



Overview of the K10 Spectrometer - KDREAMS -

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K10 and Hadron Experimental Facility Extension

• K10: K^- & $\bar{p}$ beam

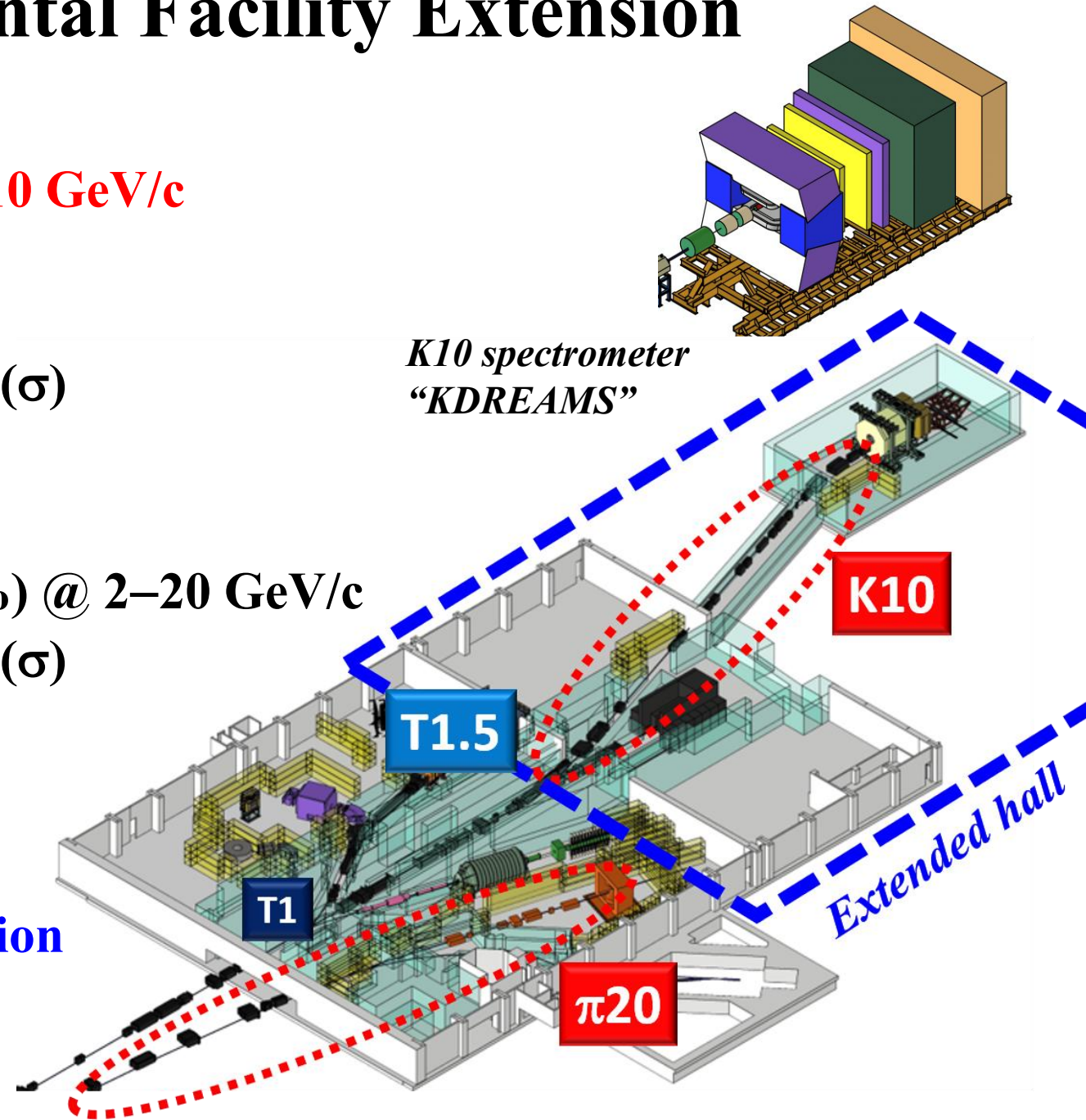
- Intensity: $>10^6$ /spill for $K^-/\bar{p}$ @ 2–10 GeV/c
- Purity: $K/\pi \sim 1/2$, $\bar{p}/\pi \sim 2/1$
 - Particle separation by RF separator
- Momentum resolution: $\Delta p/p = 0.1\%(\sigma)$

• $\pi 20$: π^- beam (Unseparated)

- Intensity: $>10^7$ /spill π^- (K^- , $\bar{p}$: 1–2%) @ 2–20 GeV/c
- Momentum resolution: $\Delta p/p = 0.1\%(\sigma)$

* High-momentum hadron beams

- Unique in the world
- Charm and strange hadron production
- High-intensity: Systematic study



Spectrometer concept for physics at K10

* Understanding of mechanism, “How quarks build hadrons ?”

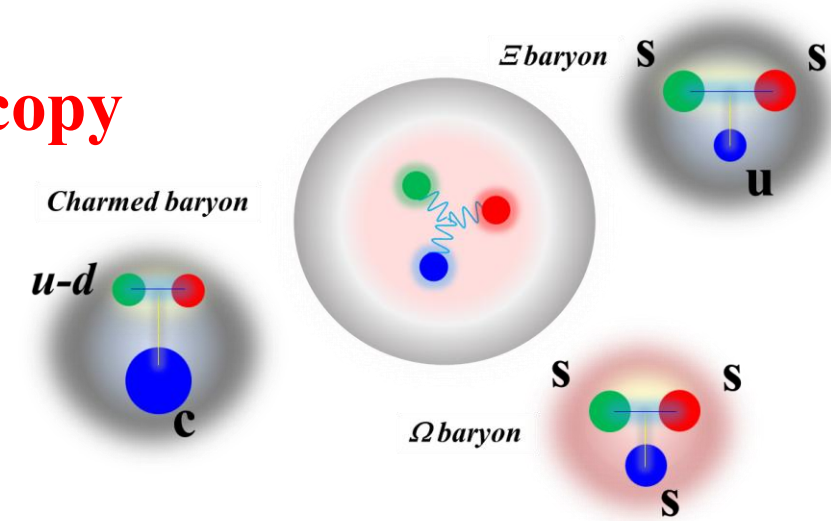
- Through investigations of various excited states

⇒ Production mechanism is a key.

- Access to **wave function**
- Hadron beams to control momentum and reaction channels

• To achieve “Physics goal” ⇒ Missing mass spectroscopy

- Comprehensive measurement: Production and Decay
 - Missing mass $\Leftrightarrow$ Invariant mass
- Nuclear target experiment
 - Inclusive measurement is essential.
 - Detection of recoil nuclei is very difficult.

