Chapter 2:
Physics Motivation

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Chapter Outline

Physics Motivation

- Study properties of QCD in extended high-density systems via the probe-medium interaction
  - Interaction depends on colour charge and mass
  - Heavy quarks test both these aspects $\Delta E_g > \Delta E_{c \approx q} > \Delta E_b$
  - Do we observe this pattern?

$$R_{AA}^{p} < R_{AA}^{D} < R_{AA}^{B} \, ?$$

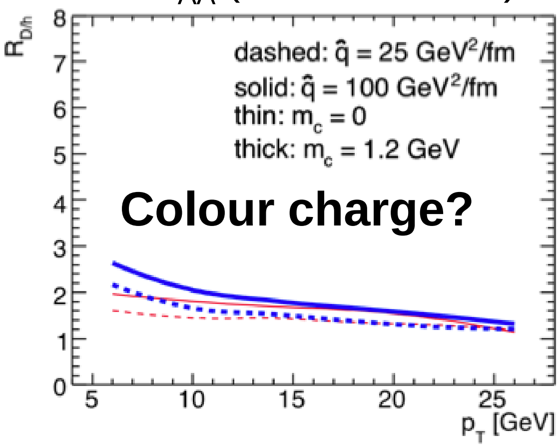
- Study the QGP thermalization and collectivity via heavy quark hadronization and flow
  - Are the quenched heavy quarks thermalized in the system?
  - Do they carry elliptic flow?
  - Do they hadronize via recombination?

$$v_{2,q} = v_{2,c} = v_{2,b} \, ?$$

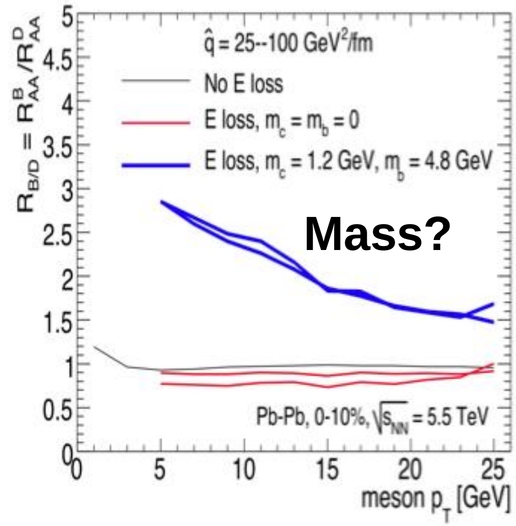
Energy Loss

- Goal: measure charm and beauty separately with high accuracy over a broad p_t range

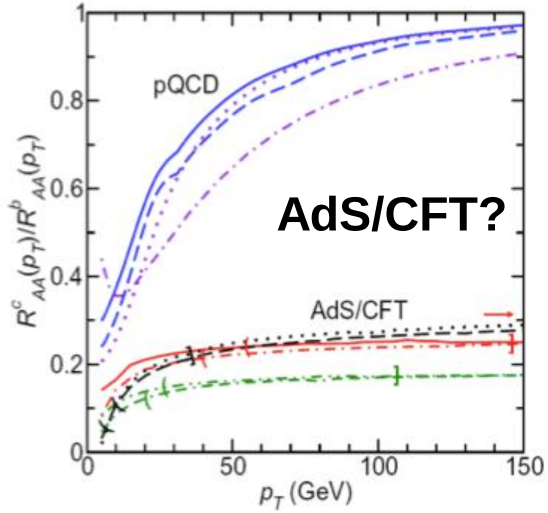
D/π R_{AA} (Armesto et al.)



B/D R_{AA} (Armesto et al.)

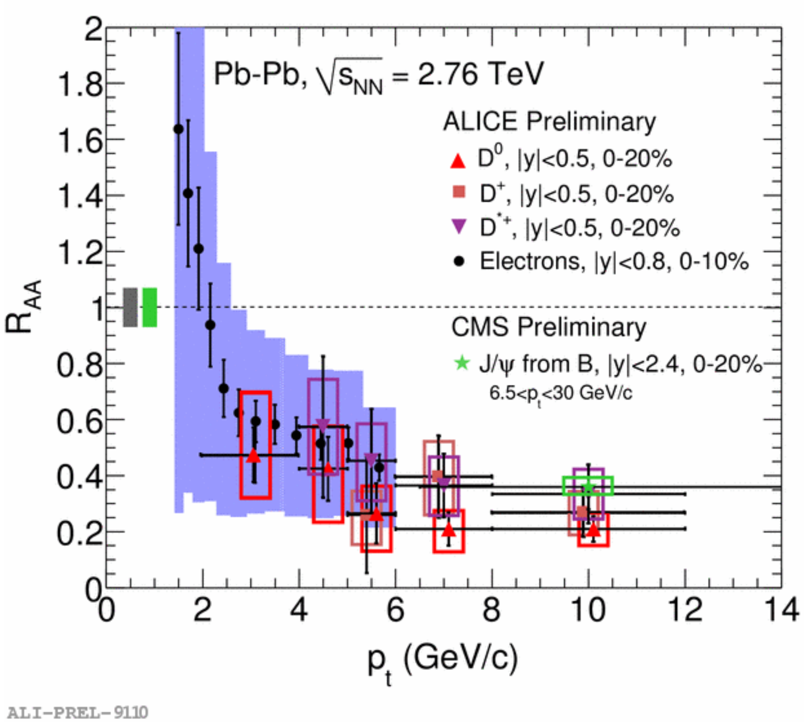


D/B R_{AA} (Horowitz et al.)



