First results from B parking with 2018 data

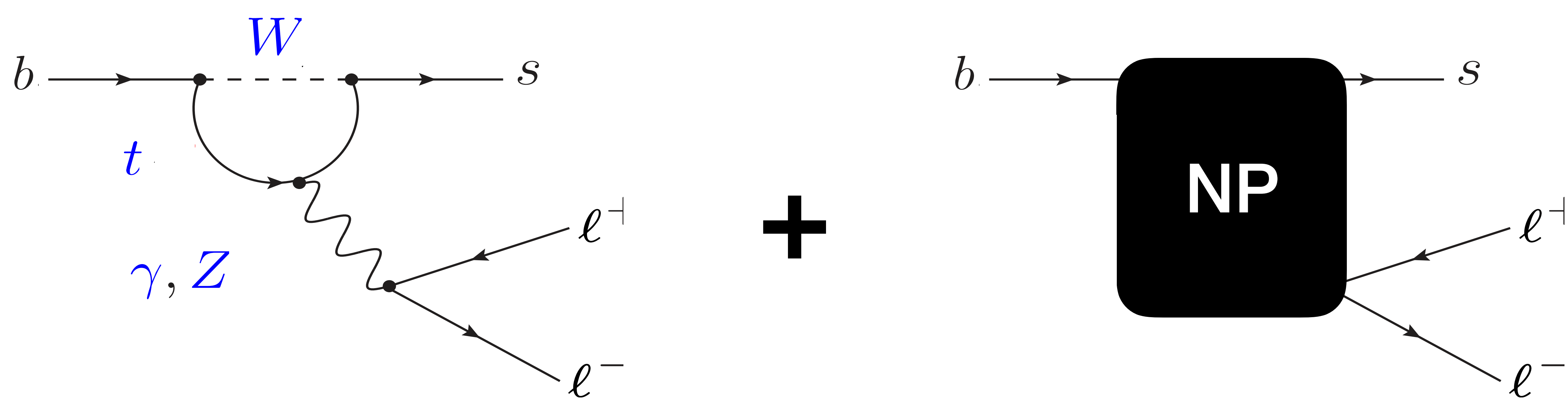
Mauro Verzetti on behalf of the proponents

June CMS Week

Rare decays are a prime location to probe for new physics

- b(d) → sℓℓ proceed with FCNC transitions
- Suppressed in the SM
  - Only at ≥ 1 loop
  - Easier to spot new physics contributions
- **How?**
  - Enhancing/suppressing decay rates
  - Introducing new CPV sources
  - Modifying the angular distributions of final-state particles

$$R(X) = \frac{\mathscr{B}(B \to X\ell(\ell))}{\mathscr{B}(B \to X\ell'(\ell'))}$$

