions of particles including

- **Charm, multi-strange hyperons (Λ, Σ, Ξ, Ω) and Hypernuclei**

1. QCD Phase Diagram

The **CBM experiment at FAIR** aims to study the QCD phase diagram of strongly interacting matter at high baryon densities.

Here you see the map of temperature versus baryochemical potential. CBM will explore the region where a transition from a hadron gas to a quark–gluon plasma may occur, and where the critical end point could be located.

The key probes are **open charm, multi-strange hyperons, and hypernuclei**.

Interaction rates up to 10^7 collisions/sec

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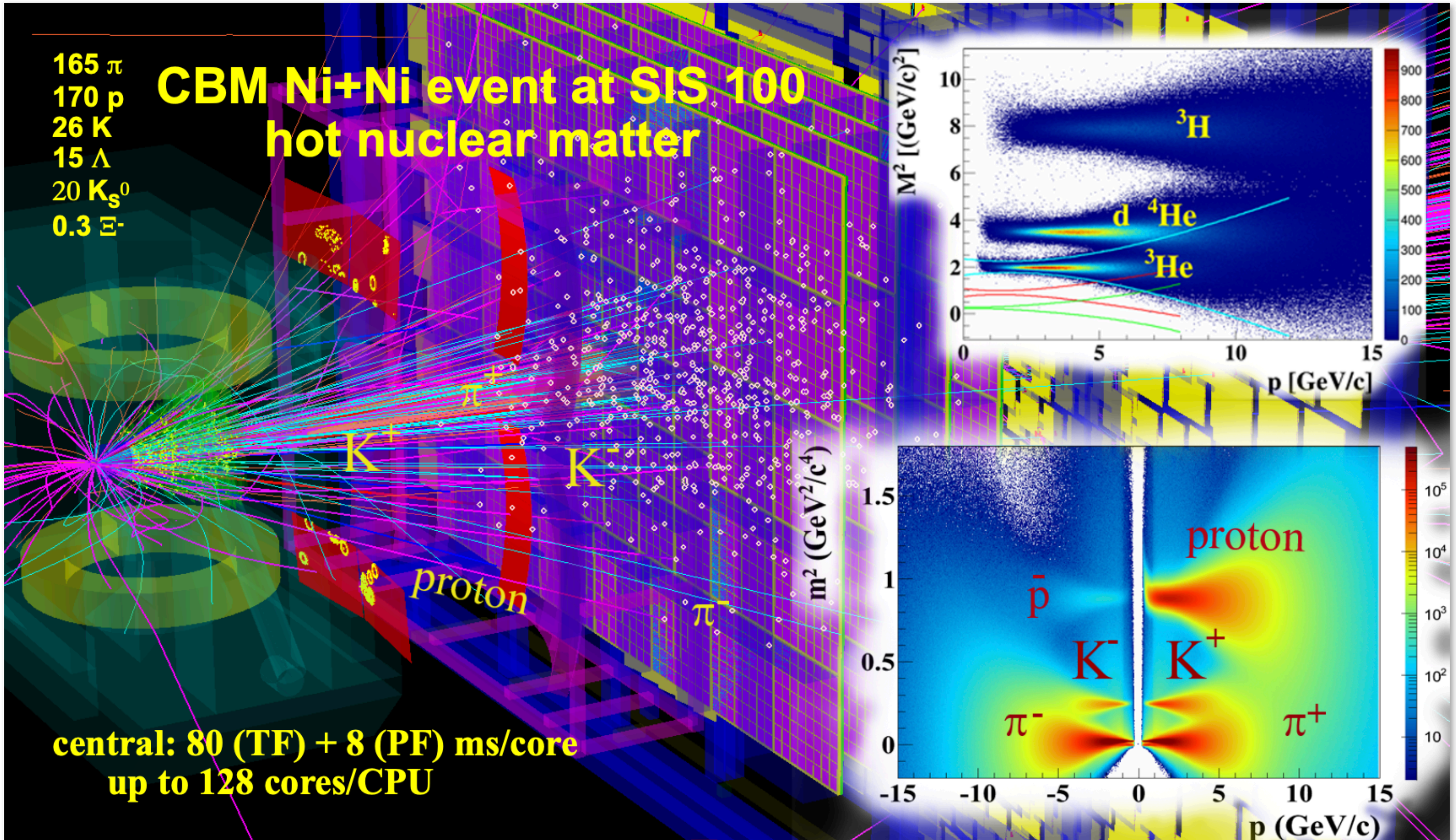