Energy Loss

- Current capability:
  - ALICE uniqueness: PID (→ charm); low p_t (low material and field);
  - ALICE limits: B/D separation difficult, especially at low p_t (electron PID + vertexing); indirect B measurement via electrons; charm difficult for $p_t \to 0$ (background is too large);
  - CMS has measured J/psi from B starting from 6.5 GeV/c

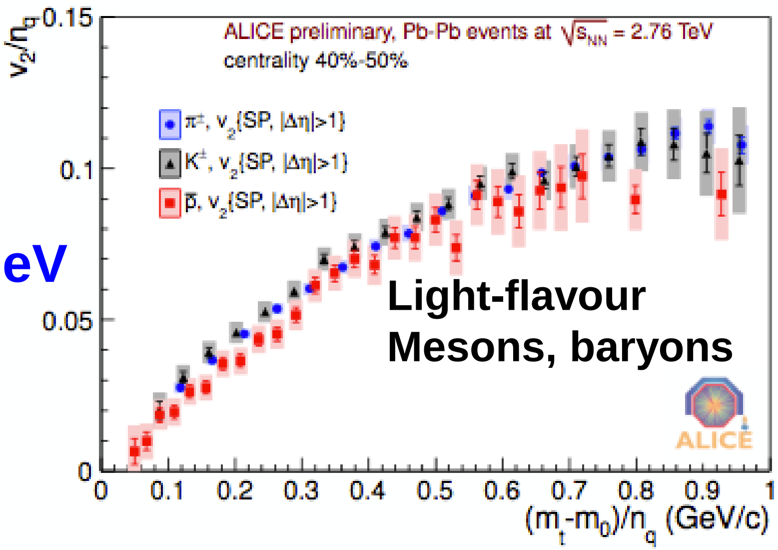


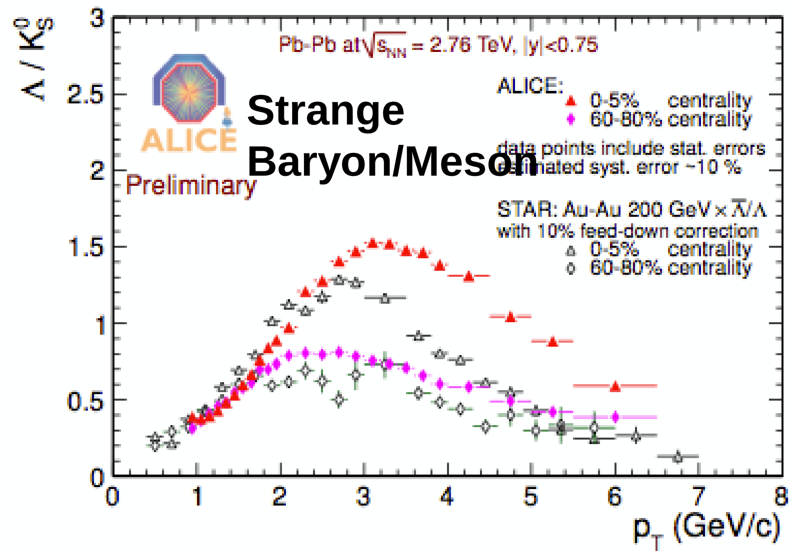
Hadronization and Flow

- Goal: measure v_2 and R_{CP} for HF mesons and baryons

v_2 constituent scaling and baryon/meson for charm (beauty?) → Λ_c

$m_{u,d}$~0
m_s~0.3 GeV



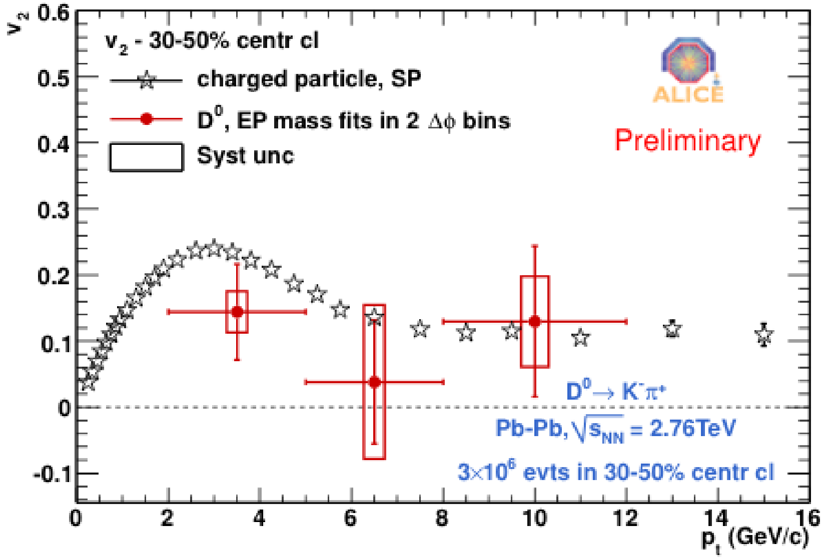


m_c~1.5 GeV **Λ_c and D elliptic flow** **Λ_c/D in central and periph.**

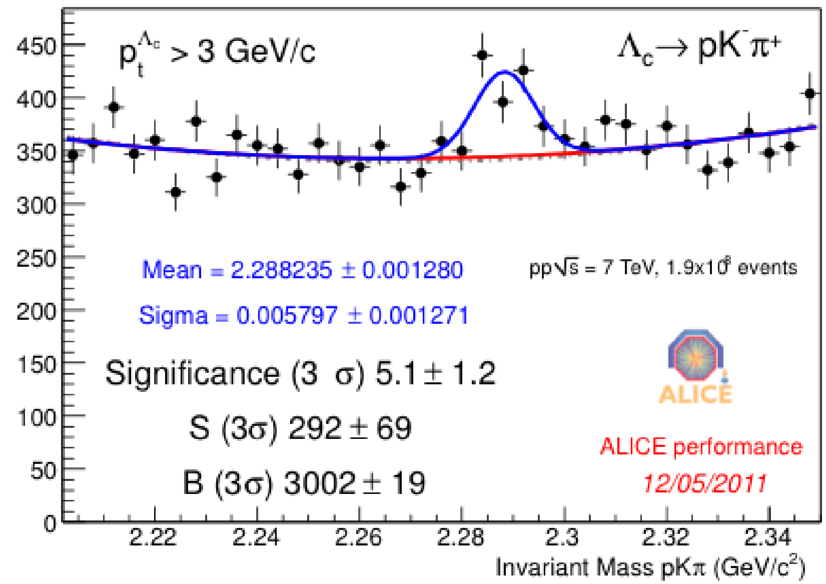
m_b~5 GeV **Λ_b vs B?**

Hadronization and Flow

- Current capability:
  - ALICE uniqueness: PID; low p_t (low material and field);
  - ALICE limits: resolution not sufficient (Λ_c $c\tau$ = 1/2 D^0 = 1/5 D^+); Λ_c at the limit in pp (only high p_t), impossible in Pb;
  - CMS limits: no PID → no Λ_c?; no dramatic resolution improvement with upgrade (25%?)



Hint of D meson flow from Pb 2010



Λ_c signal above 3 GeV in pp 2001

Possible measurements and expected yields

- Start to put together some numbers on the possibility to trigger
- Compute the expected raw yields (after selections)
- Estimate the signal yields for two cases:
  - Dedicated trigger running
  - Minimum bias running
- Caveats:
  - Acc x Eff from current data analysis + hydrid sim + guesses
  - Assume we can do at the trigger level the same selections done offline (PID + topology)
  - And that they have the same efficiency and bkg-rej. power

Yields and possible channels

Particle	Yield m.b., 0–10%	$dN/dy\|_{y=0}$ m.b., 0–10%	$c\tau$ [μm]	decay channel	B.R.	Acc.
D^0	23, 110	2.3, 11	≈ 120	$K^-\pi^+$	3.8%	1
Λ_c	2.9, 14	0.29, 1.4	≈ 60	$pK^-\pi^+$	5.0%	1
B	1.3, 6.2	0.2, 0.9	≈ 500	$J/\psi(\to e^+e^-)$	$1.2\% \times 6\%$	1
				$D^0(\to K^-\pi^+)$	$60\% \times 3.8\%$	1
				e^+	10.9%	1.8