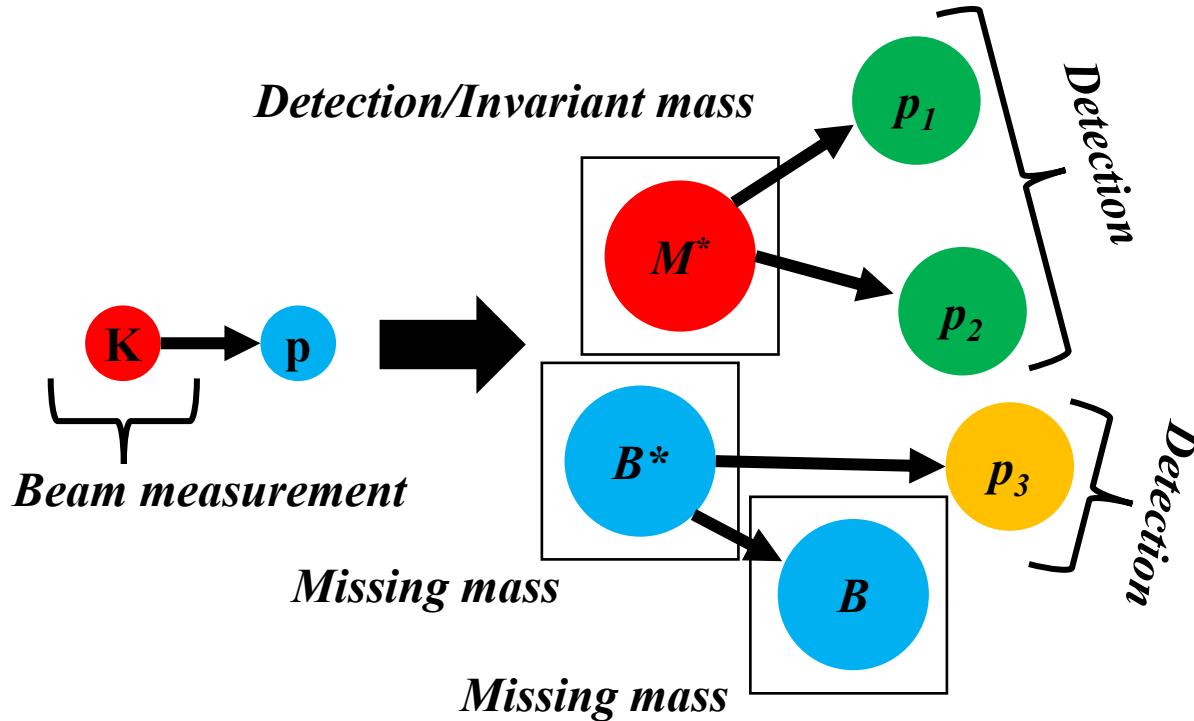


• Momenta of both beam and scattered particles measured with good resolution

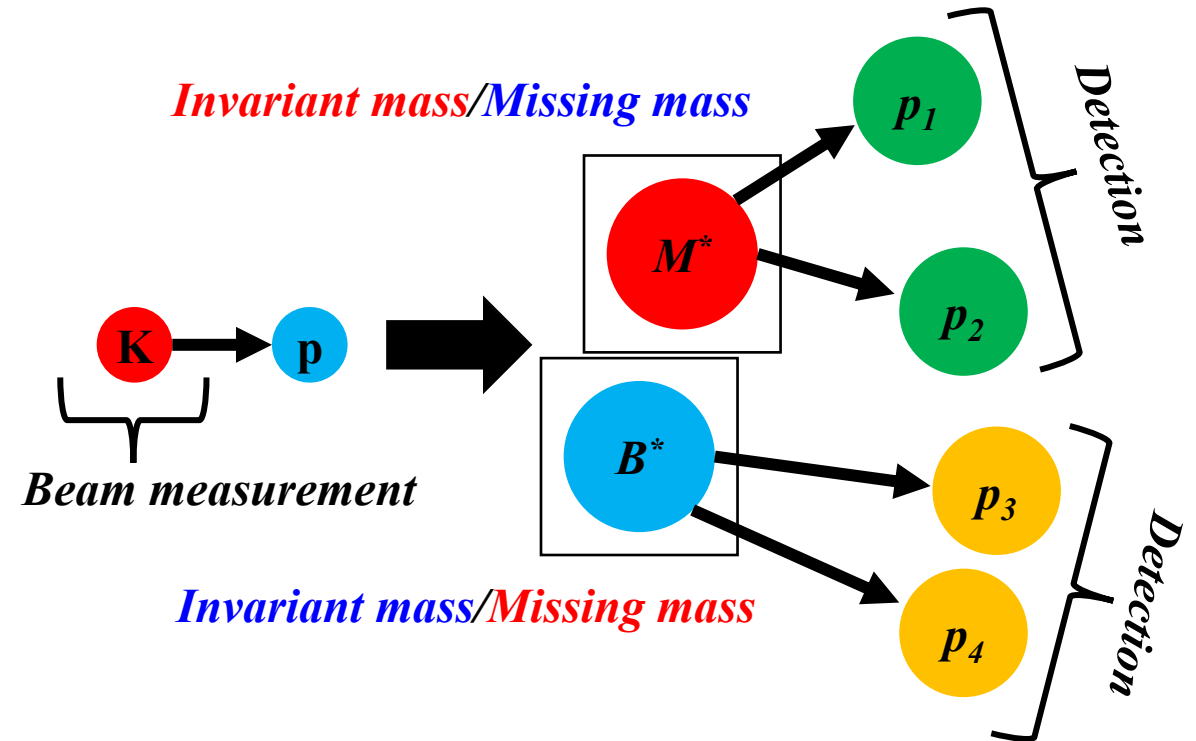
- Separation of each excited state and line shape analysis: $\sim \text{MeV}(\sigma)$ mass resolution

Experimental method: Fixed-target experiment

Baseline missing-mass measurement



Comprehensive measurement

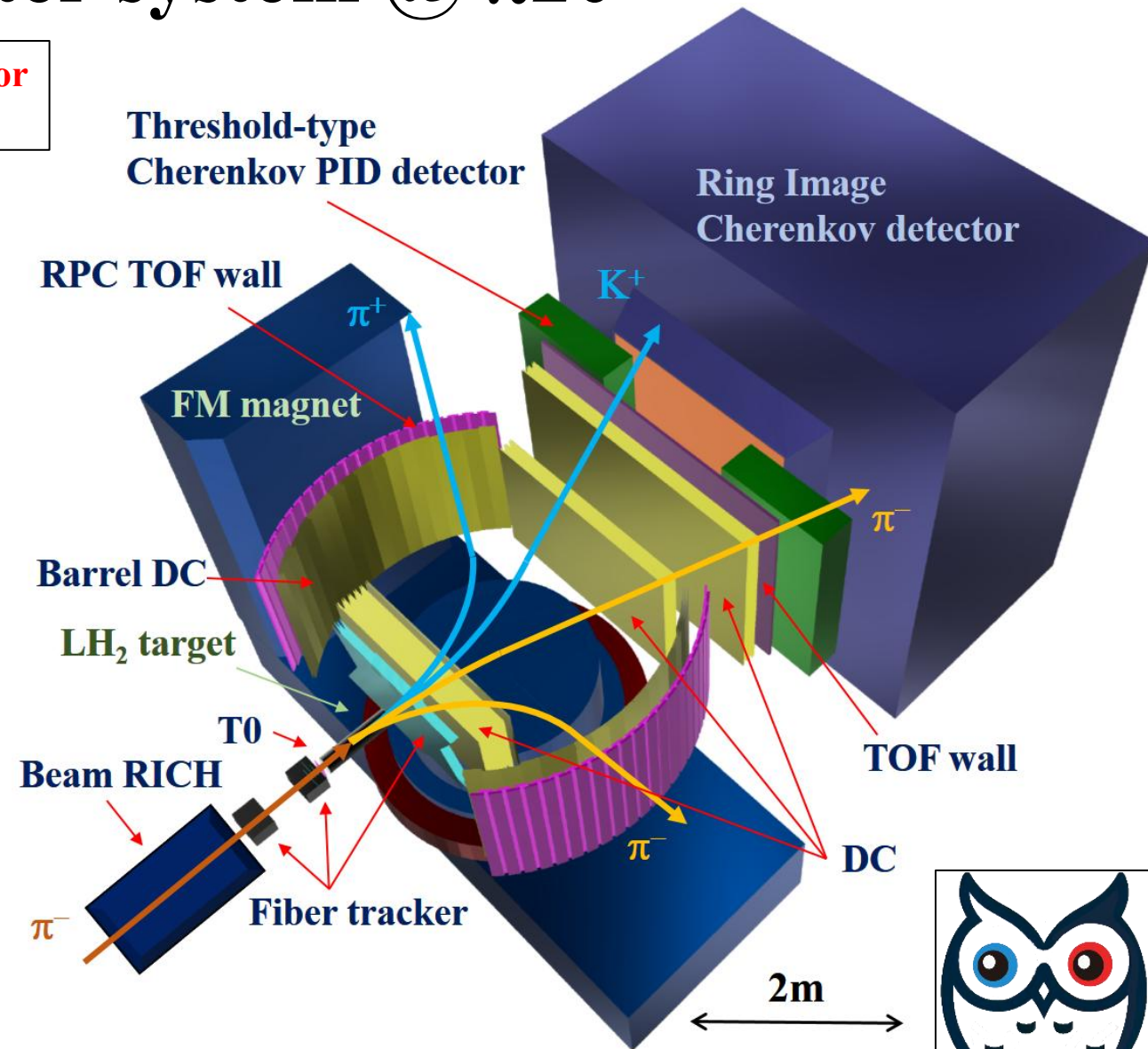


- **Comprehensive measurement: Production and decay**
 - Both invariant and missing masses for produced particles
 $\Rightarrow$ **What kinds of particles involved in production**
- * **Large acceptance forward spectrometer system**

Baseline: MARQ spectrometer system @ $\pi 20$

- High-rate beam detectors
 - Scintillation Fiber Tracker
 - Fine-segmented Cherenkov Timing detector
- High-performance PID detectors
 - RICH & Beam RICH
 - Internal TOF wall (RPC)
 - Pole-face TOF wall (RPC)
 - Threshold-type Cherenkov detector
 - Aerogel (ThAC) and Gas (ThGC)
- Large coverage detectors
 - Drift chamber/Straw tube tracker
 - Forward TOF wall
 - Muon detector (Tracker-type RPC)
- Magnetic field: 1 T w/ BL~2.1 mT
 - $\Delta p/p \sim 0.2\%(\sigma)$ @ 5 GeV/c
- Liquide LH₂ target: 4 g/cm²
 - 10 cm(diameter) × 57 cm(long) (4.5L)

