Performance studies for J/ψ measurements in p+A collisions with CBM

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Introduction

The CBM experiment at FAIR aims to explore the QCD phase diagram at moderate temperatures and high net-baryon densities. The J/ψ meson is considered to be one of the most important observables for the Quark-Gluon Plasma (QGP), since the potential that binds the $c\bar{c}$-pair can be screened by the presence of free color charges. Besides QGP effects, a part of the suppression happens because of cold nuclear matter effects. We can analyze the contribution of these effects in p+A collisions, where no QGP is expected.

In this work we present a simulation of the J/ψ production in p+Au collisions to study the performance of the detector setup in the CBM experiment. Additionally, we discuss fast simulation methods which allow to generate huge amounts of events, needed to produce a significant J/ψ signal.

J/ψ reconstruction

Cuts:

Acceptance cuts:
- $p_T > 850\frac{MeV}{c}$
- $N_{hit} > 0$ for TRD
- RICH projection

RICH PID cuts:
- $N_{hit} > 6$
- ANN-PIDe > -0.95

STS reconstruction cuts:
- $\chi^2/\mathrm{ndf} < 3$
- $N_{hit} > 3$ for STS

TRD PID cuts:
- $4 > N_{hit} > 2$
- ANN-PIDe > -0.68

Efficiency:

The efficiency depends on the detector geometry and the applied cuts. The TRD is tuned to an electron efficiency of 90%. This results in a total efficiency of $\sim$ 65% for single electron and $\sim$ 25% for J/ψ-pairs in the RICH+TRD+TOF setup.

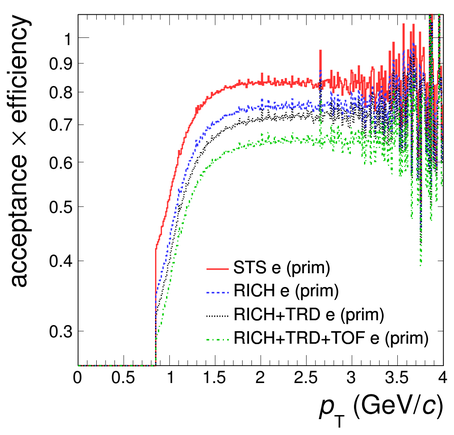

Fig. 1: Single electron efficiency of different detector setups.

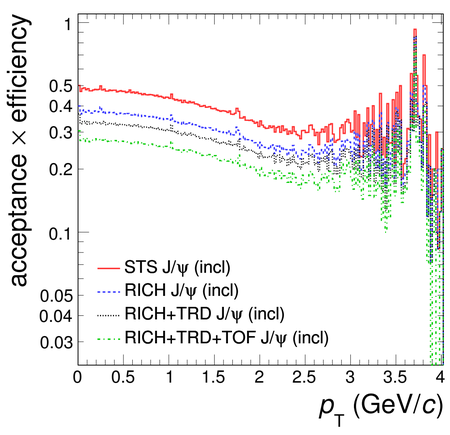

Fig. 2: J/ψ-pair efficiency of different detector setups.

Dielectron Spectrum (for p+Au collisions at E_{beam} = 30 GeV):

- main background contribution: eπ-combinations
- mixed-event method to estimate the background for further analysis $\rightarrow$ J/ψ signal extraction

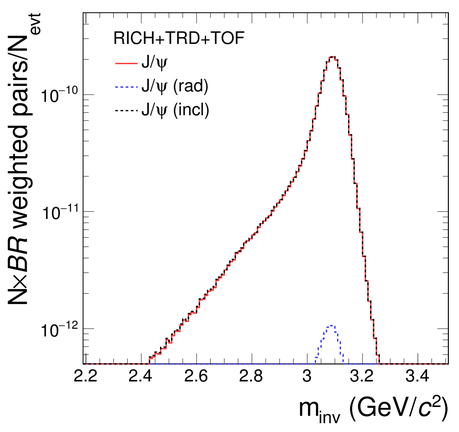

Fig. 3: Invariant mass distribution of J/ψ divided by N_{evt}.

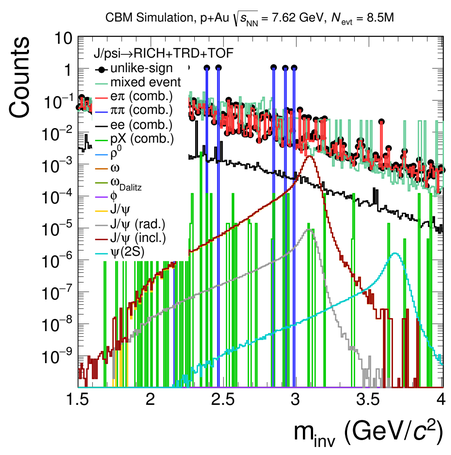

Fig. 4: Invariant mass distribution after all cuts.

