Magnet Stations for LHCb

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Magnet Side Stations - U2PG Review, February 14, 2019

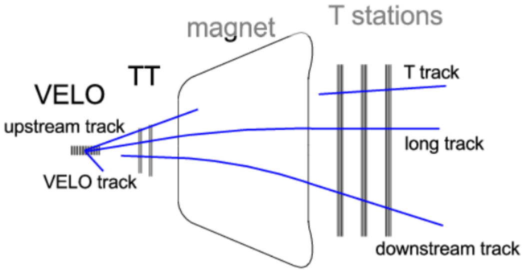
Outline

⇛ Introduction
⇛ We will review the effect of an improved tracking for specific channels:

- Prompt Charm decays
- $R(\Lambda_c^*)$
- $R(D^*)$
- Multibody B decays
- Σ_b.
- B^*.
- Gluon PDF.
- Spectroscopy.

⇛ Tracking implementations.
⇛ Outlook

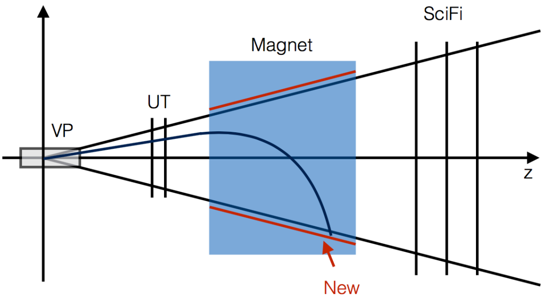
The idea



⇛ Tracks with hits in the vertex locator and the TT/UT and not in the Tstations: UPSTREAM tracks.
⇛ Those are bend outside of the T-stations acceptance by the magnetic field because of their low-momentum.
⇛ The reduced amount of field between the VELO and the TT, means that their momentum is computed with a large uncertainty.
$\Delta p/p = 20 - 25\%$ current, $\Delta p/p = 15 - 20\%$ upgrade

Proposal

⇛ Original idea comes from Sheldon Stone, Paolo Gandini, Liming Zhang: [Tuesday meeting Sept 2nd 2014]

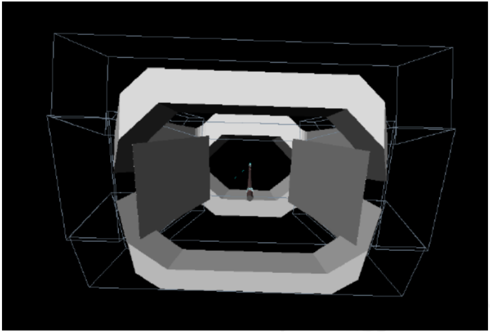


⇛ It is outside the LHCb acceptancen!! No X_0 added.

⇛ No need to have a high resolution. $\mathcal{O}(1\text{mm})$ should be enough.

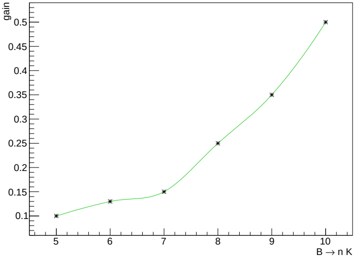
The sensitivity study

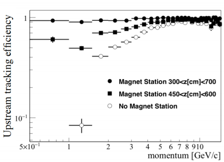
⇛ Take the Gauss `v50r0` for upgrade.
⇛ Simulate the particle gun.
⇛ Decays particles with `EvtGen`.
⇛ Put for now a plates in the Magnet (and beyond) and see where the particles hit them.
⇛ $\nu = 7.6$.

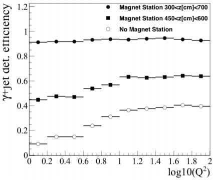


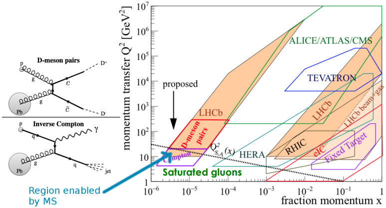
Current Physics cases

- Gains:
  - $\Rrightarrow$ $D^* \to D(\pi K)\pi_{\rm slow}$: gain 21 %.
  - $\Rrightarrow$ $B \to \tau\tau$: gain: 24 %.
  - $\Rrightarrow$ $R(\Lambda_c^*) = \frac{\mathcal{B}(\Lambda_b \to \Lambda_c^* \tau\nu)}{\mathcal{B}(\Lambda_b \to \Lambda_c^* \mu\nu)}$, $\Lambda_c^* \to p\pi_{\rm slow}\pi_{\rm slow}$: gain 60 %.
  - $\Rrightarrow$ $R(D^*) = \frac{\mathcal{B}(B \to D^* \tau\nu)}{\mathcal{B}(B \to D^* \tau\nu)}$: gain 26 %.
  - $\Rrightarrow$ $B \to nK$: gain 10 – 50 %.
  - $\Rrightarrow$ $\Sigma_b \to \Lambda_b\pi$: gain 29 %.
  - $\Rrightarrow$ Gluon PDF: Enabled measurement.