– Photon detector
– Gas detector

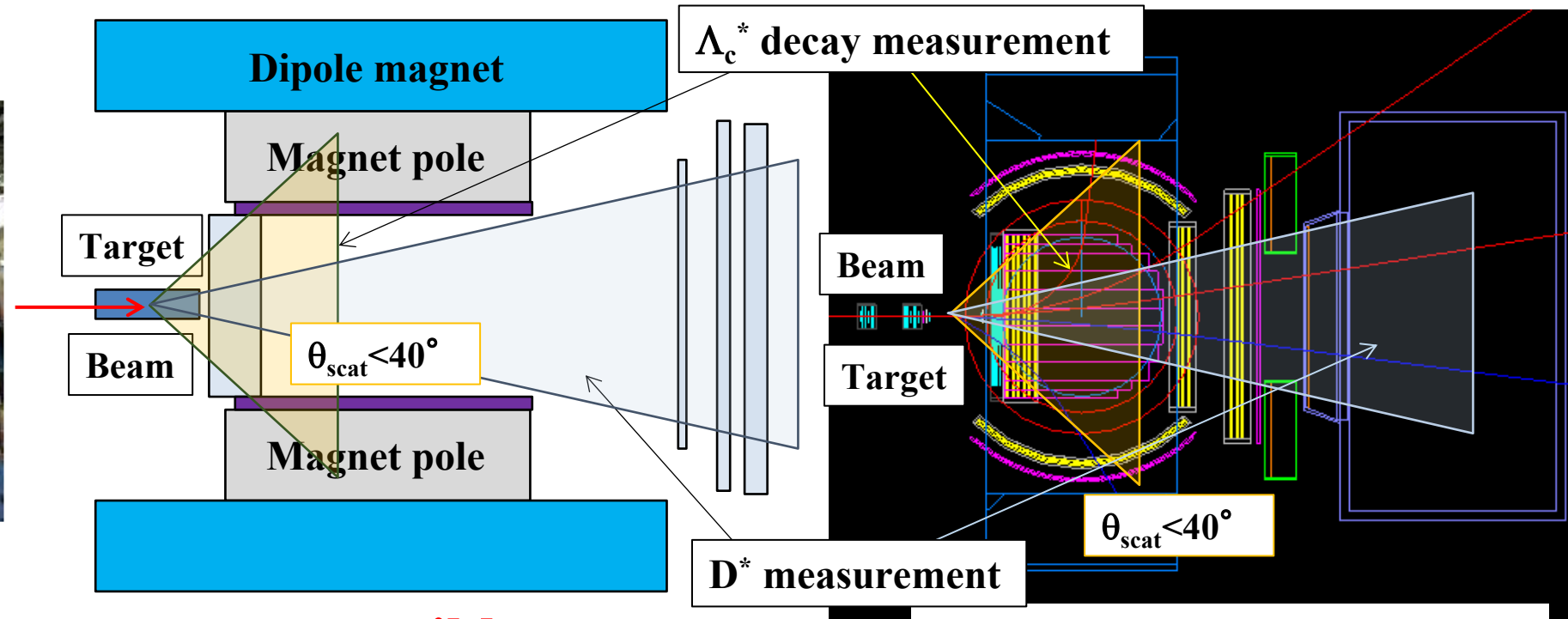


* $\pi^- p \rightarrow D^{*-} Y_c^{*+}$ reaction @ 20 GeV/c



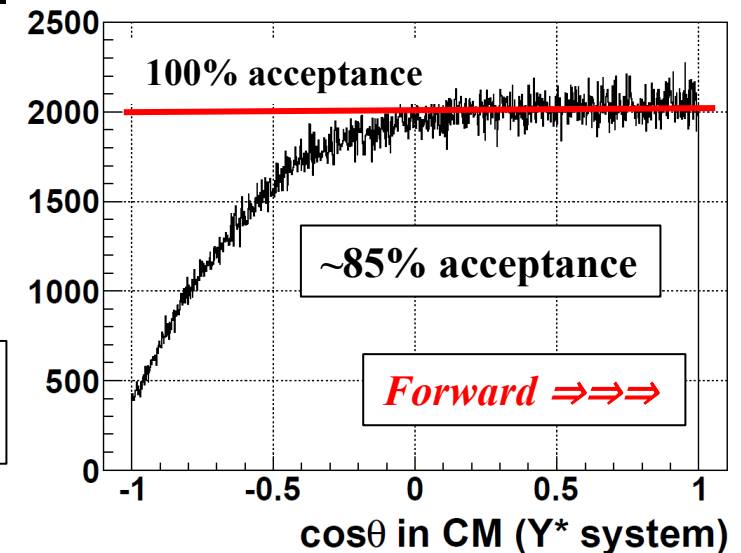
Baseline: MARQ design concept

FM magnet

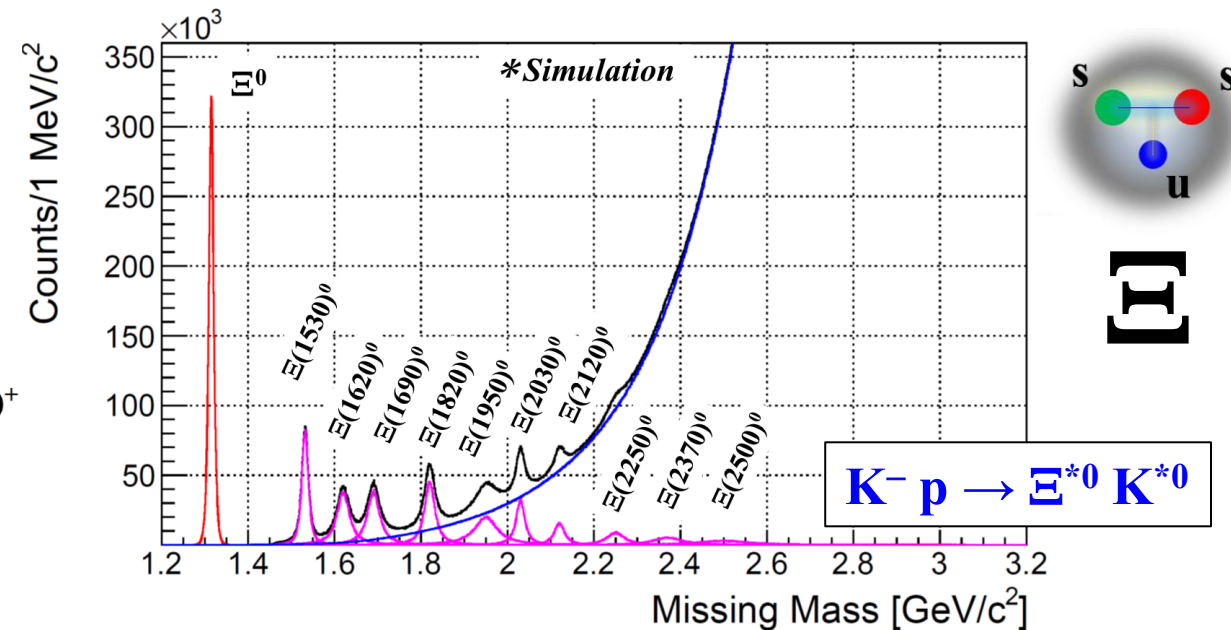
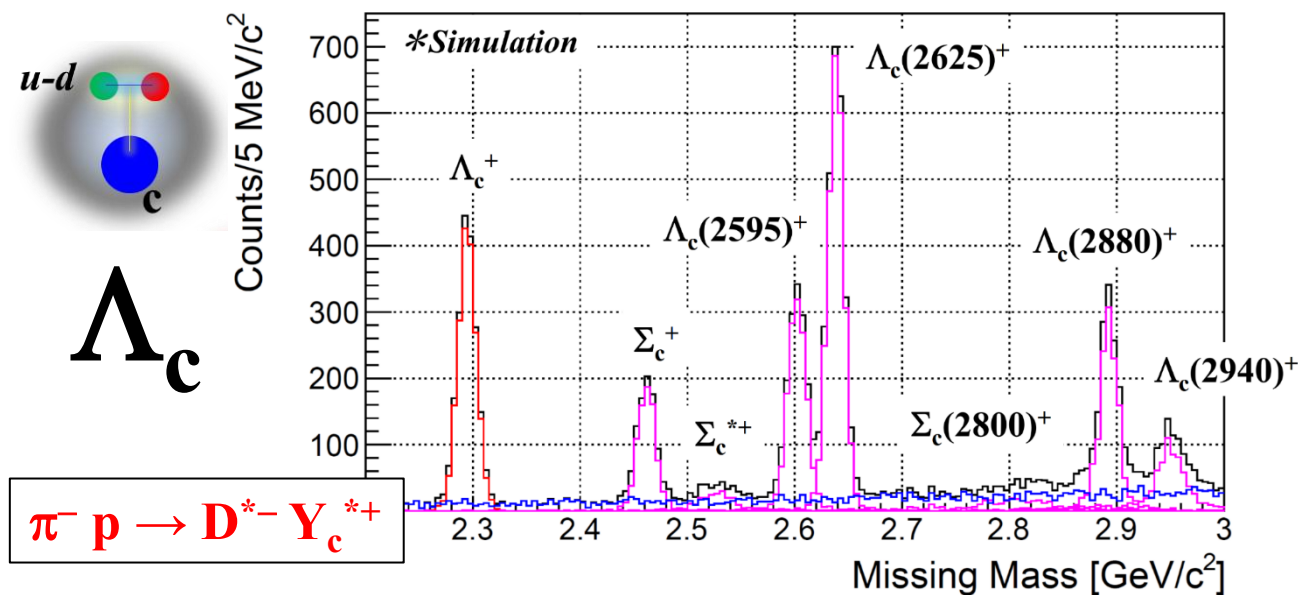
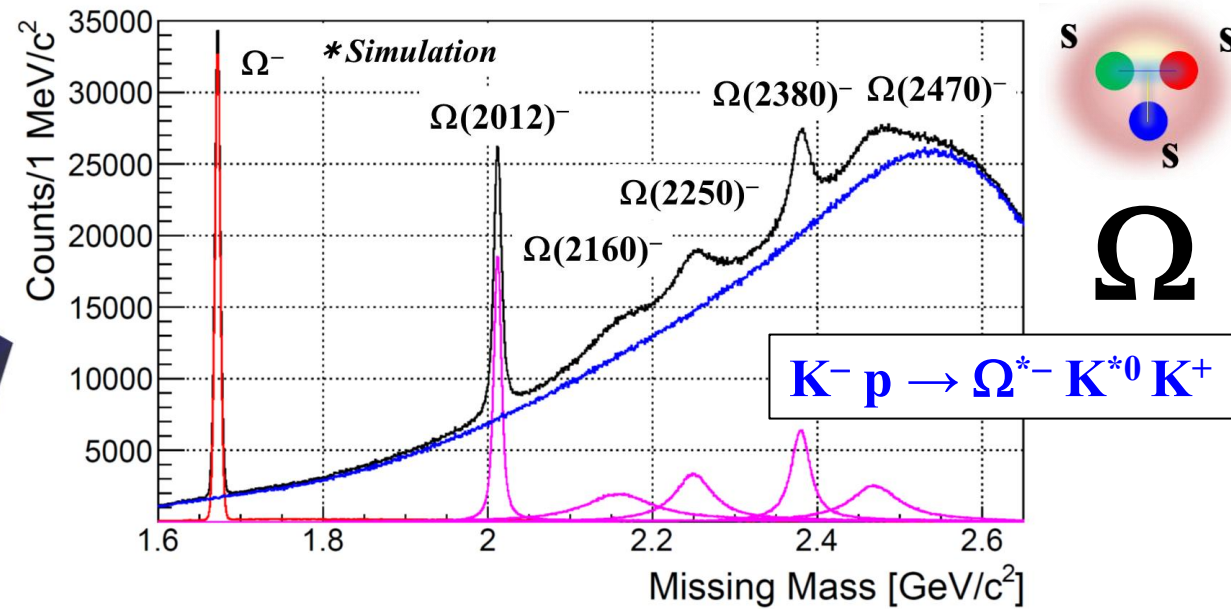
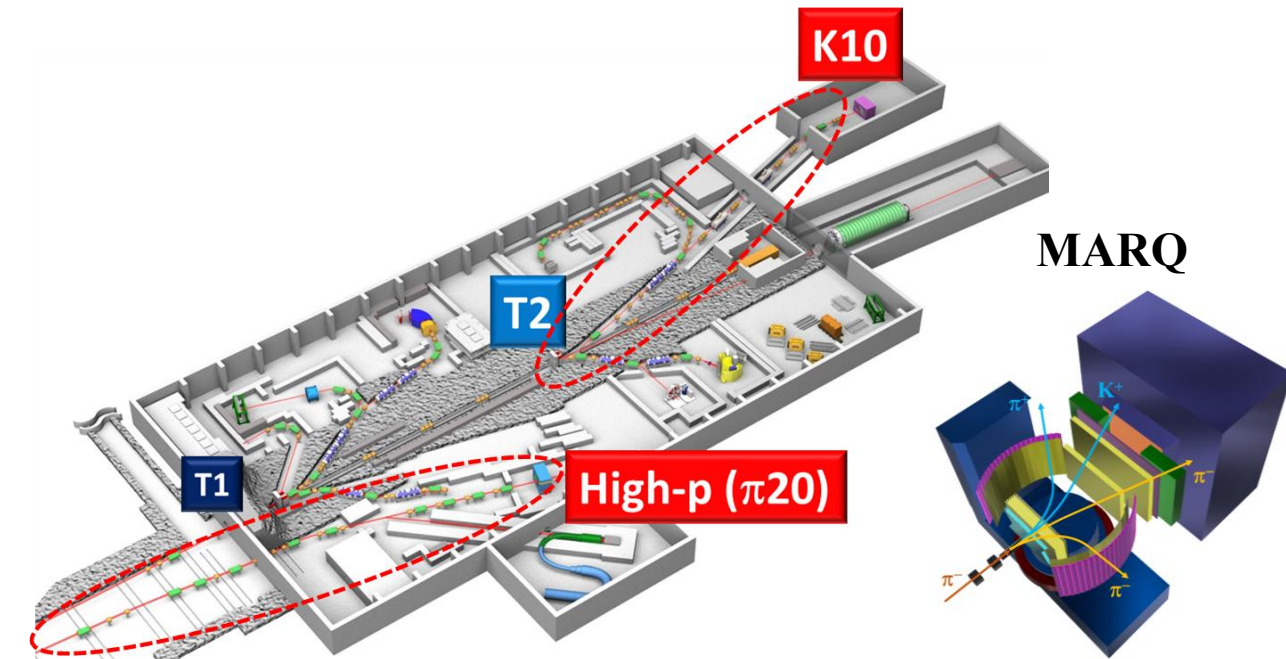