B^+	0.6, 2.7	0.1, 0.4	≈ 500	$J/\psi(\to e^+e^-)K^+$	$0.1\% \times 6\%$	1
B_s^0	0.2, 0.9	0.03, 0.13	≈ 500	$J/\psi(\to e^+e^-)\phi(\to K^+K^-)$	$0.14\% \times 6\% \times 50\%$	1
Λ_b	0.1, 0.5	0.015, 0.07	≈ 400	$\Lambda_c(\to pK^-\pi^+) + e^-$	$9.9\% \times 5\%$	1
				$\Lambda_c(\to pK^-\pi^+) + h^-$	$90\%(\text{guess}) \times 5\%$	1

Pb-Pb running scenario

We consider the following running scenario for Pb–Pb, as a working hypothesis:

- instantaneous luminosity: 10^{27} cm^{-2}s^{-1}, which (using $\sigma_{\rm PbPb}^{\rm hadronic} = 8$ b) gives a hadronic interaction rate of 8 kHz (0.8 kHz in the 0–10% centrality class);
- effective running time: 5×10^5 seconds (20 days $\times$ 30% of time with stable beams);
- sustainable rate of collection of minimum-bias collisions (0–100%): 520 Hz (determined by the TPC readout time), out of which 52 Hz in the centrality class 0–10%;
- sustainable rate for rare triggers (per trigger): no limitation; currently this figure is about 100 Hz, but here we consider it as arbitrarily high, in order to estimate the maximum possible benefit of dedicated triggers.

Within the Upgrade Strategy task-force, a more ambitious scenario is being defined, which corresponds to a LHC luminosity increased by x10 → ~10^{28} cm^{-2}s^{-1} i.e. ~50-80 kHz
This could be added to the section for December release

Signal statistics: Pb-Pb m.b. 8 kHz

Particle	Eff	S/ev	S/B	trigger rate (Hz)	S without trigger	S with trigger
D^0	0.01	0.8×10^{-3}	0.06	340	2.2×10^5	3.2×10^6
Λ_c	0.01	1.4×10^{-4}	0.01	340	3.8×10^4	5.6×10^5
"	"	"	0.1	34	3.8×10^4	2.8×10^5
$B \to D^0(\to K^-\pi^+)$	0.01	0.4×10^{-4}	0.06	18	1.0×10^4	1.6×10^5
$B \to J/\psi(\to e^+e^-)$	0.1	1.3×10^{-5}	0.01	32	2.7×10^3	5.2×10^4
$B \to e^+$	0.05	1.3×10^{-2}	0.2	520	3.4×10^6	5.2×10^7
$B^+ \to J/\psi K^+$	0.01	0.5×10^{-7}	0.01	0.05	1.0×10^1	5.0×10^1
$B_s^0 \to J/\psi\phi$	0.01	1.1×10^{-8}	0.01	0.02	2.0×10^0	1.0×10^1
$\Lambda_b(\to \Lambda_c + e^-)$	0.01	0.7×10^{-6}	0.01	2	1.8×10^2	2.8×10^3
$\Lambda_b(\to \Lambda_c + h^-)$	0.01	0.7×10^{-5}	0.01	18	1.6×10^3	2.6×10^4