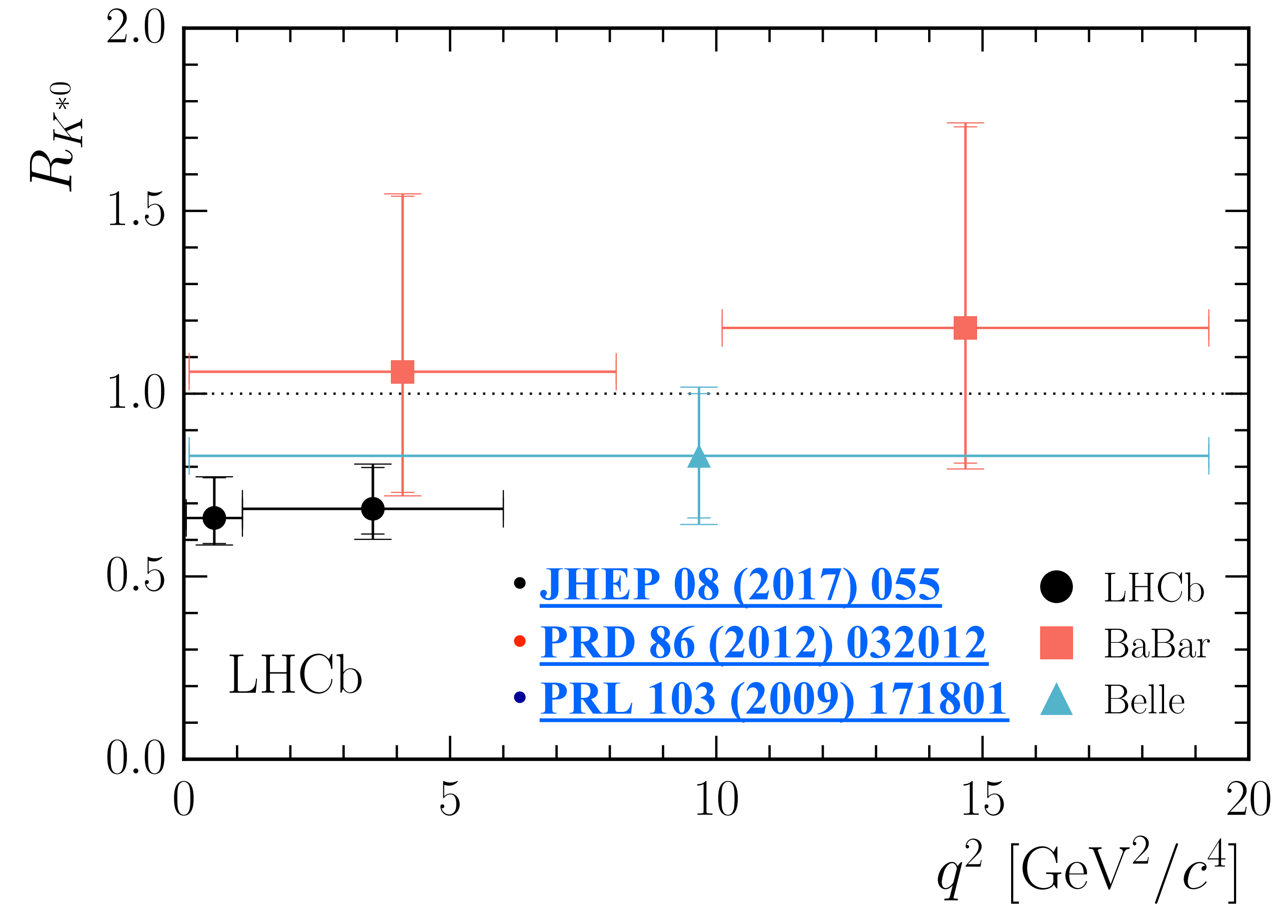


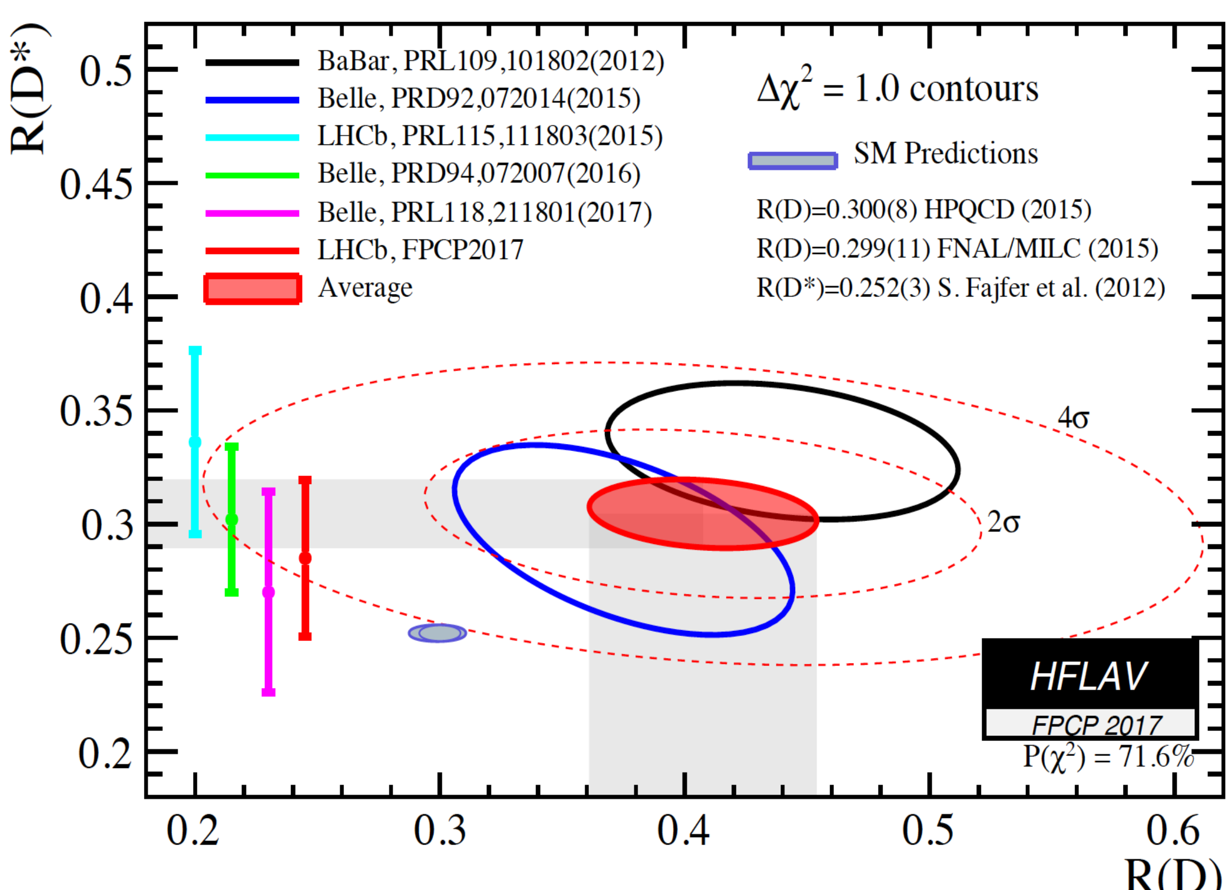
Currently the biggest deviation from the SM