- Target as close to magnet gas as possible
 - Forward detectors
 - D^* detection: High momentum particles
 - Internal detectors
 - Y_c^* decay particle detection
- $\Rightarrow$ Wide angular coverage**
- Both polar and azimuthal angles

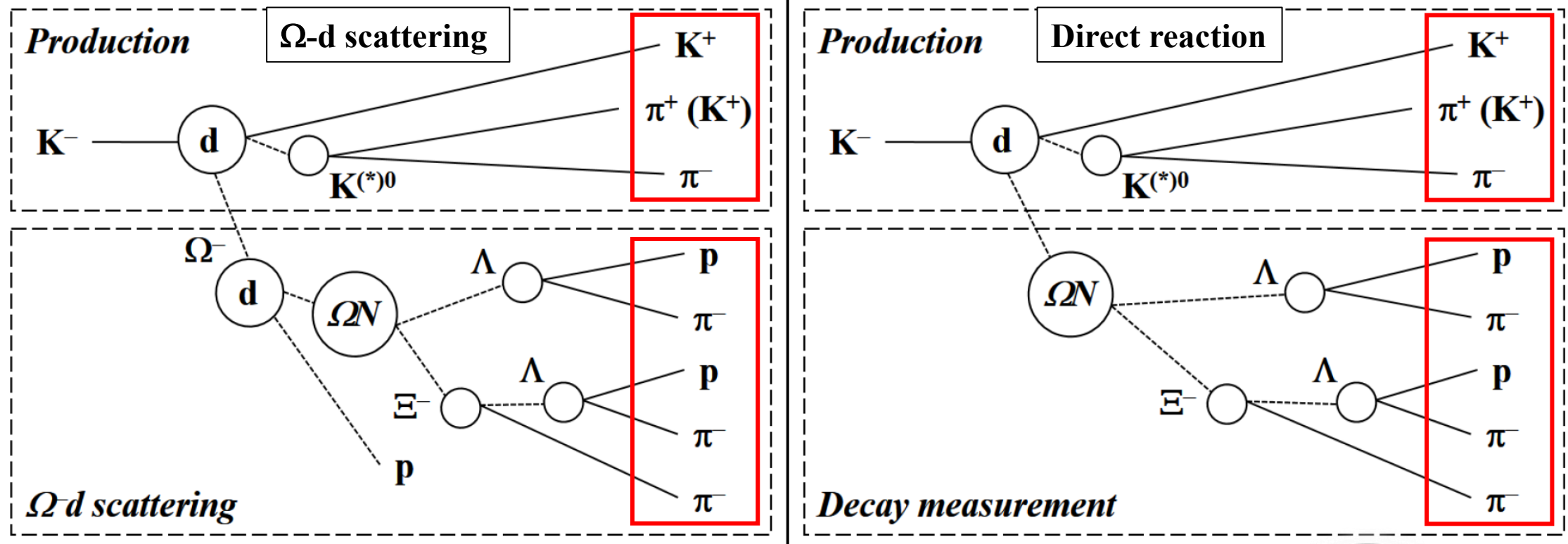
Decay angle:
 $\Lambda_c^{*+} \rightarrow \Sigma_c^0 + \pi^+$



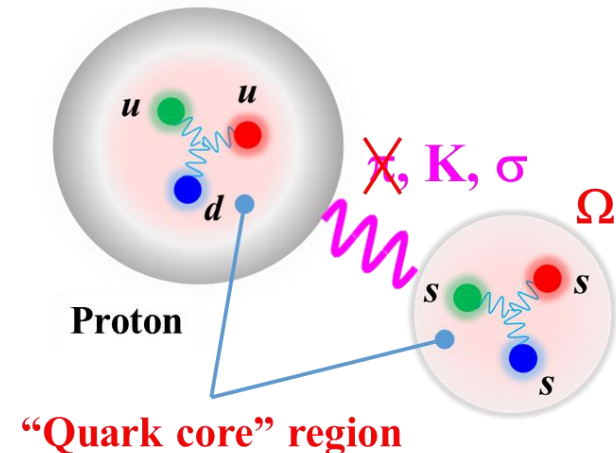
Expected mass spectra: Λ_c/Σ_c , Ξ , Ω systems