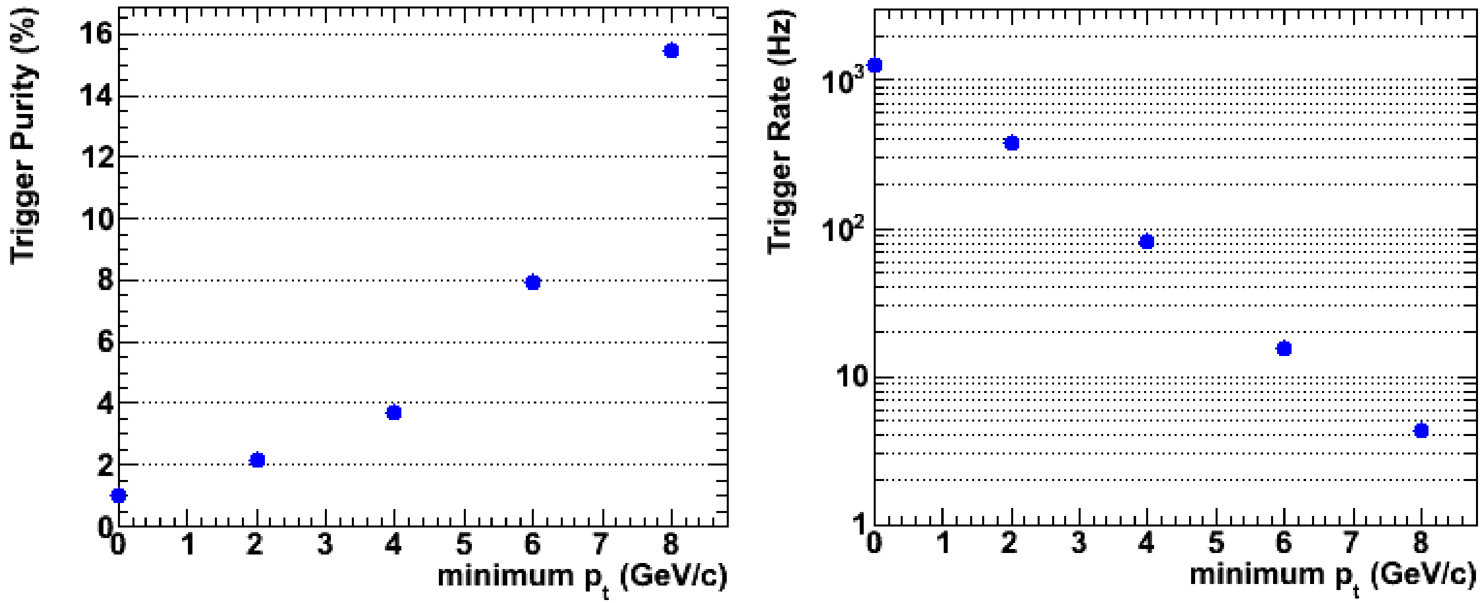
- The trigger rates are in the range 10^{-2}-10^2 Hz
- Factor 15 more signal with trigger
- Λ_b and reco-B signals interesting in view of 50 kHz or higher efficiency…

- To be continued:
  - Minimum p_t threshold
  - Realistic cut and PID efficiencies and bkg rejection

Ongoing update:
trigger rates vs p_t

- Add a set of figures with rate, purity, yield vs. p_t^{min}
  - for the D^0 as an example

D^0, 5.5 TeV
PbPb m.b. 8 kH

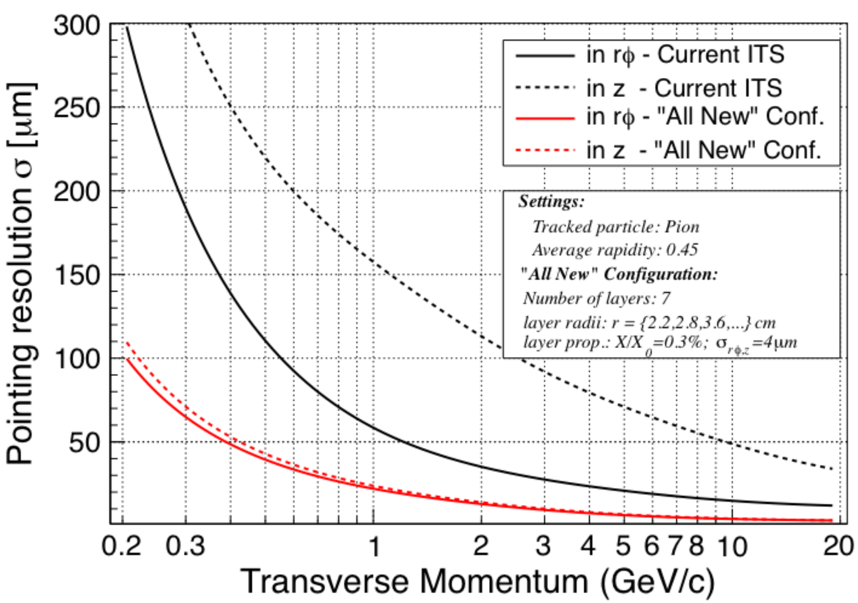


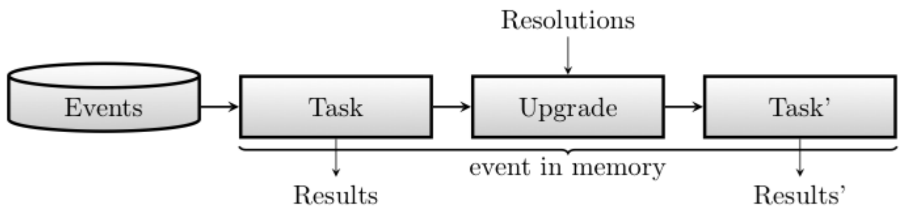
- + Add the cases Pb-Pb minimum-bias at 50 kHz? (80 kHz?)