Bulk particles: p, π, K, Λ, φ, Σ

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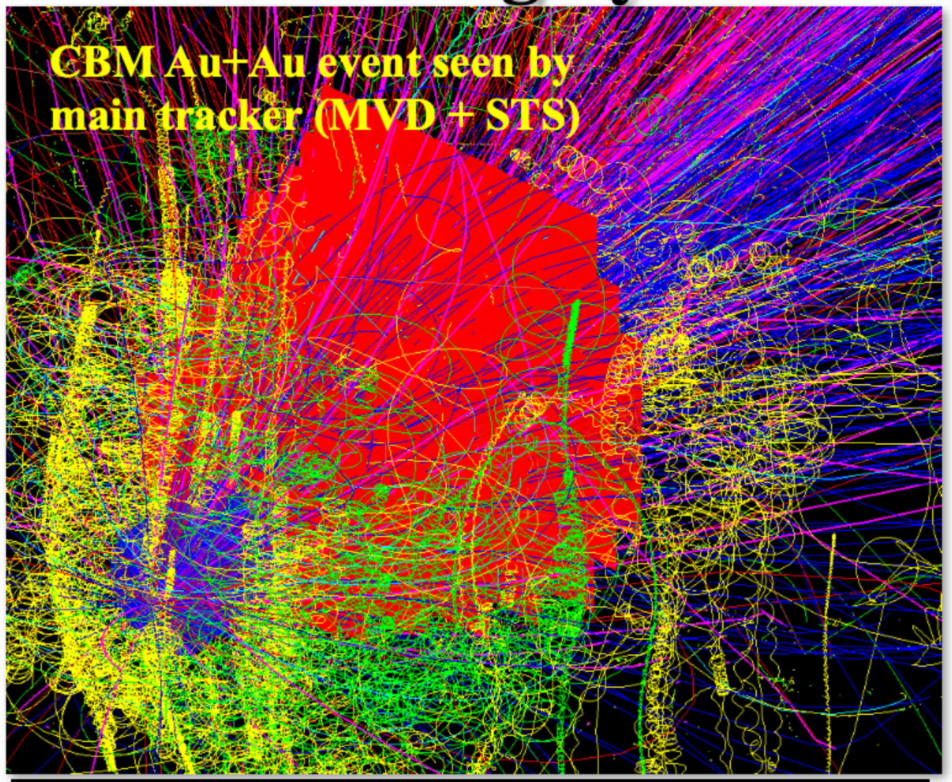
2. Experimental Conditions

CBM will operate at unprecedented intensities: up to **10^7 collisions per second**.

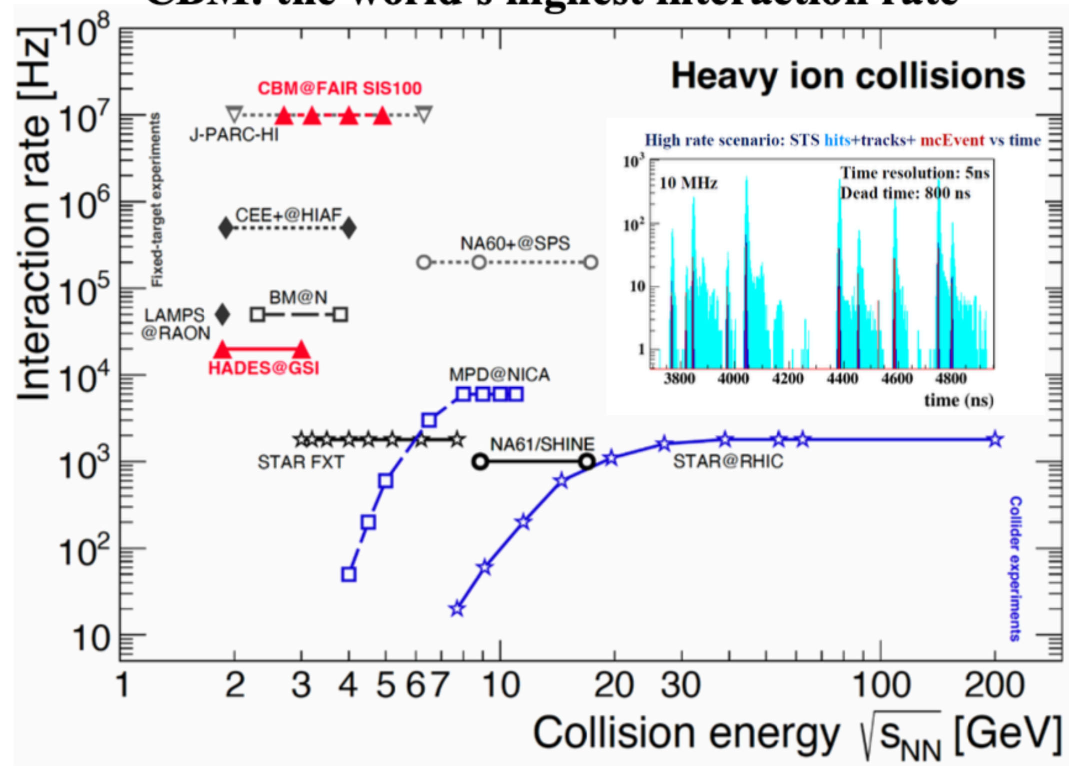
A single Ni+Ni collision will produce hundreds of charged particles, reaching baryon densities of about **$5\rho_0$**, comparable to the core of neutron stars.