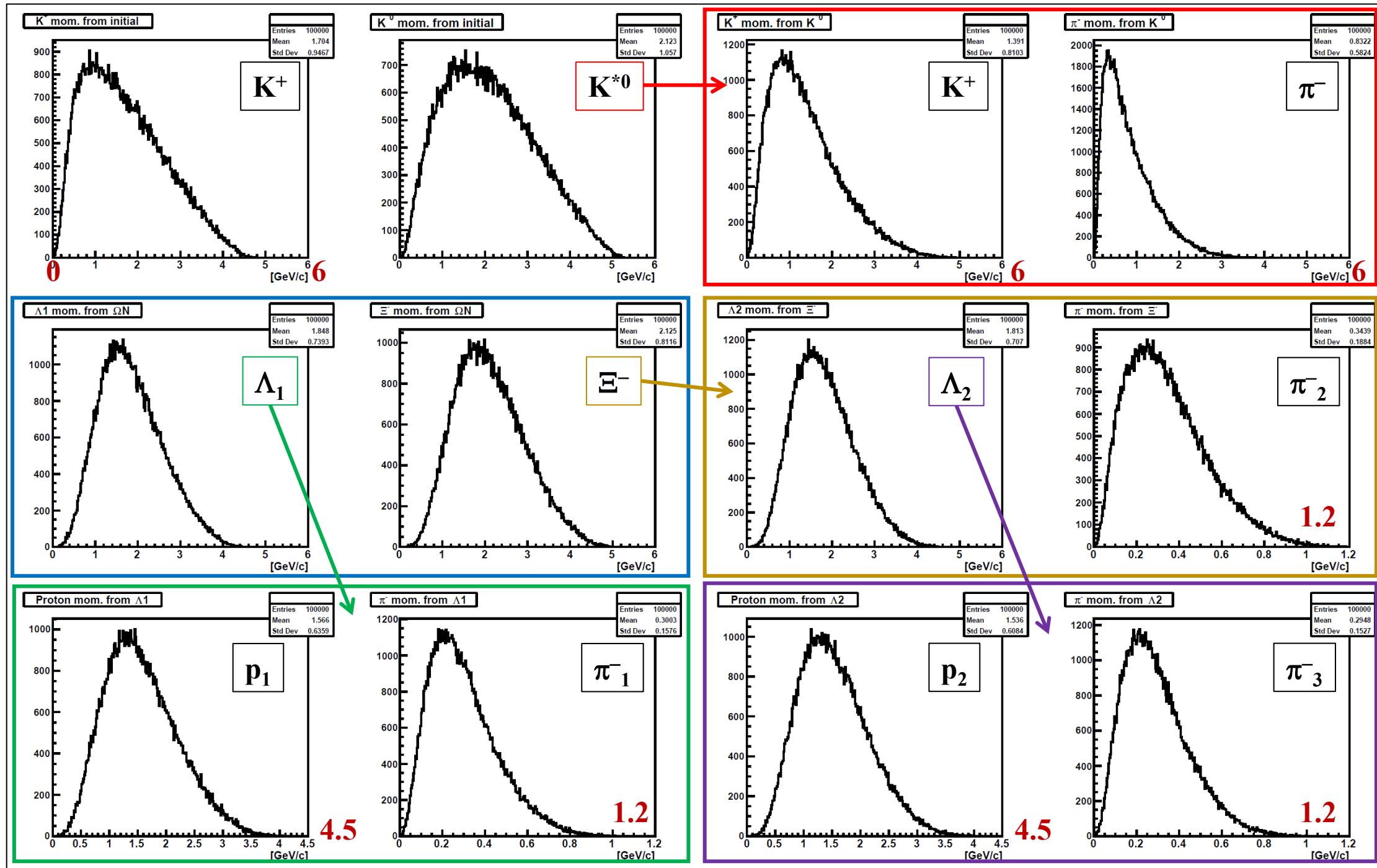


Benchmark reaction: ΩN state production

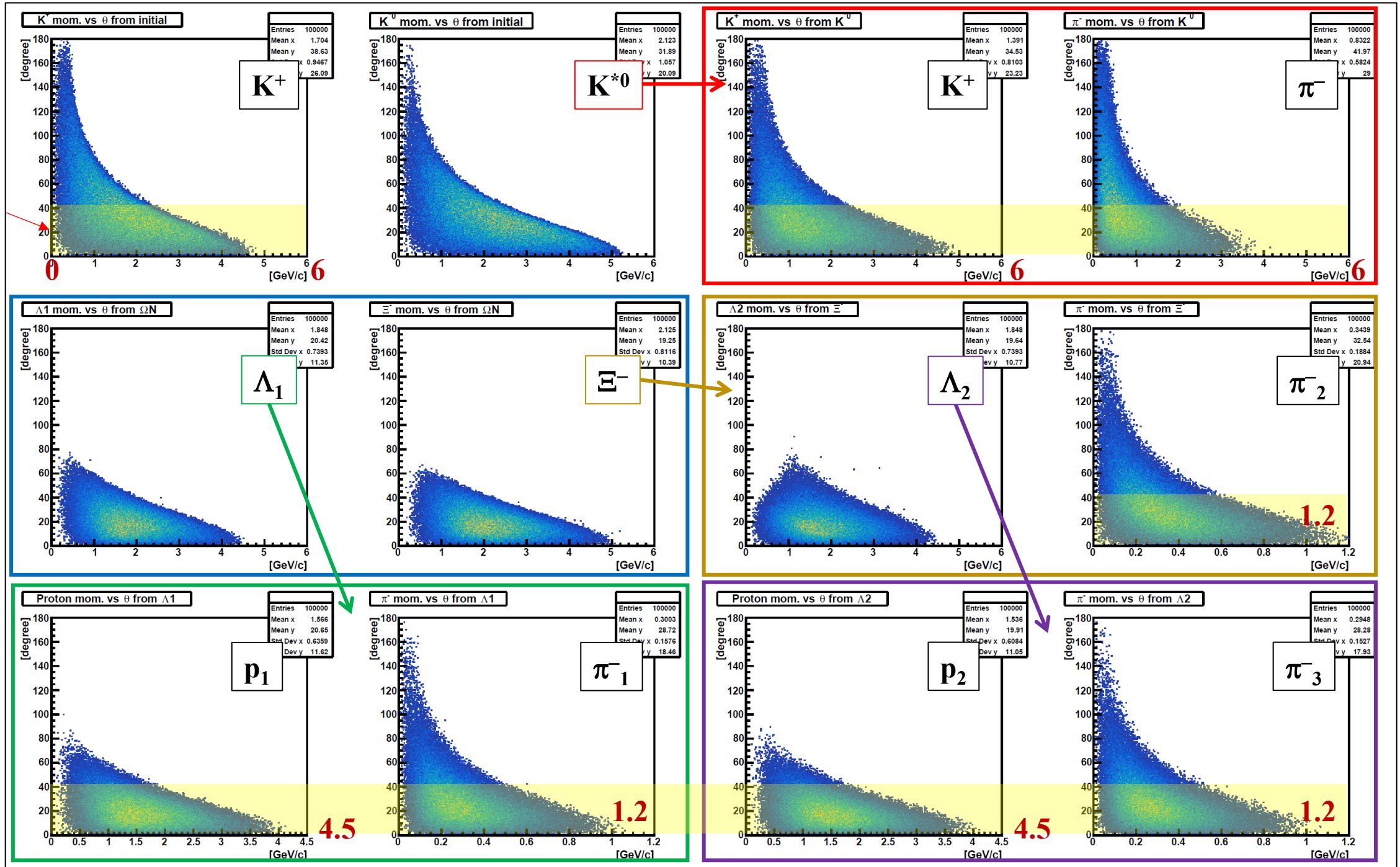


- **ΩN state production: Ω^- -d scattering / Direct reaction**
 - Missing mass (production) and invariant mass (decay) measurements (J^P)
 - $\Gamma \sim$ a few MeV
 - $K^- + d \rightarrow X(\Omega^- n) + K^{(*)0} + K^+ @ 5-7 \text{ GeV}/c$
 - ΩN decay mode: $\Omega^- n \rightarrow \Xi^- \Lambda_1$
 - $\Lambda_1 \rightarrow p_1 \pi_1^-$ and $\Xi^- \rightarrow \Lambda_2 \pi_2^- \rightarrow p_2 \pi_3^- \pi_2^-$
- $\Rightarrow$ Final state: $K^+ \times 2, p \times 2, \pi^- \times 4 \Rightarrow$ Total 8 particles (+ 1 beam particle)**





MARQ
 $\theta < 40^\circ$



Simulation: Ω^-n reconstruction

- **Reaction:**



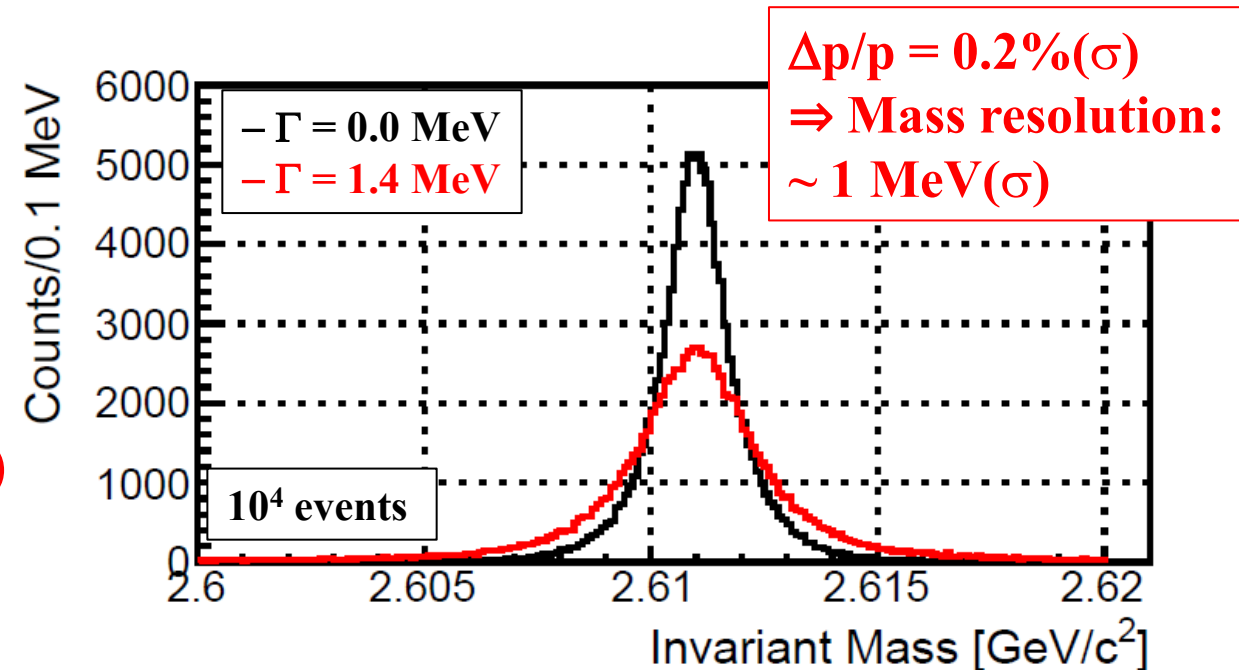
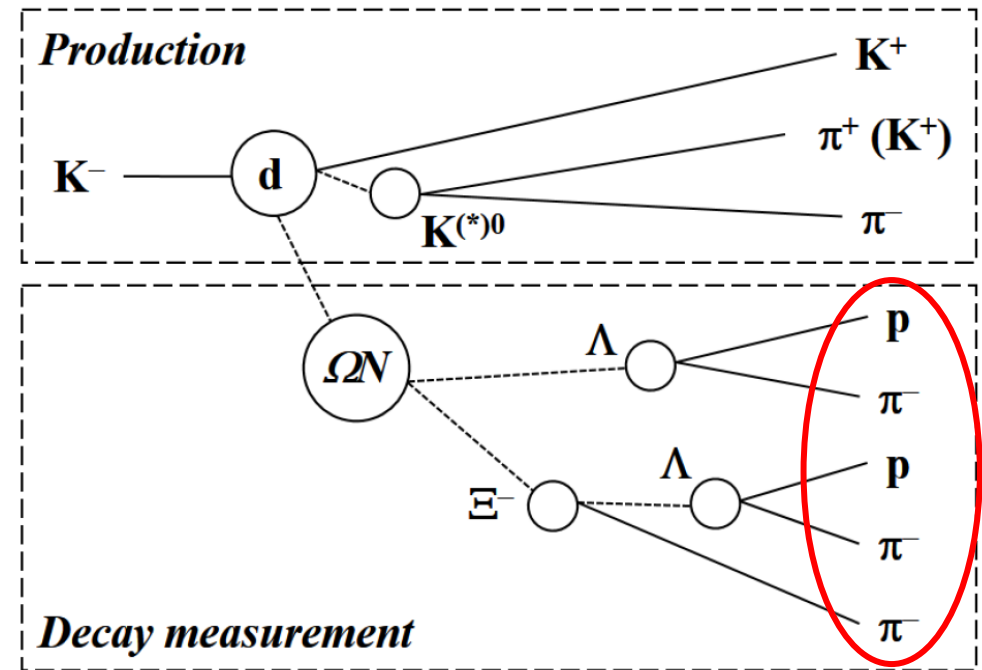
- **Mass and width (Assumed)**