$\Rightarrow$ not enough statistics to produce a significant J/ψ signal with a full simulation. A possible solution is the 'fast simulation' concept.

Simulation

Central proton-gold (p+Au) collisions at $\sqrt{s_{NN}}$ = **7.62 GeV**. Particle transport with Geant3.

Software & Setup:

- SIS100 electron setup: STS, RICH, TRD, TOF // no MVD
- default geometries for all detectors

Generated events:

- background particles with UrQMD
- low-mass vector-meson cocktail with pluto + yield prediction with HSD
- J/ψ and ψ(2S) with pluto

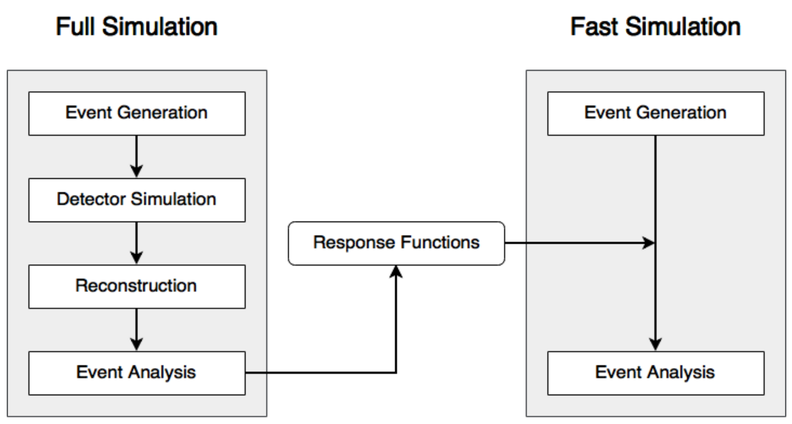

Fig. 5: Comparison of the full Simulation to the fast simulation.

Fast Simulation

Advantages: skips time-consuming particle transport and track reconstruction.
$\Rightarrow$ more statistics in less time

Response function:

Information of full simulation are gathered in response functions. It consist of three main parts:

1. Efficiency: detection probability for different particles
2. Smearing or resolution: accuracy of reconstructed values
3. Particle identification: probability for identifying electrons as pions

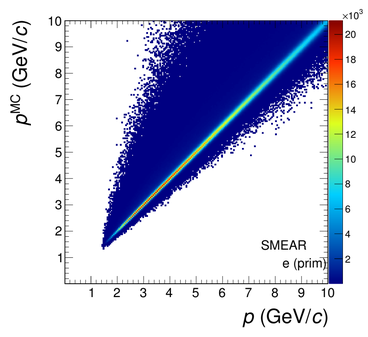

Fig. 6: Example of p smearing of electrons.

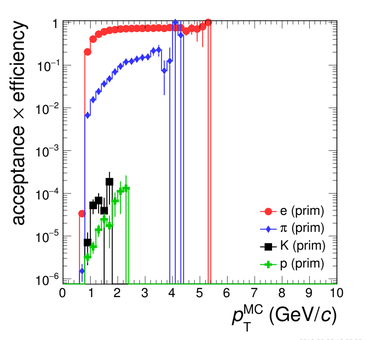

Fig. 7: p_T efficiency of different particles.

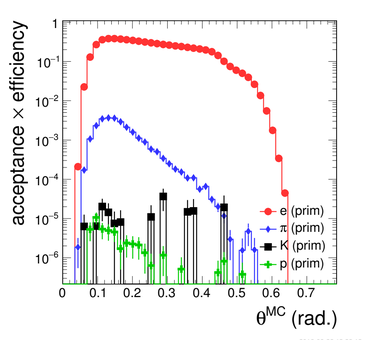

Fig. 8: Θ efficiency of different particles.

Dielectron Spectrum (for p+Au collisions at E_{beam} = 30 GeV):

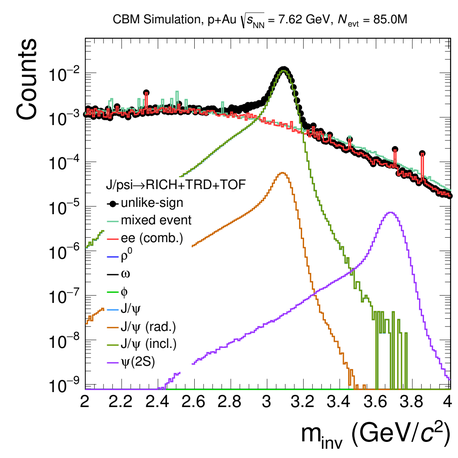

Fig. 9: Invariant mass distribution with fast simulation method.

- J/ψ signal and background shape matches full simulation shapes
- background of misidentified pions not yet included; will be added in the future

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