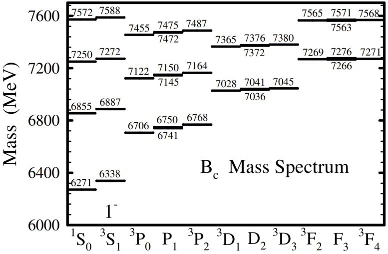






Additional Physics cases

S.Godfrey, PHYSICAL REVIEW D 70 054017



- Additional:
  - $\Rrightarrow$ $\Sigma_c \to \Lambda_c \pi_{\text{slow}}$: gain $19\ \%$.
  - $\Rrightarrow$ Low-mass Drell-Yan: gain $15\ \%$.
  - $\Rrightarrow$ $B_c^+(2S) \to B_c^+ \pi_{\text{slow}} \pi_{\text{slow}}$: gain $50\ \%$.
  - $\Rrightarrow$ Radiative decays?

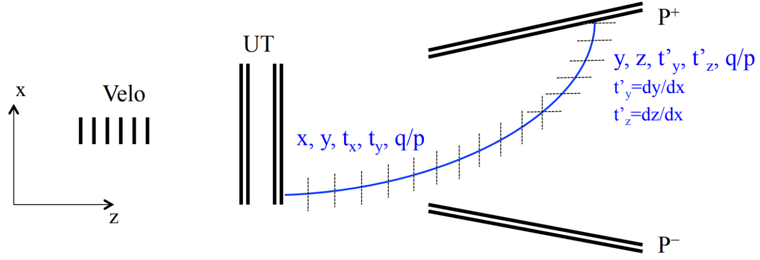
Additional Physics cases

$\Rrightarrow$ This is just the tip of the ice berg!

Transition	Expression for Rate	$(c\bar{b})$ rate (keV)
$2^3S_1 \to 1^3S_1 + \pi\pi$	$A_0(0,0)$	57 ± 7
$2^1S_0 \to 1^1S_0 + \pi\pi$	$A_0(0,0)$	57 ± 7
$3^3S_1 \to 2^3S_1 + \pi\pi$	$A'_0(0,0)$	3.1 ± 0.6
$3^1S_0 \to 2^1S_0 + \pi\pi$	$A'_0(0,0)$	3.1 ± 0.6
$3^3S_1 \to 1^3S_1 + \pi\pi$	$A''_0(0,0)$	4.2 ± 0.6
$3^1S_0 \to 1^1S_0 + \pi\pi$	$A''_0(0,0)$	4.2 ± 0.6
$2^3P_2 \to 1^3P_2 + \pi\pi$	$\frac{1}{3}A_0(1,1) + \frac{1}{4}A_1(1,1) + \frac{7}{60}A_2(1,1)$	1.0
$2^3P_2 \to 1P'_1 + \pi\pi$	$\frac{1}{12}A_1(1,1) + \frac{3}{20}A_2(1,1)$[a]	0.004[b]
$2^3P_2 \to 1P_1 + \pi\pi$	$\frac{1}{12}A_1(1,1) + \frac{3}{20}A_2(1,1)$[a]	0.021[b]
$2^3P_2 \to 1^3P_0 + \pi\pi$	$\frac{1}{15}A_2(1,1)$	0.011
$2P'_1 \to 1^3P_2 + \pi\pi$	$\frac{5}{36}A_1(1,1) + \frac{1}{4}A_2(1,1)$[c]	0.004[b]
$2P_1 \to 1^3P_2 + \pi\pi$	$\frac{5}{36}A_1(1,1) + \frac{1}{4}A_2(1,1)$[c]	0.037[b]
$2P'_1 \to 1P'_1 + \pi\pi$	$A_0(1,1) + A_1(1,1) + \frac{1}{3}A_2(1,1)$[d]	1.2[e]
$2P'_1 \to 1P_1 + \pi\pi$	$A_0(1,1) + A_1(1,1) + \frac{1}{3}A_2(1,1)$[d]	0.1[e]
$2P_1 \to 1P'_1 + \pi\pi$	$\frac{1}{3}A_0(1,1) + \frac{1}{12}A_1(1,1) + \frac{1}{12}A_2(1,1)$[f]	0.02[e]
$2P_1 \to 1P_1 + \pi\pi$	$\frac{1}{3}A_0(1,1) + \frac{1}{12}A_1(1,1) + \frac{1}{12}A_2(1,1)$[f]	2.7[e]
$2P'_1 \to 1^3P_0 + \pi\pi$	$\frac{1}{9}A_1(1,1)$[g]	0
$2P_1 \to 1^3P_0 + \pi\pi$	$\frac{1}{9}A_1(1,1)$[g]	0
$2^3P_0 \to 1^3P_2 + \pi\pi$	$\frac{1}{3}A_2(1,1)$	0.0547
$2^3P_0 \to 1P'_1 + \pi\pi$	$\frac{1}{3}A_1(1,1)$[h]	0
$2^3P_0 \to 1P_1 + \pi\pi$	$\frac{1}{3}A_1(1,1)$[h]	0
$2^3P_0 \to 1^3P_0 + \pi\pi$	$\frac{1}{3}A_0(1,1)$	0.97
$1^3D_{1,3} \to 1^3S_1 + \pi\pi$	$\frac{1}{5}A_2(2,0)$[i]	4.3
$1D'_2 \to 1^3S_1 + \pi\pi$	$\frac{1}{5}A_2(2,0)$[i]	2.1[b]
$1D_2 \to 1^3S_1 + \pi\pi$	$\frac{1}{5}A_2(2,0)$[i]	2.2[b]
$1D'_2 \to 1^1S_0 + \pi\pi$	$\frac{1}{5}A_2(2,0)$[i]	2.2[b]
$1D_2 \to 1^1S_0 + \pi\pi$	$\frac{1}{5}A_2(2,0)$[i]	2.1[b]

