Heavy-flavour production

Estimation of γ, π^0 and η ratios in the photonic background in proton-proton collisions at $\sqrt{s} = 7$ TeV with ALICE

Fabrizio Grosa

University of Turin, Italy

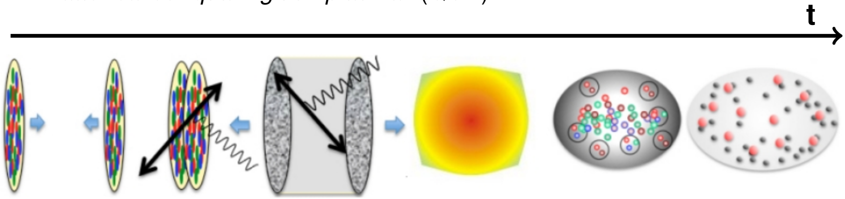
GSI Summer Student Program 2014

Outline

1. Heavy-flavour production in heavy-ion collisions
2. Photonic background
3. Results and outlook

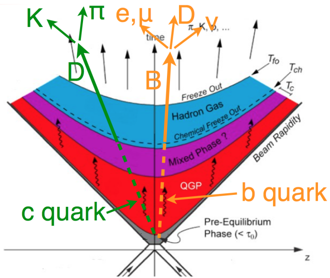
Quark-gluon plasma

- QCD predicts that under extreme conditions of very high temperature or energy densities, hadronic matter transit to a deconfined phase of matter called *“quark-gluon plasma“* (QGP)



- **Collision**: large number of hard scatterings between partons.
- **Thermalization** : the thermal equilibrium is reached.
- **QGP**: the fireball is created, in which quarks and gluons are free.
- **Hadronization** : the quarks and the glouns are recombined in hadrons.
- **Chemical freeze-out**: inelastic scattering cease.
- **Kinetic freeze-out** : elastic scattering cease.

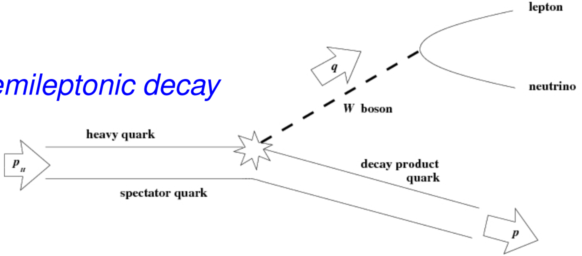
Heavy-flavour production



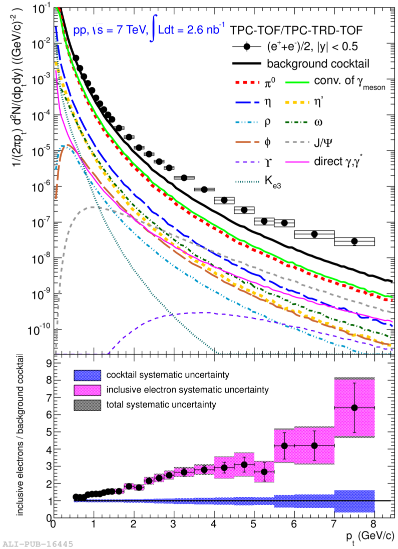
- Heavy-flavour production happens through initial hard partonic scattering processes when the medium is more dense
- Heavy-flavour quarks lose energy travelling in the QGP

Probe for the QGP

semileptonic decay

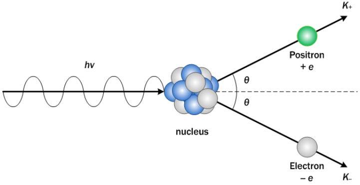


Background of heavy-flavour hadron decays

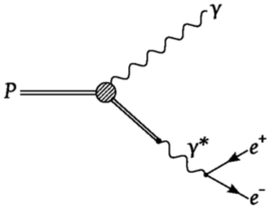


- There are other sources of leptons which form the background for the heavy-flavour hadron semileptonic decay.
- The *inclusive* electrons and positrons are all the $e^{\pm}$ measured, which are decay products of both hadrons carrying heavy quarks, and the background sources.
- After the subtraction of the background only the remaining p_T spectrum contains electrons from heavy-flavour hadron decays only.