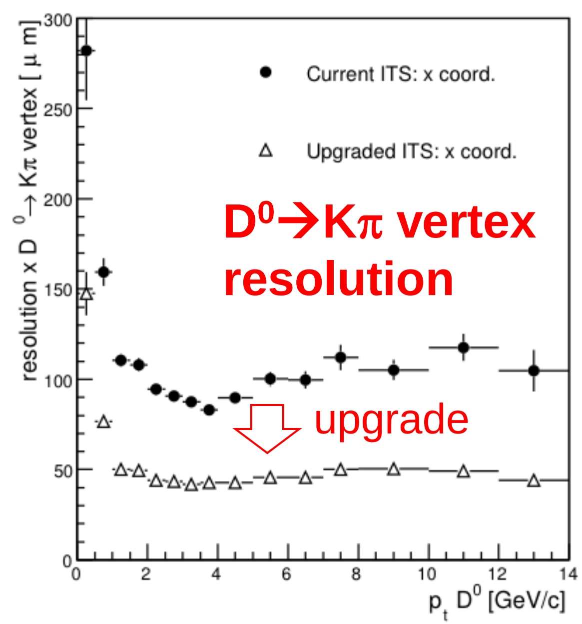
“Hybrid” simulation method

M. Mager

- Baseline upgrade scenario: “AllNew”, 7 layers of pixels with resolution $4x4\mu m^2$ and thickness 0.3% x/X_0
- Impact parameter and p_t resolutions from Fast Estimation Tool applied to existing ALICE simulations by rescaling the track parameter residuals (wrt MC truth)