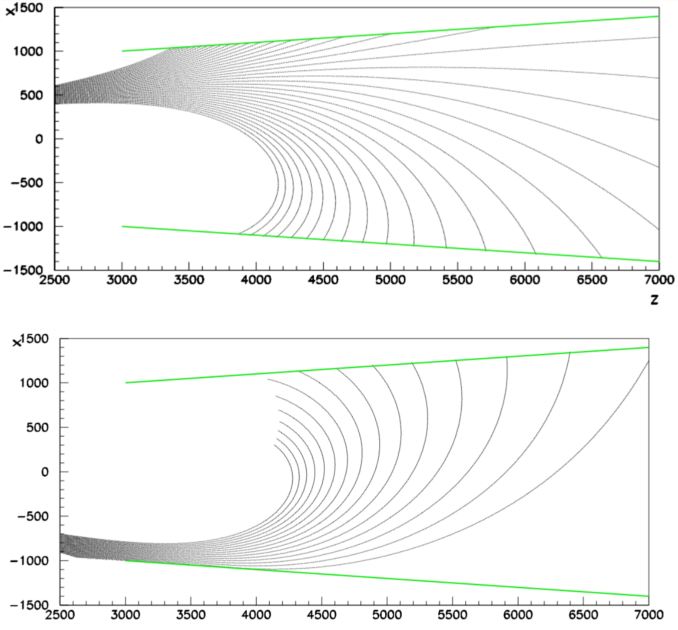
Tracking studies

2-fold Runge-Kutta for MS, P.Billoir



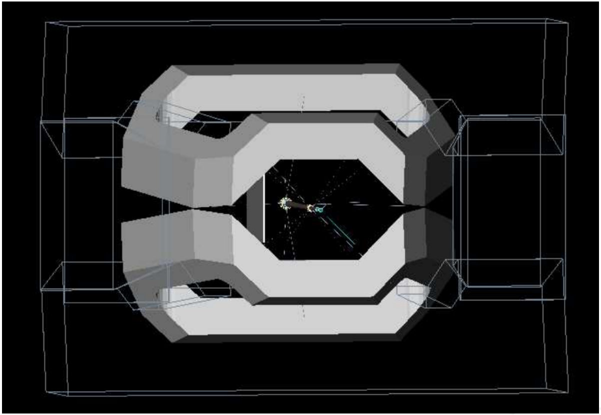
⇛ We start from „standard" Runge-Kutta method.
⇛ If $|t_x| > 1$ we switch steps to x.
⇛ With VELO + UT we know precisely: x, y, t_x, t_y. We poorly know: $\frac{q}{p} \rightarrow$ MS can help.
⇛ Runge-Kutta method has to be inverted with the Newton-Raphson method.

2-fold Runge-Kutta for MS, P.Billoir



Detector Implementation

Gauss implementation



- ⇛ Cloned structures of the SciFi.
- ⇛ Digitalization missing.
- ⇛ Run full MC simulations.

Outlook

⇛ The physics program of magnet stations is growing.
⇛ For many channels, the MS are improving the efficiencies from $20-30\%(R(D^*))$ to 60%.
⇛ For other, such as the study of Gluon saturation, the MS are enabling the measurement.
⇛ MS help when little PHSP is available.
⇛ Spectroscopy measurements enhanced.
⇛ Tagging of charm meson and baryon decays → reduce background.

⇛ Tracking algorithms are being developed.
⇛ Implementing the MS in Gauss.

Backup