Main sources of the photonic background

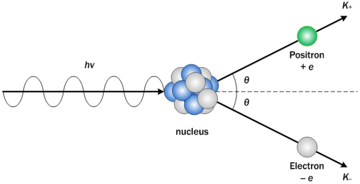


- Photon conversion: $\gamma \rightarrow e^+e^-$

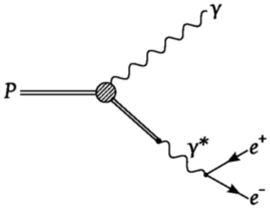


- Dalitz decays:
$$\pi^0 \rightarrow e^+e^-\gamma$$
$$\eta \rightarrow e^+e^-\gamma$$
$$\eta' \rightarrow e^+e^-\gamma$$
$$\omega \rightarrow e^+e^-\pi_0$$
$$\phi \rightarrow e^+e^-\eta$$

Main sources of the photonic background



- Photon conversion: $\boxed{\gamma \rightarrow e^{+}e^{-}}$

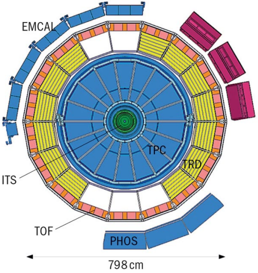


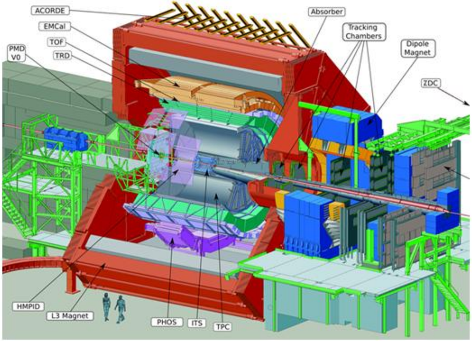
- Dalitz decays: $\boxed{\begin{array}{l}\pi^{0} \rightarrow e^{+}e^{-}\gamma \\ \eta \rightarrow e^{+}e^{-}\gamma\end{array}}$
$$\eta' \rightarrow e^{+}e^{-}\gamma$$
$$\omega \rightarrow e^{+}e^{-}\pi_{0}$$
$$\phi \rightarrow e^{+}e^{-}\eta$$

The aim of this study is to calculate the ratio between photon conversions and Dalitz decays in the photonic background

The ALICE detector

- ALICE is the experiment at LHC dedicated to heavy-ion collisions





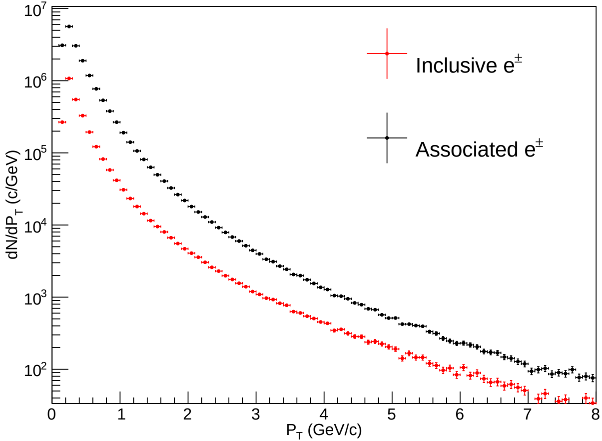
- **I**nner **T**racking **S**ystem: first sub detector reached by the particles originating in the primary vertex
- **T**ime **P**rojection **C**hamber: the main tracking detector

Data samples

- simulated proton-proton collision events at $\sqrt{s} = 7\,TeV$
  - decayed with *Pythia 6*
  - propagation through detectors described with ***GE****ometry* ***AN****d* ***T****racking* 3
  - tracks reconstructed with AliROOT
- this study is focused on proton-proton collisions because they are the reference system for the Pb-Pb collisions