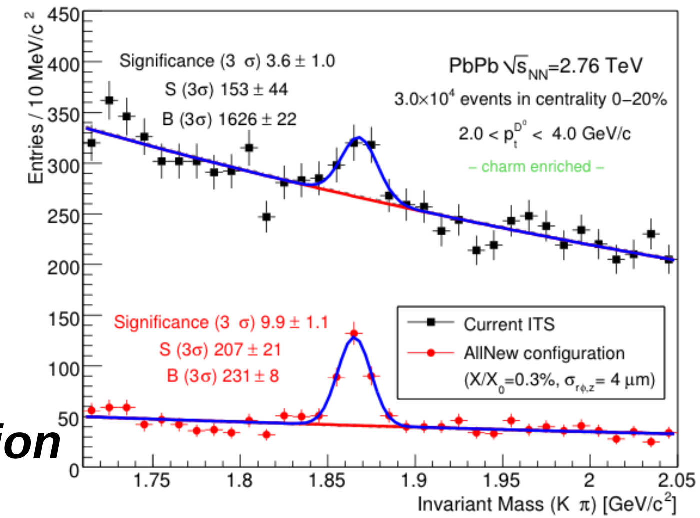




D^0 as a benchmark channel

A. Rossi, S. Moretto

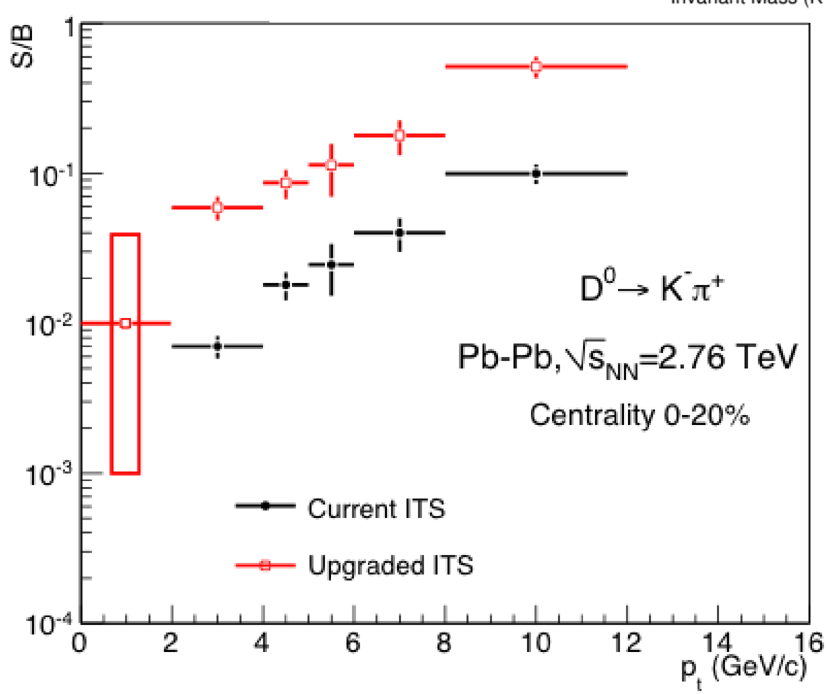
With partial cuts optimization

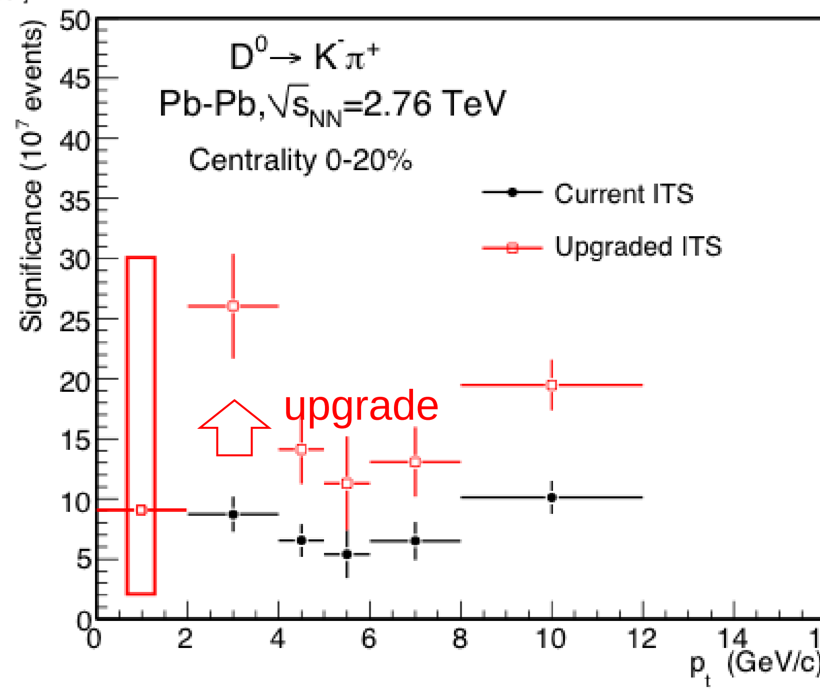


$D^0 \rightarrow K\pi$ in Pb-Pb:

→ ~0 p_t

→ S/B x10

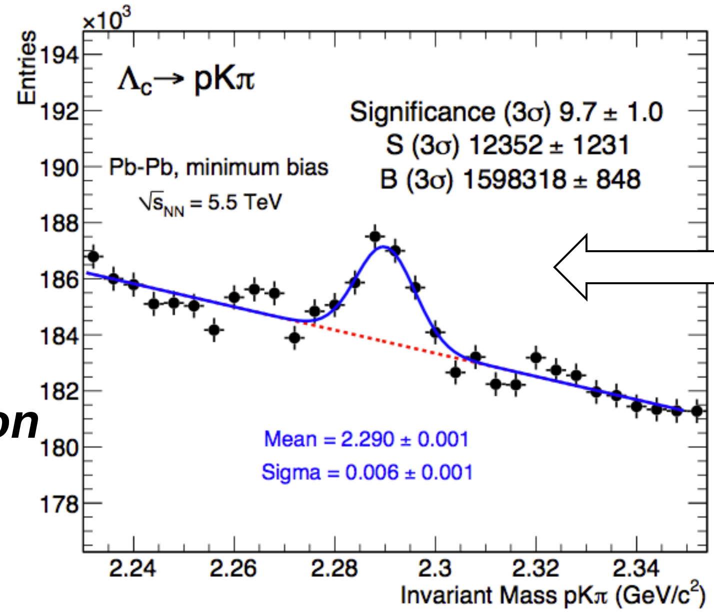




Charm baryons: Λ_c

C. Terrevoli, M. Mager

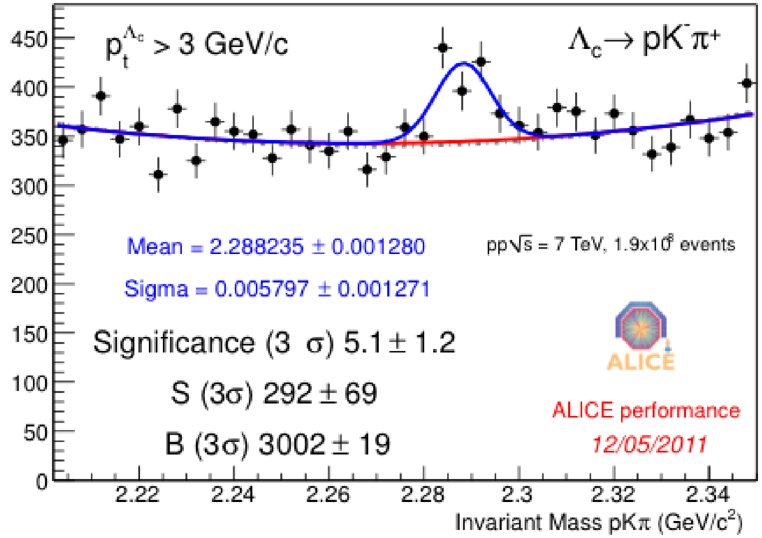
With partial cuts optimization



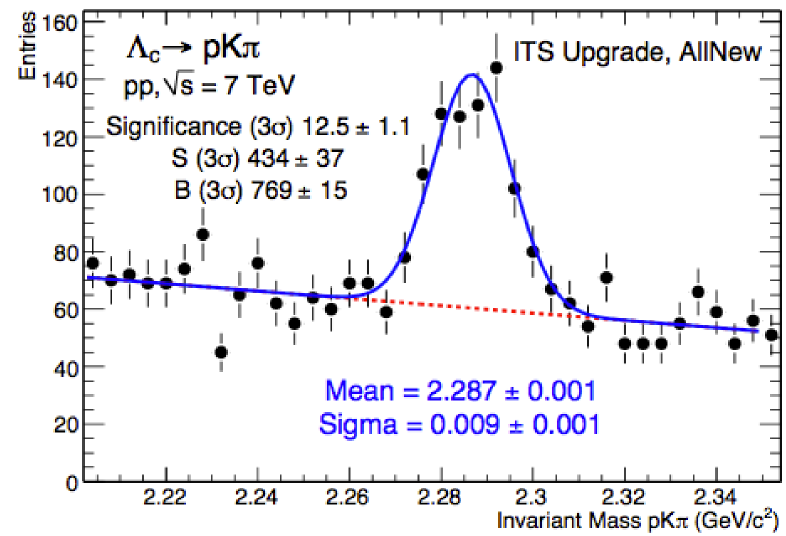
$\Lambda_c \to pK\pi$:

→ $p_t > 4$ in Pb-Pb

→ $p_t > 3$ in pp



upgrade

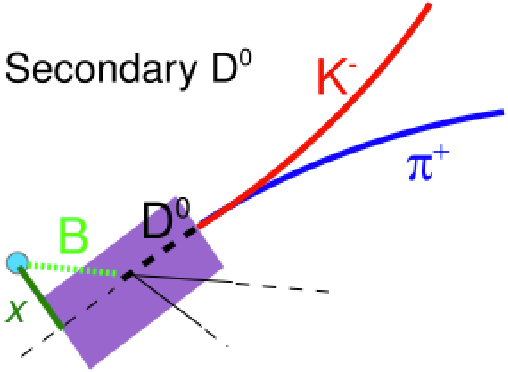


Ongoing updates: D^0 and Λ_c with other scenarios

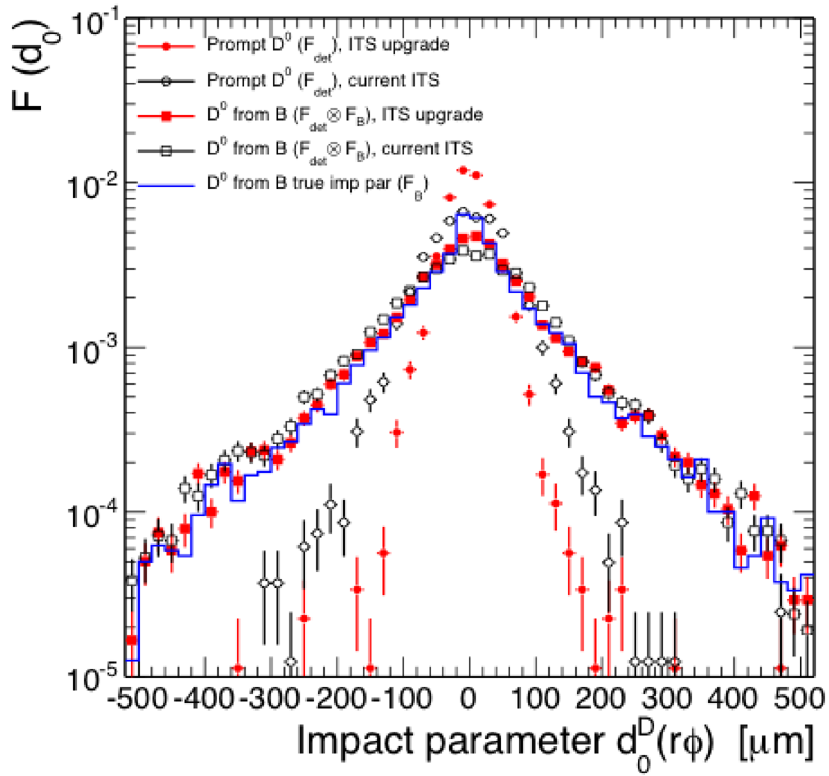
- Show the dependence of the performance on the detector thickness. Consider a case with 0.1% x/X_0 instead of 0.3%
- Consider a "high-rate" scenario in which tracking and PID are performed without TPC (ITS+TRD+TOF)
  - This configuration could run with $L \sim 10^{28}$ $cm^{-2}s^{-1}$
- Try to include Λ_c results from the new dedicated simulations at 5.5 TeV, with enhanced Λ_c signal (cuts tuning), and ITS fully active (no dead areas)