- Ω^-n : $2.611 \text{ GeV}/c^2$, $\Gamma = 1.4 \text{ MeV}$ (BW)

- **Decay mode: $\Omega^-n \rightarrow \Xi^- \Lambda_1$**

- $\Lambda_1 \rightarrow p_1 \pi_1^-$
- $\Xi^- \rightarrow \Lambda_2 \pi_2^- \rightarrow p_2 \pi_3^- \pi_2^-$
- **Final state: $p_1 p_2 \pi_1^- \pi_2^- \pi_3^-$**
* 2-body uniform distribution

- **Momentum resolution: $\Delta p/p < 0.2\%(\sigma)$**
+ **Optimum target coverage**
*MARQ case: $\sim 10\%$ acceptance



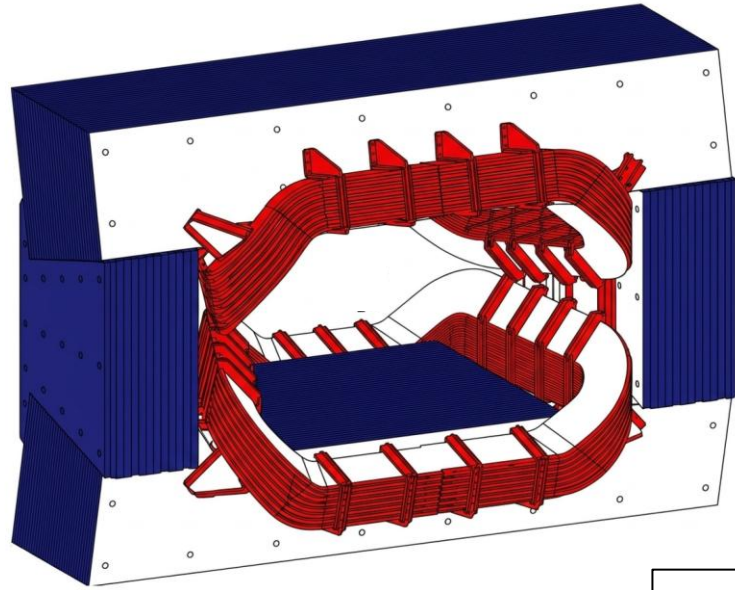
Requitements for K10 spectrometer

- **Forward dipole type magnet:** Forward scattering due to kinematics
 - **Acceptance** for forward scattered particles
 - Wide angler coverage ($\theta < 90^\circ$) for both missing mass and decay measurement
 - **Good momentum resolution** for forward scattered particles
 - $\Delta p/p \sim 0.2\%$ level @ 5 GeV/c
- **Detectors for spectrometer system**
 - High-rate detectors for high-intensity $K^-/\bar{p}$ (+contaminated π^-) beam measurement
 - Good PID system with both good efficiency and little wrong identification
 - Multi-layer tracking system for measuring multi-track events
 - Large size detectors for covering widely scattered particles
 - **Target surrounding detector system for precise vertex measurement**
 - **Neutral particle (γ -ray, $e^\pm$) detector using calorimeter technique**
- **Trigger-less streaming readout DAQ system (SRODAQ)**
 - Simultaneous data taking of many reaction channels

⇒ **MARQ-like forward spectrometer with extended capabilities**

A conceptual image of K10 spectrometer

Super-conducting dipole magnet



* LHCb-type dipole magnet:
Saddle-type coil structure with
trapezoidal profiles

Side view

*Magnet and detector
sizes are not scaled.

Beam detector
(Timing & Tracking)

Beam

Beam PID detector

Target surrounding system
(Timing & Tracking)

Magnet internal detector
(Tracking & Timing & Calorimeter)