$e^{\pm}$ identification

- Inclusive $e^{\pm}$ $\longrightarrow$ stringent cuts are required
- Associated $e^{\pm}$ $\longrightarrow$ relaxed cuts are required: tracks resolution is lost, but efficiency is maximised



Finally, using the MC truth information, only the tracks that really belong to $e^{\pm}$ are selected

Invariant mass analysis

According to Special Relativity the four-momentum $p = (E, \vec{p})$ of a physics system is always conserved, and the mass of a particle is equal to:

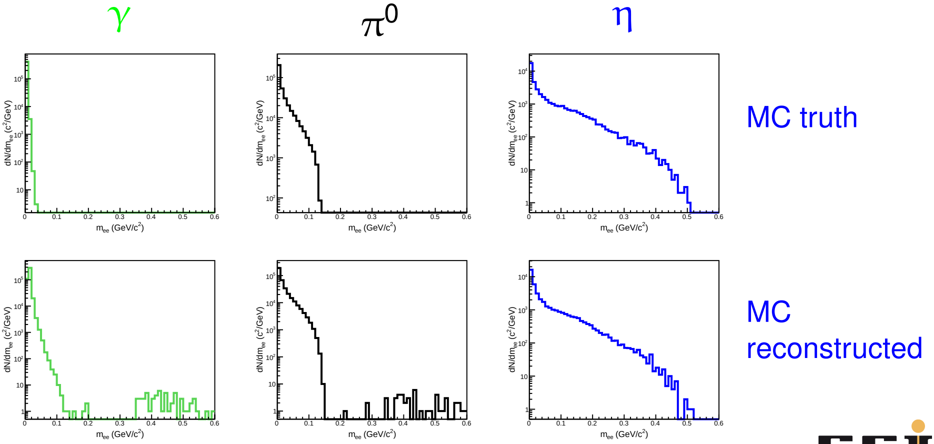
$$\boxed{m_i^2 = E_i^2 - \vec{p_i}^2 \equiv p_i^2}$$

$\longrightarrow$ we can calculate the invariant mass of a particle from its decay products

$$\boxed{m_{ee} = \sqrt{(p_1 + p_2)^2} = \sqrt{(E_1 + E_2)^2 - (\vec{p_1} + \vec{p_2})^2}}$$

Invariant mass distributions from MC truth

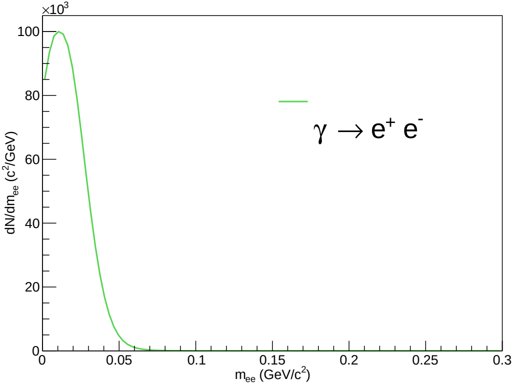
$\longrightarrow$ Using the MC truth information is possible to know the mother particle of every e^+e^- pair $\longrightarrow$ obtained the invariant mass distribution of each source



Distribution for photons

- For the photon conversion $\longrightarrow$ exponentially modified Gaussian distribution:

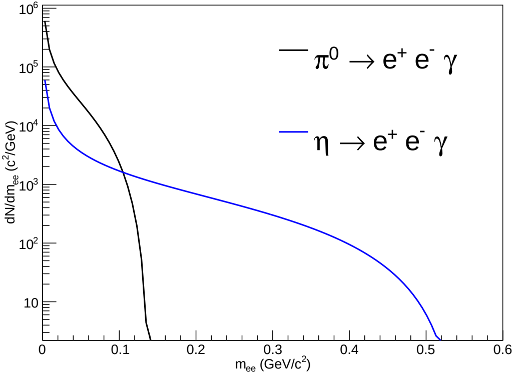
$$\frac{dN}{dm_{ee}} = N_{\gamma} \cdot e^{-\frac{(m_{ee}-M_{\gamma})^2}{2\sigma^2}} + \Theta(m_{ee} - M_{\gamma})\, e^{\frac{m_{ee}-M_{\gamma}}{\tau}}$$