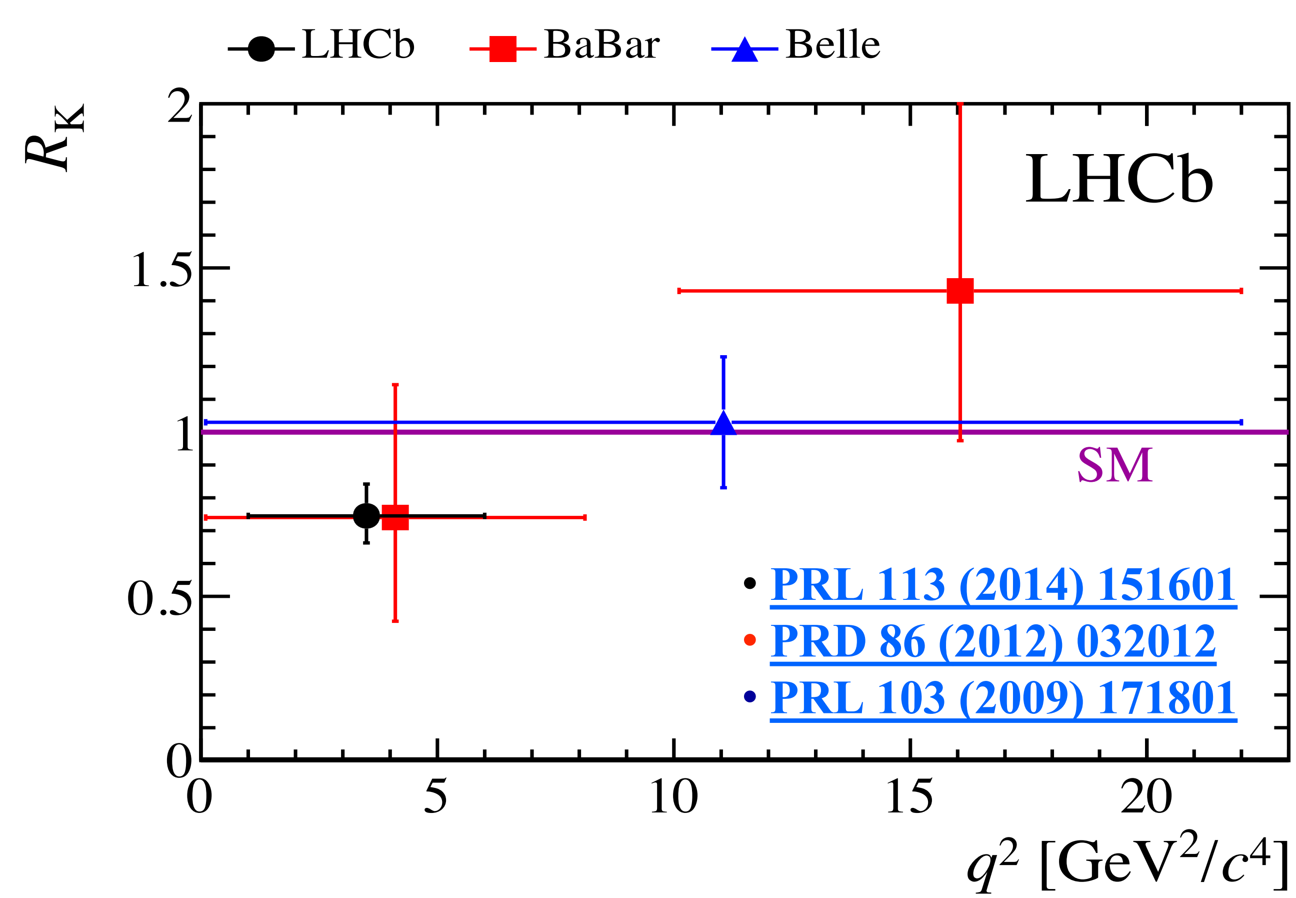
Mostly related to angular observables and lepton-flavour universality test