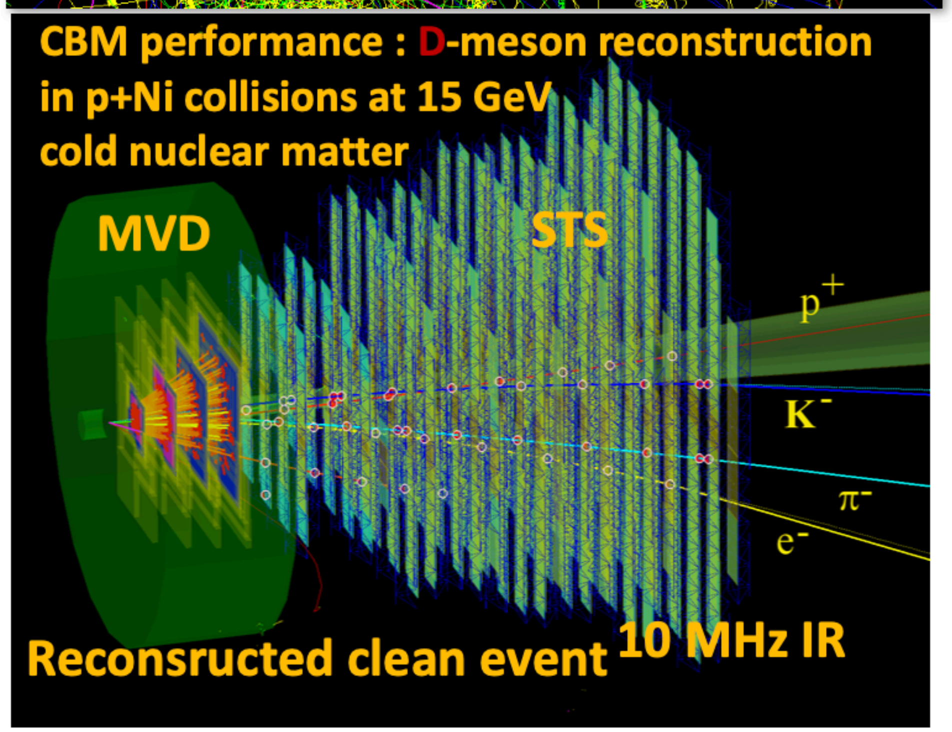
Here you see mass and momentum distributions: CBM will be able to identify protons, π, K, Λ, Ξ and even light nuclei. This means we can study both bulk matter and rare probes such as D mesons and hypernuclei.