Dipole magnet

Magnet pole

Target

Magnet pole

Muon & Calorimeter

Scattered particle tracker

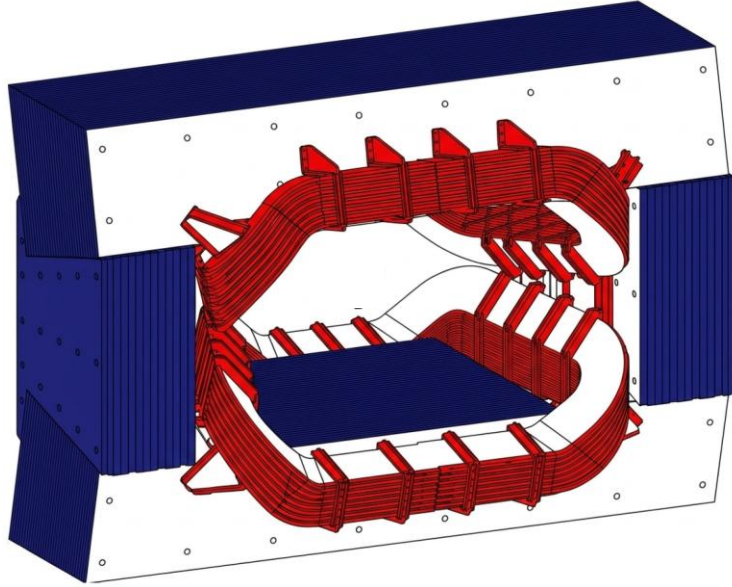
Scattered particle TOF

Scattered particle PID

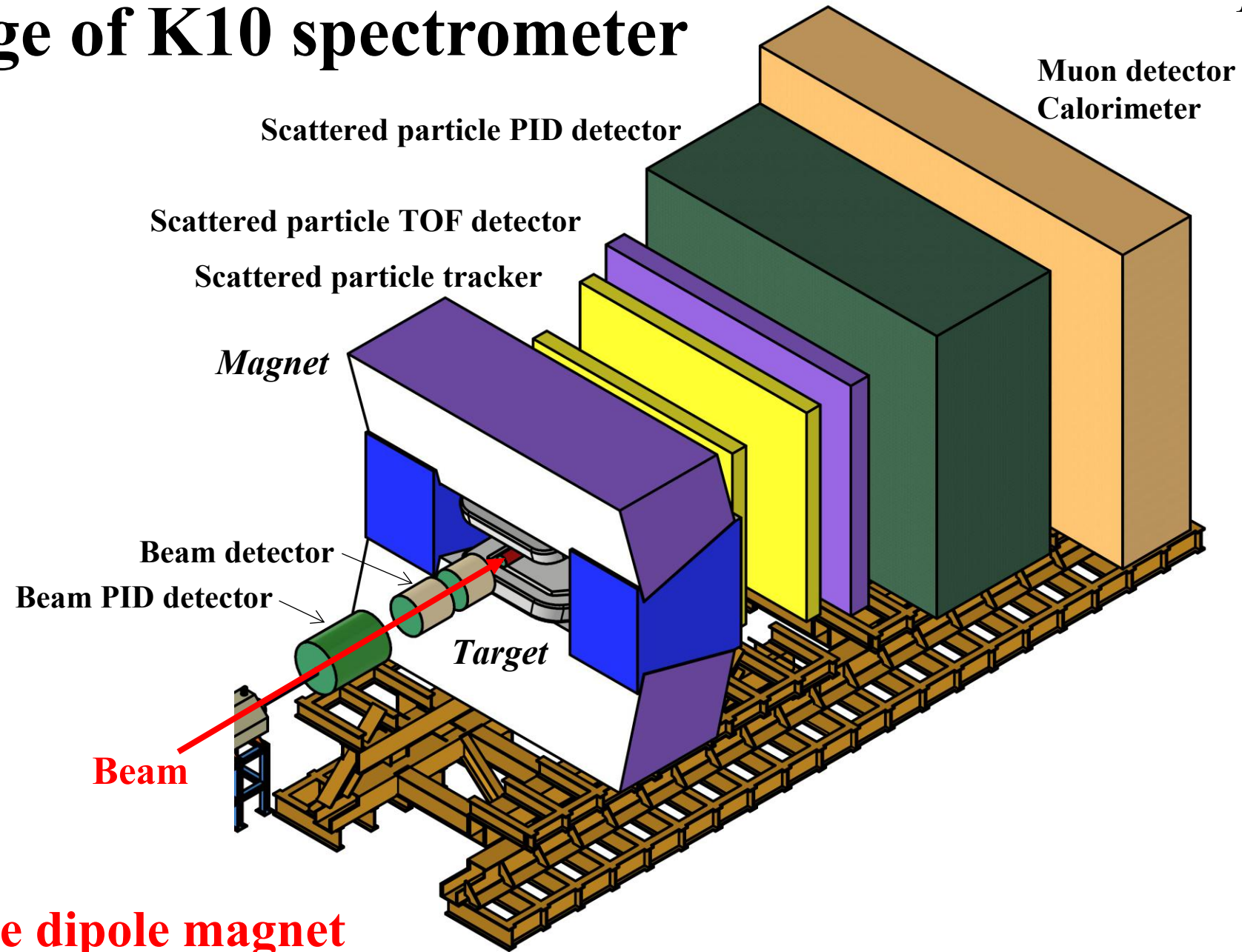
- **Super-conducting single dipole magnet**
- **In-magnet target station** for covering wide scattering angles

A conceptual image of K10 spectrometer

Super-conducting dipole magnet



* LHCb-type dipole magnet:
Saddle-type coil structure with
trapezoidal profiles

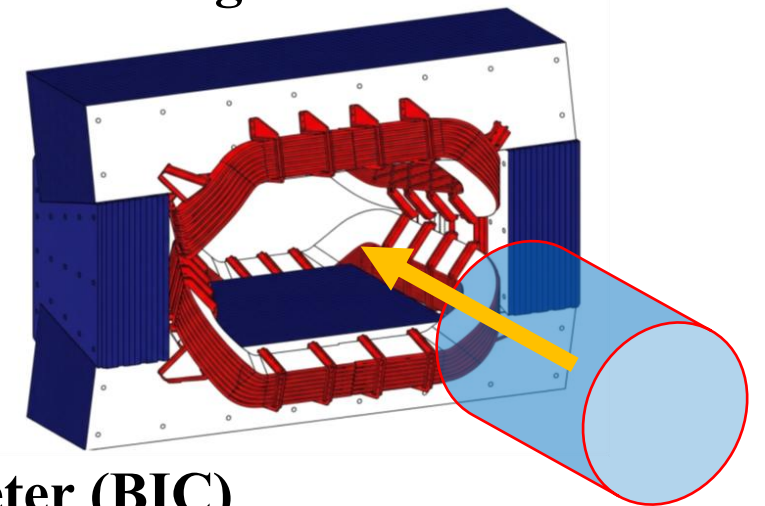
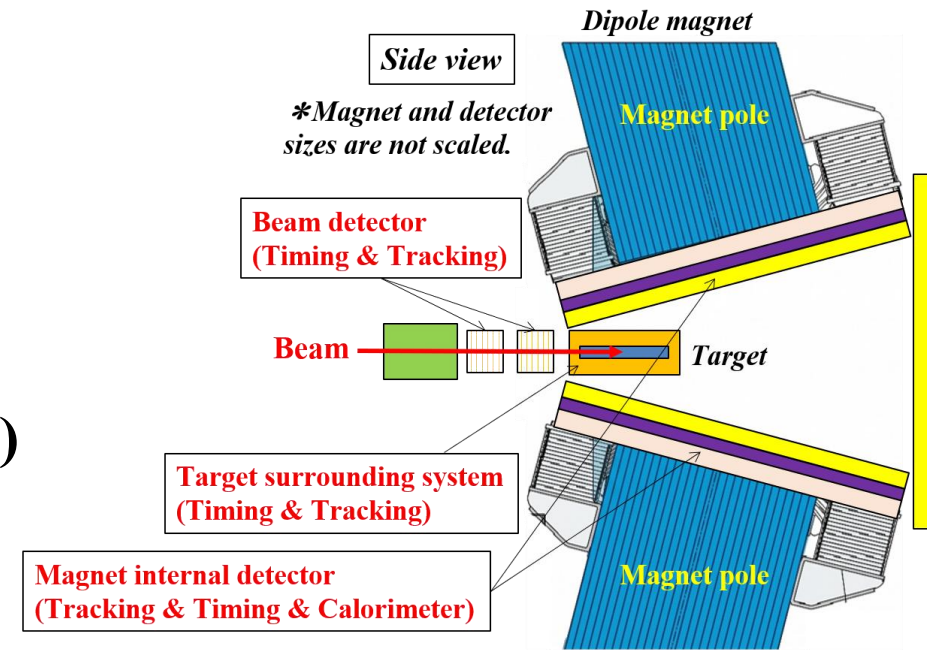


- Super-conducting single dipole magnet
- In-magnet target station for covering wide scattering angles

Detector candidates to design K10 spectrometer

* There are various candidate detectors.

- Let's design new spectrometer system !
- Beam and target surrounding detectors
 - * High-rate capability and low material
 - Scintillating fiber tracker (used by MARQ→“MARQ”)
 - Fine segmented timing detector (MARQ)
 - Fine segmented detector (e.g. AC-LGAD: 4D tracking)
 - Monolithic Active Pixel Sensors (MAPS)
 - Micro-Pattern Gaseous Detectors (MPGDs): GEM and Micromegas
- Magnet internal detectors
 - * Large coverage (cylinder/cone-shape configuration?)
 - Drift chamber (DC) (MARQ)
 - Resistive Plate Chamber (RPC) (MARQ)
 - Plastic scintillator timing detector (PS) (MARQ)
 - MPGDs: GEM and Micromegas
 - Calorimeter technique ($e^\pm/\gamma$): Barrel Imaging Calorimeter (BIC)

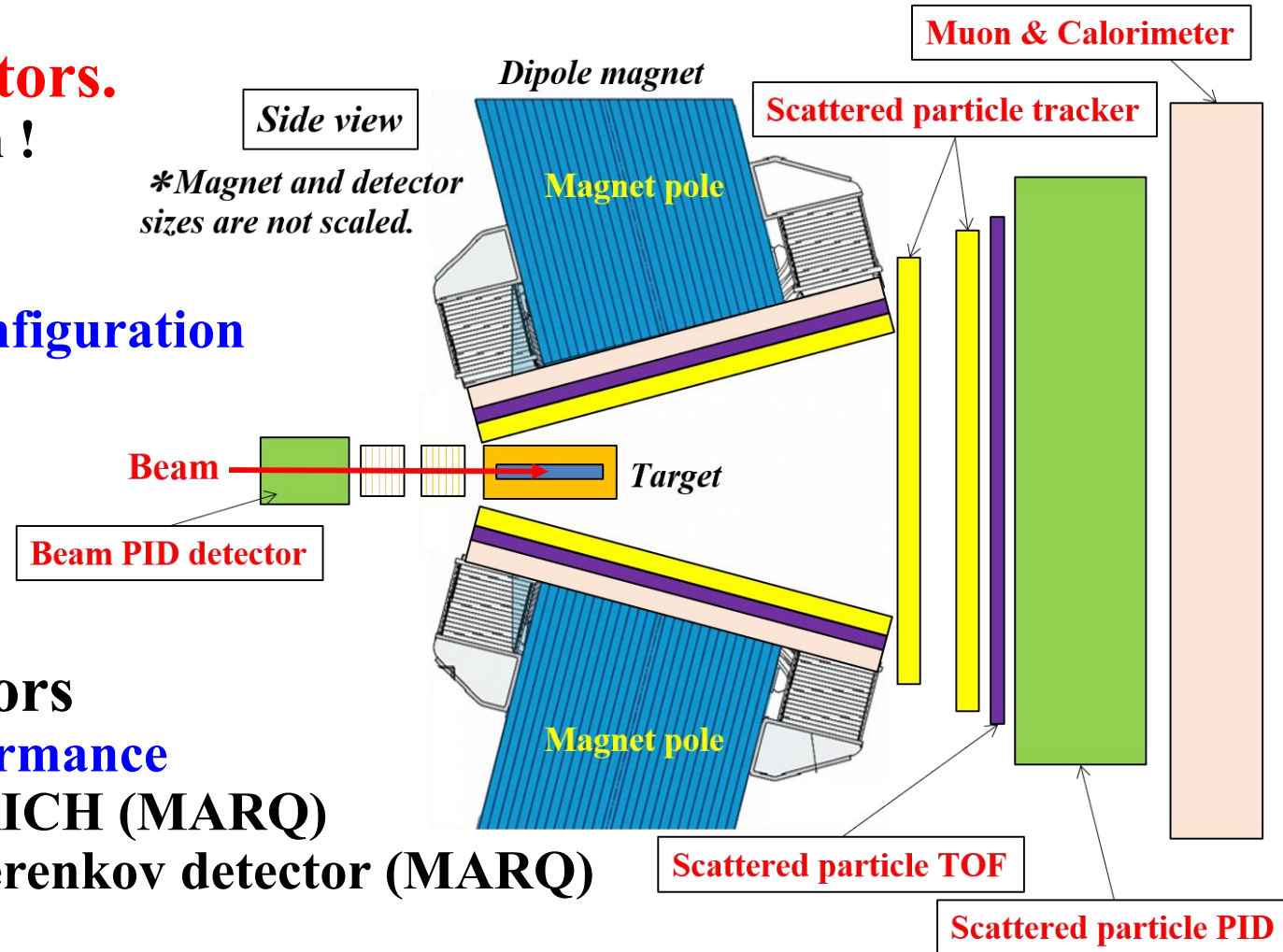


Cylinder-type system?