To play a major role we need more than just muons!

Trigger has been the major limiting factor … so far.

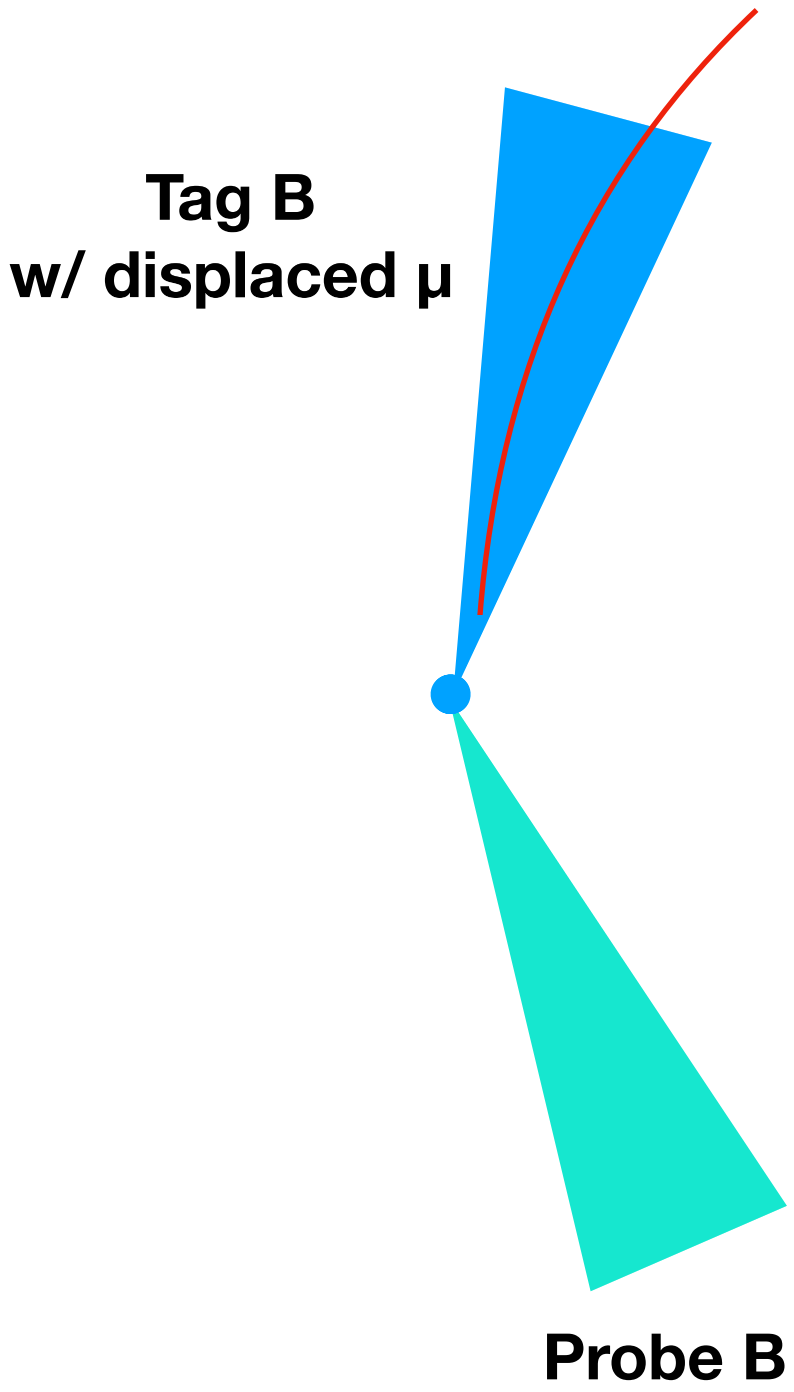






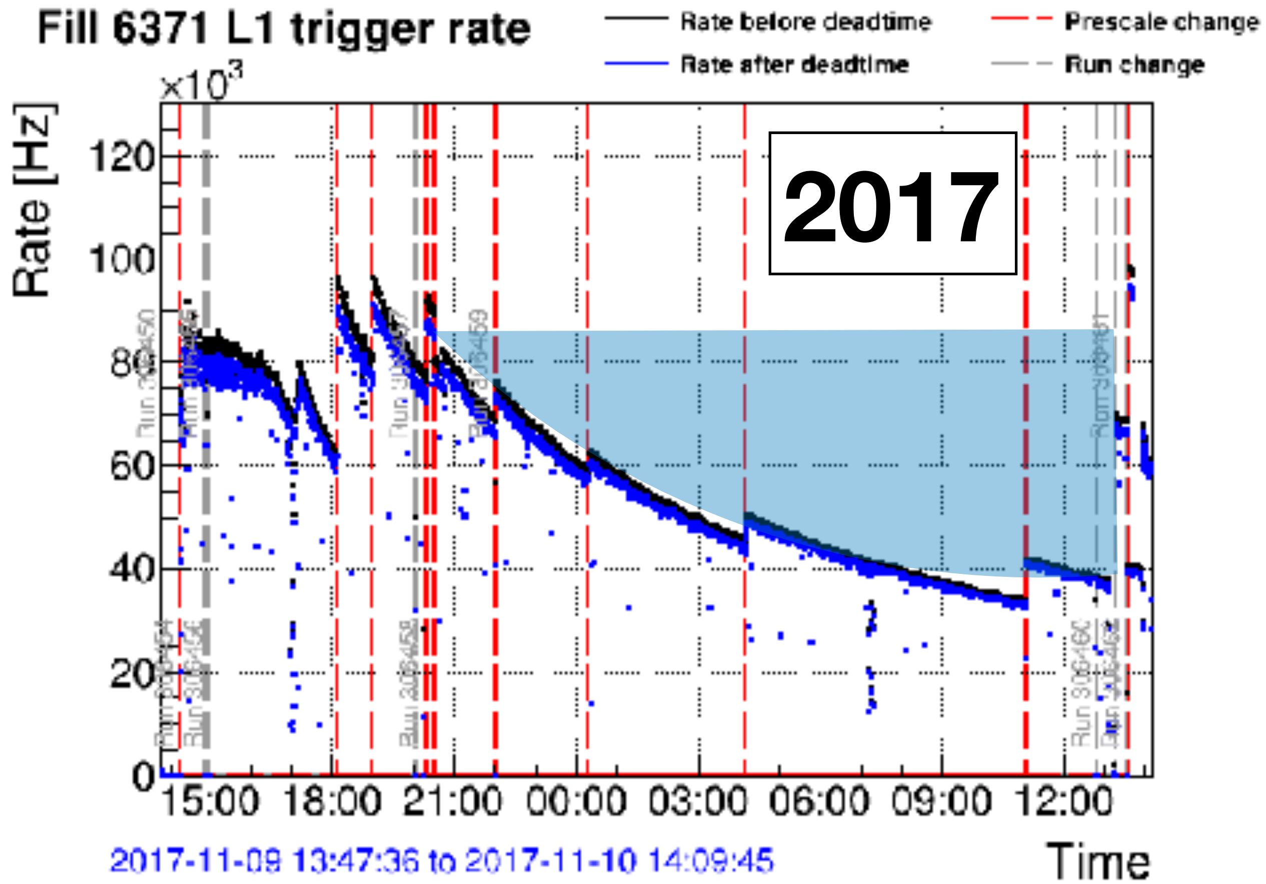