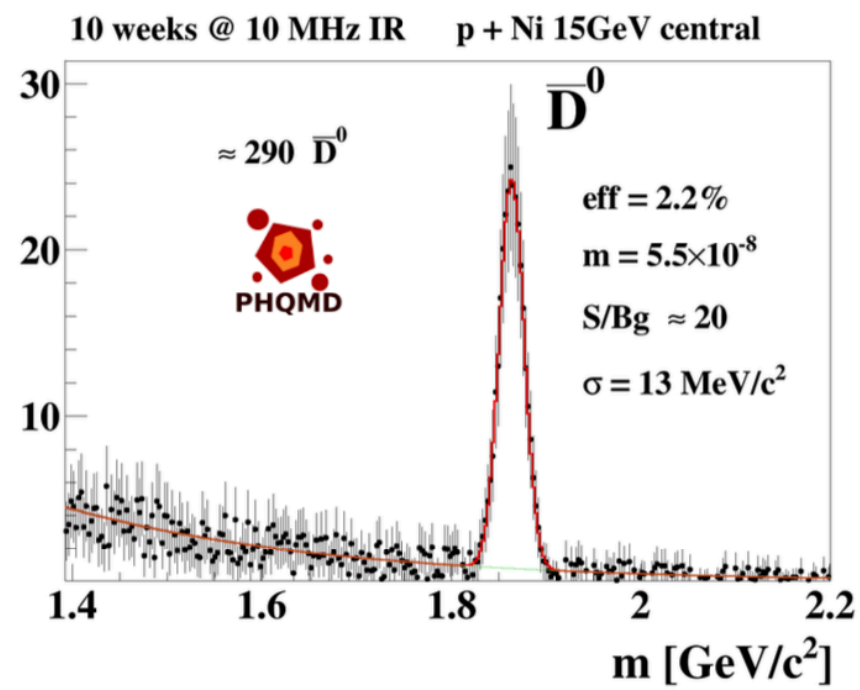
Fast and highly efficient 4D tracking with STS detector