Detector candidates to design K10 spectrometer

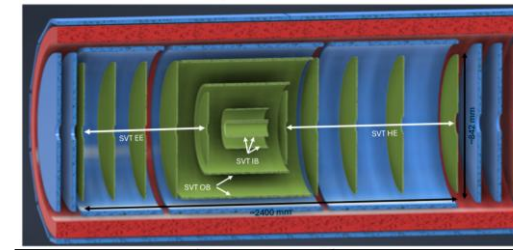
* There are various candidate detectors.

- Let's design new spectrometer system !
- Scattered particle detectors
 - * Large coverage and planer-shape configuration
 - DC (MARQ)
 - Straw-Tube tracker (STT) (MARQ)
 - PS and RPC (MARQ)
 - MPGD: GEM and Micromegas
- Particle identification (PID) detectors
 - * Large coverage with good-PID performance
 - Ring-Imaging Cherenkov detector: RICH (MARQ)
 - Beam-RICH and Threshold-type Cherenkov detector (MARQ)
 - Muon detector (MARQ)
 - Calorimeter technique ($e^\pm/\gamma$): BIC
- Beamline spectrometer: Same as beam and target surrounding detectors

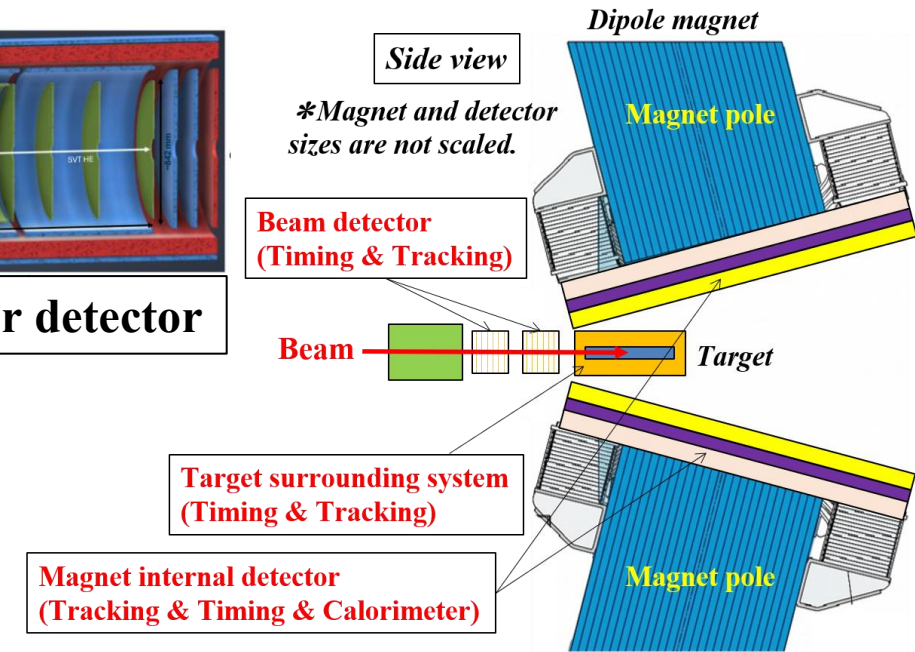


Detector R&D collaboration work

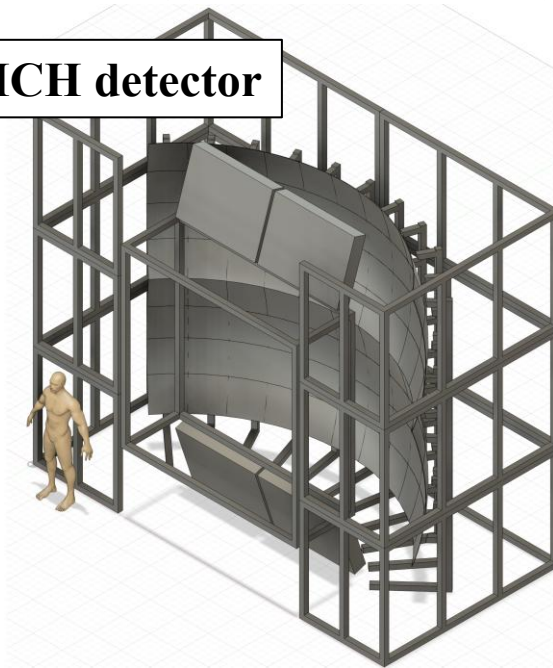
- Target surrounding system
 - Detector and FEE R&D
- Magnet internal detector
 - Design of detector configuration
 - Tracker, timing detector, calorimeter technique ($e^\pm/\gamma$)
- Large downstream detectors
 - RICH: Collaboration with MARQ RICH
 - Large-size DC/STT/MPGDs
- Muon and neutral particle ($e^\pm/\gamma$) detector (e.g. BIC)
 - Large size calorimeter for $e^\pm/\gamma$ (up to 10 GeV/c)
 - Muon ID method development
- Mini-ePIC @ $\pi 20$: EIC detector and DAQ integration test



e.g. EIC inner detector

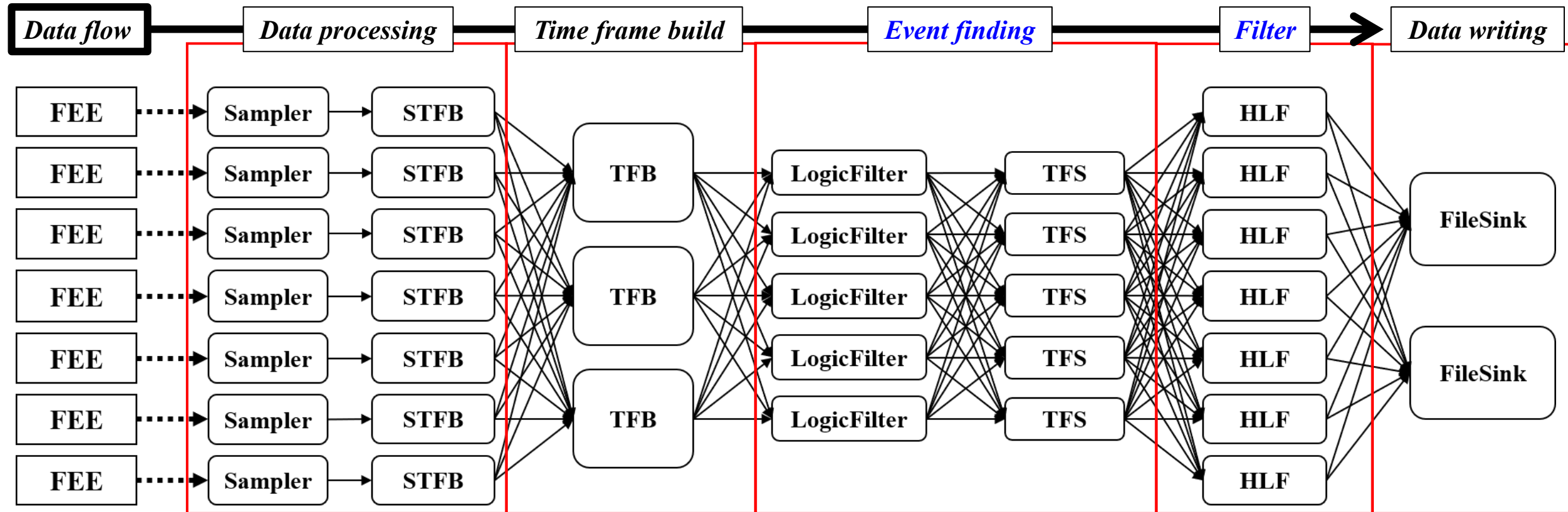


MARQ-RICH detector



*** R&D with next-generation detector technologies**

DAQ concept: Trigger-less streaming-readout DAQ



*** SRODAQ: Flexibility and scalability for various experimental conditions**

⇒ Simultaneous data taking of many reaction channels

- **Front-End-Electronics (FEE):** Common feature and Timing synchronization
- **Data selection based on software (CPU/GPU):** **Filter condition** by each experiment

Summary

- **Spectrometer concept for physics at K10: Missing mass spectroscopy**
 - Comprehensive measurements: Production and Decay
 - Production measurement accessing to wave function
- **K10 spectrometer design concept: Forward single dipole type system**
 - Single dipole system: Large acceptance with good momentum resolution
 - In-magnet target station
 - Multi-particle detection by maintaining good momentum resolution
- **Detector and DAQ R&D with next-generation detector technologies**
 - Beam detectors
 - Target surrounding detector system
 - Magnet internal detector system
 - Large scattered particle detectors
 - Streaming readout DAQ system

****Let's realize "KDREAMS" at J-PARC K10 !***