Trigger strategy

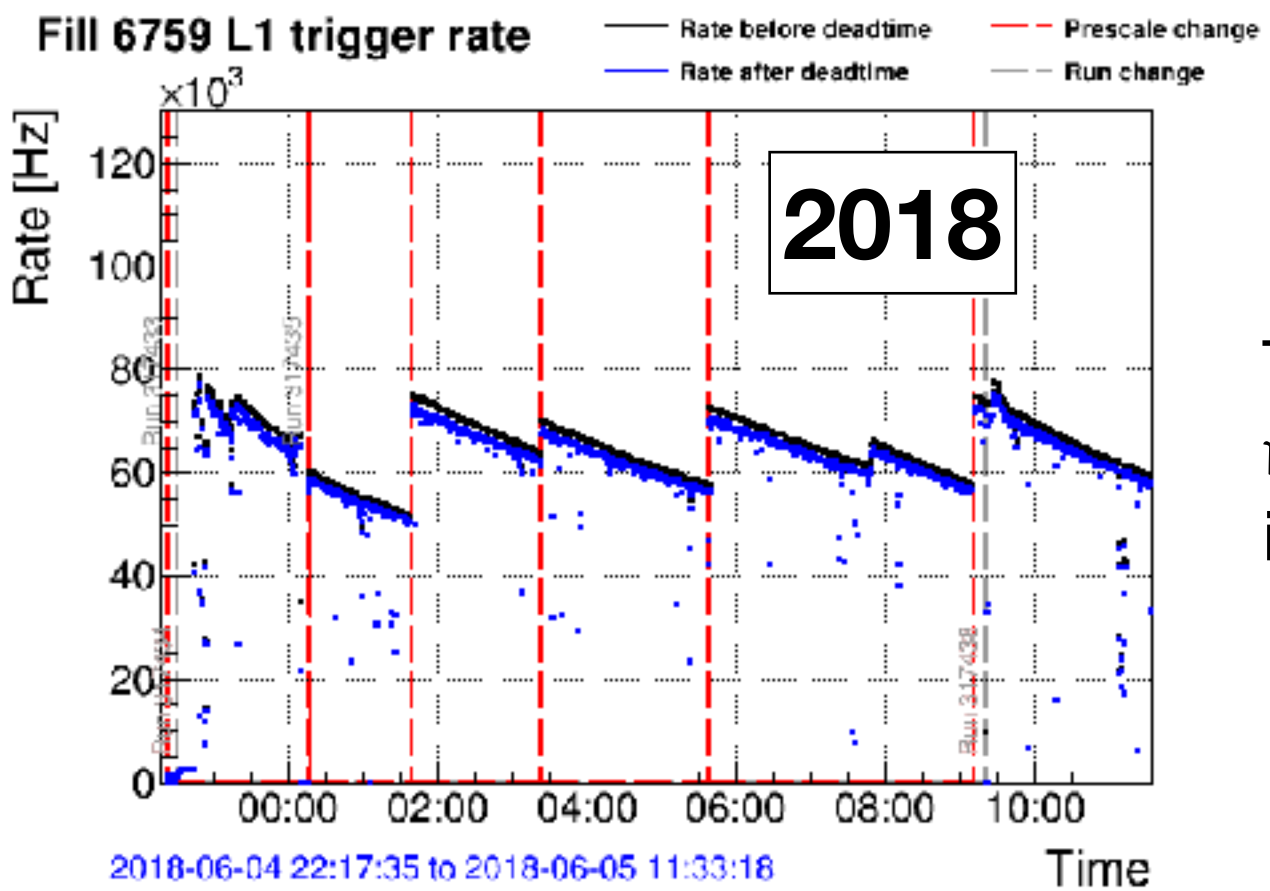
Probe B is unbiased,
even better than LHCb
that triggers on the decaying B
they use for analysis