Kroll-Wada distribution

- For the Dalitz decays $\longrightarrow$ Kroll-Wada distribution:

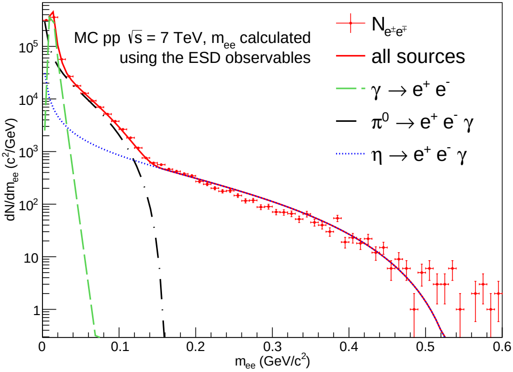
$$\frac{dN}{dm_{ee}} = N_X \cdot \frac{2}{m_{ee}} \left\{ (1+(m_{ee}/M_X)^2)^2 - 4(m_{ee}/M_X)^2 \right\}^{3/2} \sqrt{1 - \frac{4(m_e/M_X)^2}{(m_{ee}/M_X)^2}} \cdot \left\{ 1 + \frac{2(m_e/M_X)^2}{(m_{ee}/M_X)^2} \right\} \cdot F_X(m_{ee}^2)$$



where
$$\begin{cases} F_{\pi^0}(m_{ee}^2) = \frac{1}{(1-5.5 \cdot m_{ee}^2)^2} \\ F_\eta(m_{ee}^2) = \frac{1}{(1-1.9 \cdot m_{ee}^2)^2} \end{cases}$$

Fit template

- Select e^+e^- pair with same γ, π^0 or η mother particle from MC truth
- Calculate their invariant mass and obtain the relative distribution
- Fit with the function which is the sum of the three contributions



From MC truth

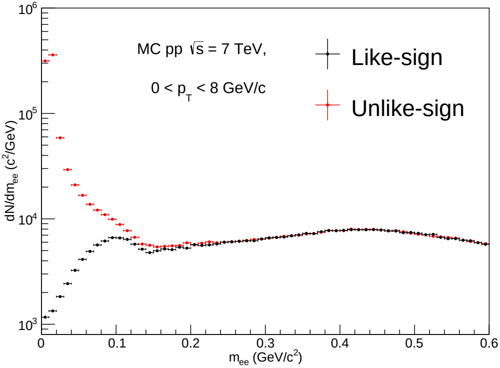
number of γ	418300 ± 600
number of π^0	362000 ± 600
number of η	42100 ± 200
n_γ/n_{π^0}	1.156 ± 0.003
n_γ/n_η	9.94 ± 0.05
$n_\gamma/(n_{\pi^0}+n_\eta)$	1.035 ± 0.002

From the Fit

M_γ	$0.01107 \pm 0.00018\ GeV/c^2$
M_{π^0}	$0.1611 \pm 0.0003\ GeV/c^2$
M_η	$0.558 \pm 0.004\ GeV/c^2$
Integral of γ	418300 ± 1100
Integral of π^0	355000 ± 2000
Integral of η	49200 ± 600
I_γ/I_{π^0}	1.179 ± 0.007
I_γ/I_η	8.50 ± 0.11
$I_\gamma/(I_{\pi^0}+I_\eta)$	1.035 ± 0.006