CBM: the world's highest interaction rate







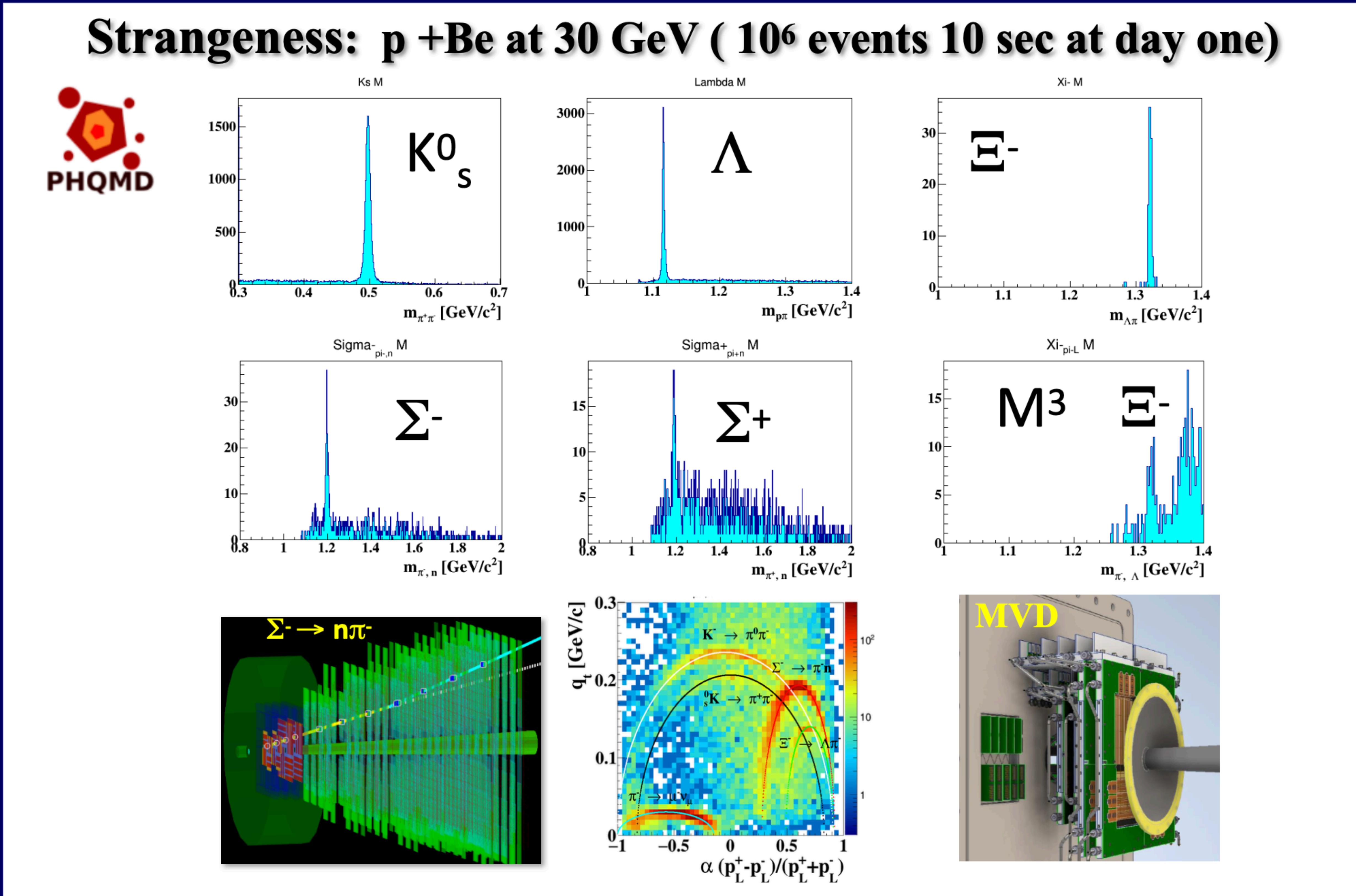
3. CBM Technologies: STS and MVD

To handle such rates we need fast and highly efficient 4D tracking.

On the left you see an Au+Au simulated collision in STS and MVD. We can process up to **10 MHz of events in real time**.

On the top right you see a comparison: CBM will have **the highest interaction rate**.

The lower graph shows that we can already reconstruct D^0 mesons in central p+Ni collisions. This proves that charm signals will be accessible.



4. Strangeness

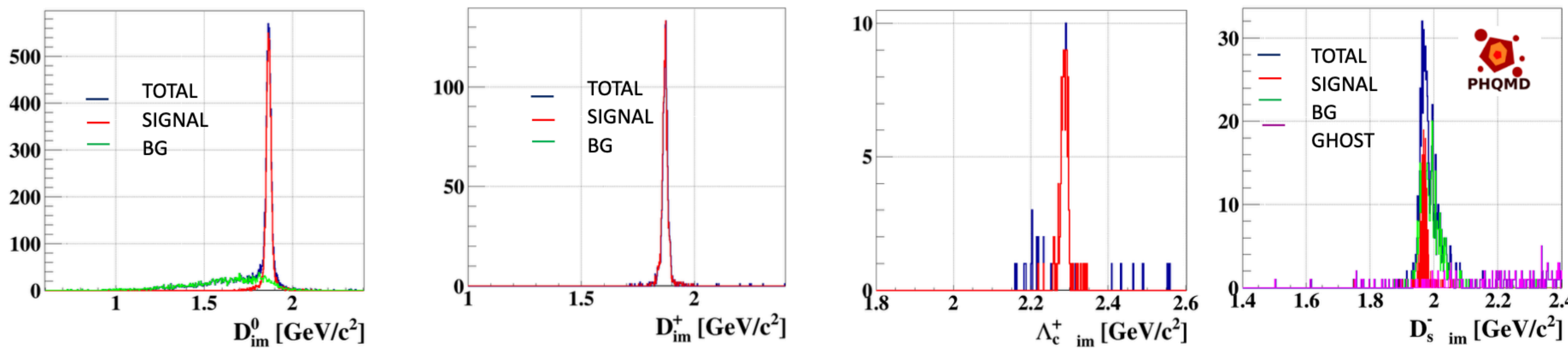
This slide shows our results on strange particles.

In just **10 seconds of running** (10^6 p+Be events) we will observe clean peaks for K^0s, Λ, Ξ, as well as signals for Σ^+ and Σ^-.

On the left is the reconstructed decay of Σ^-, in the center a correlation analysis, and on the right the MVD detector, crucial for vertex reconstruction.

These results confirm CBM's sensitivity to multi-strange hyperons and open the way for hypernuclear studies.