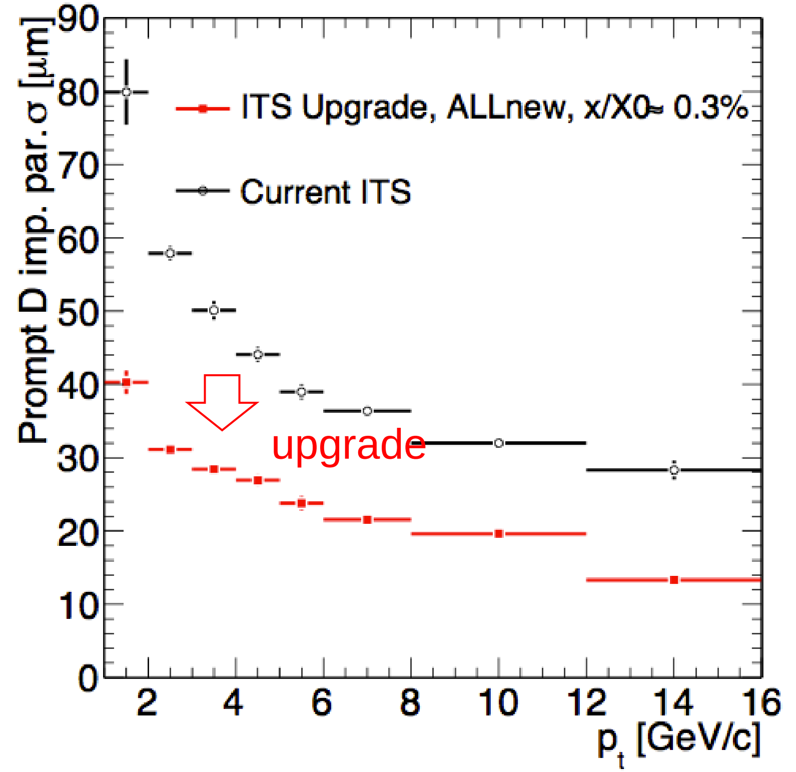
Beauty via displaced D^0

A. Rossi



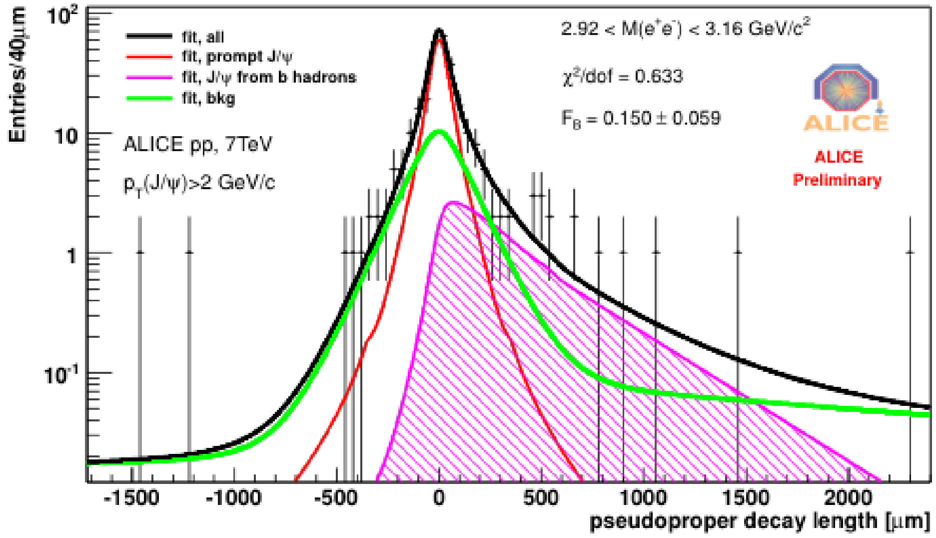
- Measure prompt charm
- And measure beauty production



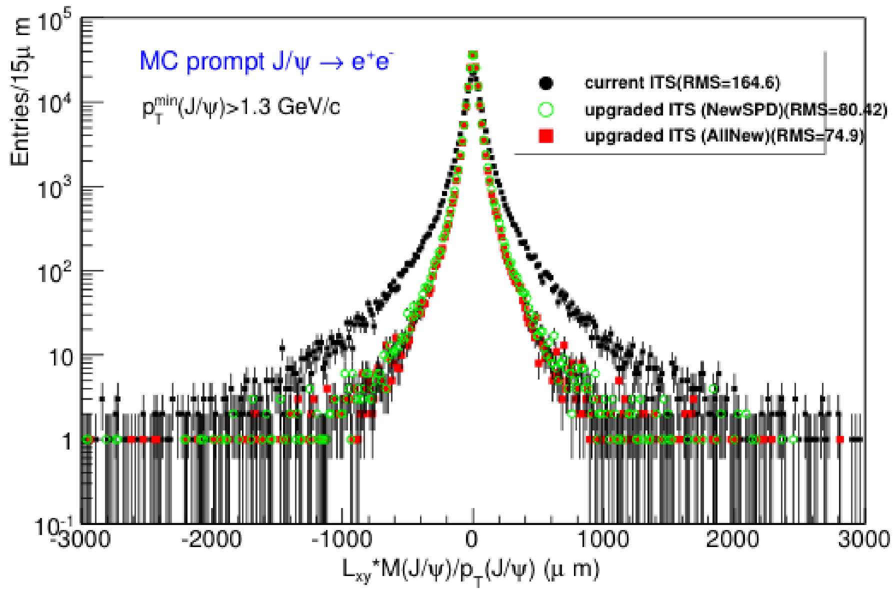


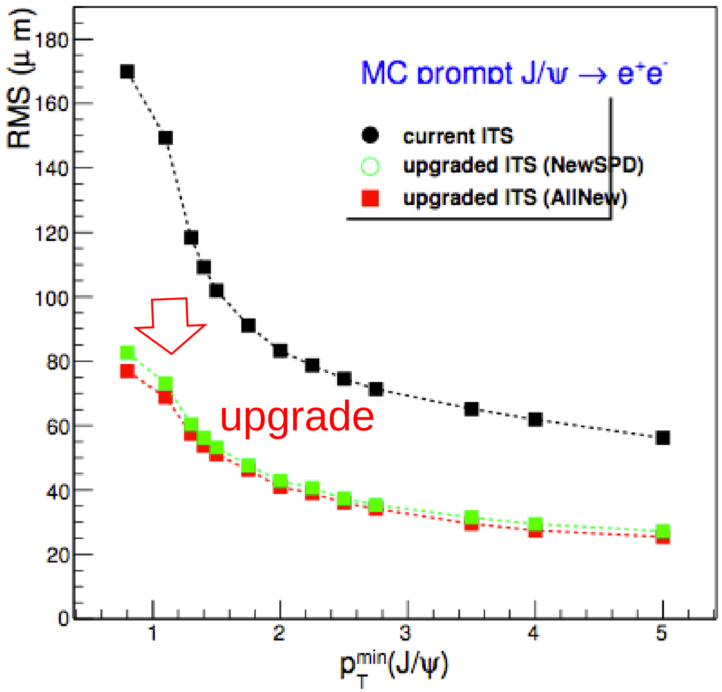
Beauty via displaced J/ψ

C. Di Giglio



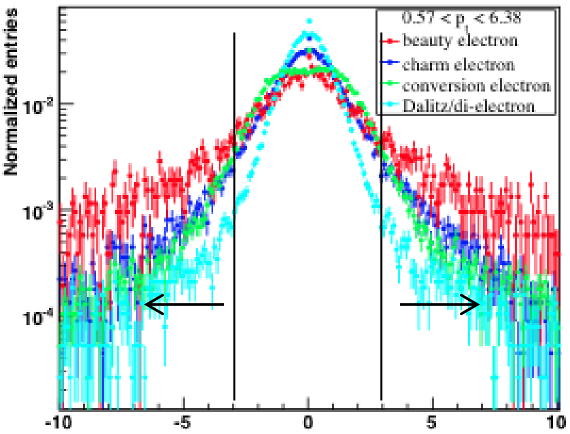
- Measure prompt J/ψ
- And measure beauty production





Beauty via displaced electrons

M. Kweon



- The impact of the ITS upgrade is two-fold:
  - Reduced x/X_0 decreases γ conversions, one of the main background sources
  - Better impact parameter resolution improves the separation of displaced electrons (from B)

background B signal