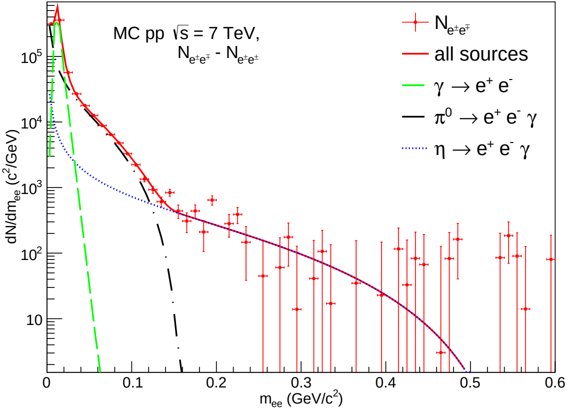
Like-sign and Unlike-sign distributions

- Unlike-sign distribution
  - → inclusive $e^{\pm}$ + associated $e^{\mp}$
    - → photonic signal + combinatorial background
- Like-sign distribution
  - → inclusive $e^{\pm}$ + associated $e^{\pm}$
    - → combinatorial background



Fit of the photonic background

- The like-sign distribution is subtracted to the unlike-sign distribution



- The resulting photonic signal is fitted with the template obtained from the MC truth

Integral of γ	423000 ± 6000
Integral of π^0	354000 ± 4000
Integral of η	42000 ± 3000
I_γ/I_{π^0}	1.19 ± 0.02
I_γ/I_η	10.0 ± 0.8
$I_\gamma/(I_{\pi^0}+I_\eta)$	1.07 ± 0.02

Results

Particle	Number from MC truth	Relative statistical error	Integral from photonic signal fit	Relative statistical error
γ	418300 ± 600	0.14%	423000 ± 6000	1.4%
π^0	362000 ± 600	0.17%	354000 ± 4000	1.1%
η	42100 ± 200	0.48%	42000 ± 3000	7.1%

Ratios	MC truth	Photonic signal fit	Gaussian test (num of σ)
γ/π^0	1.156 ± 0.003	1.19 ± 0.02	1.68
γ/η	9.94 ± 0.05	10.0 ± 0.8	0.07
$\gamma/(\pi^0 + \eta)$	1.035 ± 0.002	1.07 ± 0.02	1.73

Results

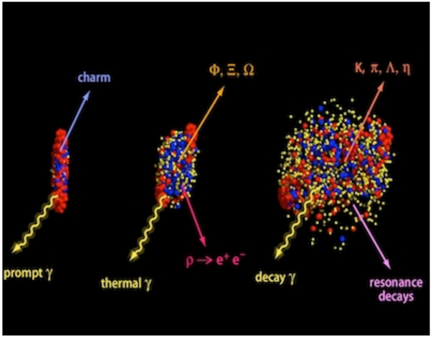
Particle	Number from MC truth	Relative statistical error	Integral from photonic signal fit	Relative statistical error
γ	418300 ± 600	0.14%	423000 ± 6000	1.4%
π^0	362000 ± 600	0.17%	354000 ± 4000	1.1%
η	42100 ± 200	0.48%	42000 ± 3000	7.1%

Ratios	MC truth	Photonic signal fit	Gaussian test (num of σ)
γ/π^0	1.156 ± 0.003	1.19 ± 0.02	1.68
γ/η	9.94 ± 0.05	10.0 ± 0.8	0.07
$\gamma/(\pi^0+\eta)$	1.035 ± 0.002	1.07 ± 0.02	1.73

LARGE STATISTICAL ERROR

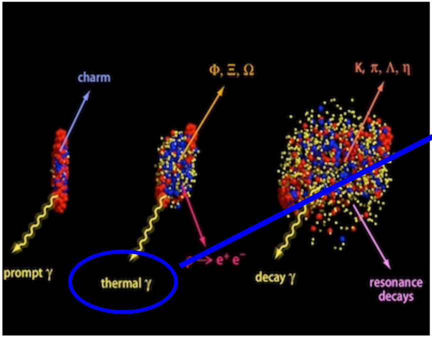
pp and Pb-Pb data

- look into proton-proton data and verify that the same ratios are found
- Pb-Pb events : What would be different?



pp and Pb-Pb data

- look into proton-proton data and verify that the same ratios are found
- Pb-Pb events : What would be different?



An excess of γ, due to the thermal photons generated by the fireball, is expected

$\downarrow$

the ratio between gamma conversion and Dalitz decays should be larger