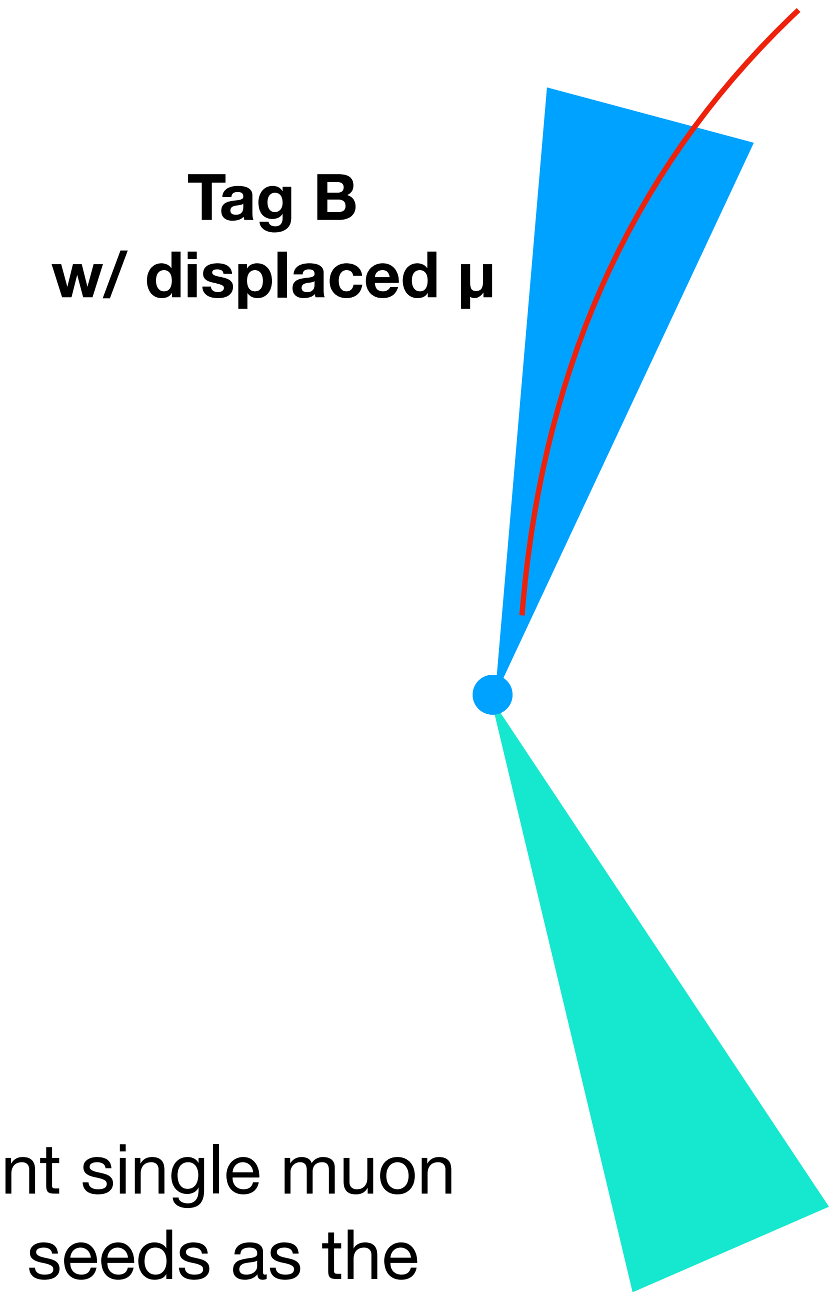


Trigger strategy — L1

S. Fiorendi
R. Manzoni
M. Verzetti



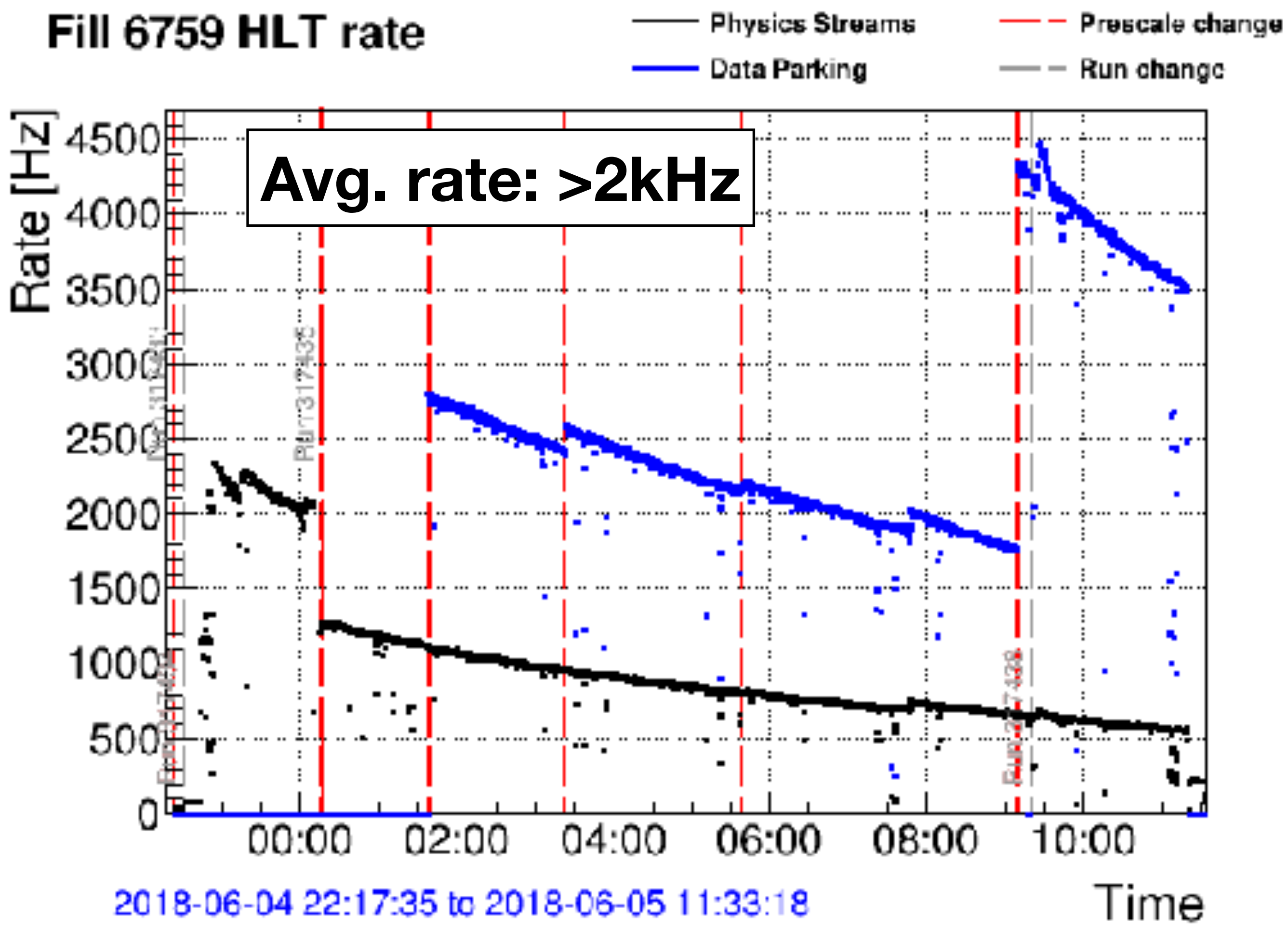