Open charm in CBM at SIS100 with p + Be at 30 GeV



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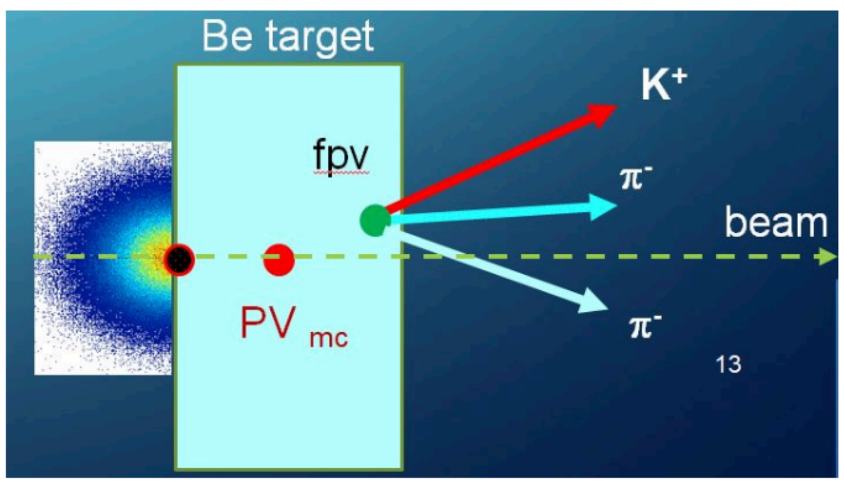

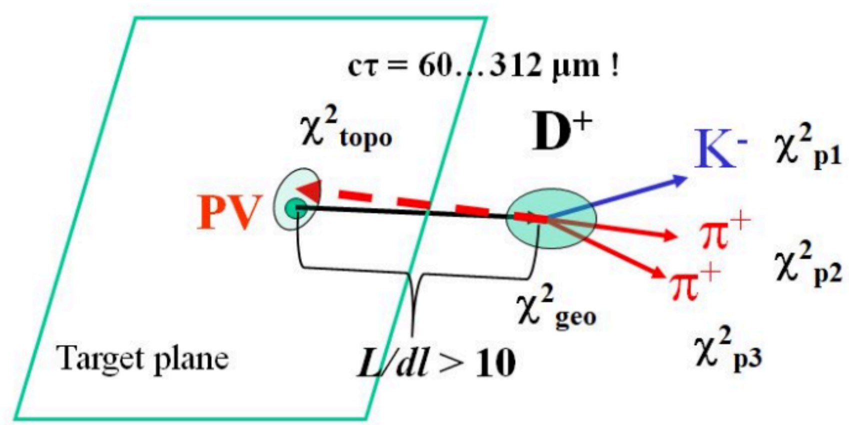

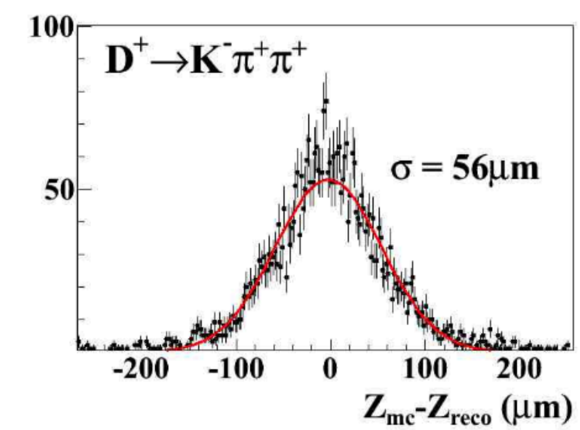

Excellent open charm decay vertex resolution with KFParticle Finder package

5. Open Charm

Charm will be our main rare probe. The upper plots show invariant mass distributions for D^0, D^+, Λc^+ and Ds^+ from PHQMD simulations.

You can clearly see sharp signal peaks, even in the presence of background and ghost events.

On the left is a schematic of the D^+ decay, in the center the topological reconstruction of the secondary vertex. On the right is the vertex resolution along Z: only **56 µm**.
This excellent performance demonstrates that CBM will be able to resolve open charm signals right at the production threshold.

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6. Summary

CBM will work with proton beams up to 30 GeV and light nuclei beams up to 15 GeV.

CBM will focus on three main goals:

1. Measuring the **excitation function of open charm** to understand its production mechanism.
2. Studying **charm propagation in cold nuclear matter**.
3. Investigating **charm and hypermatter production in hot and dense matter**.

In conclusion, CBM@SIS100 is designed to systematically study open charm and multi-strange systems at high baryon density.