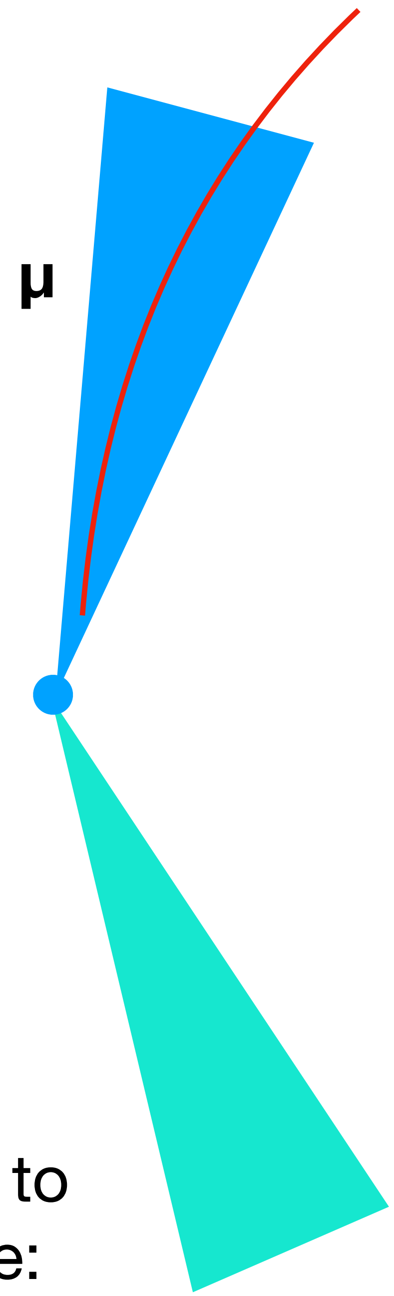
Turn on different single muon η-restricted L1 seeds as the inst. luminosity decreases

Trigger strategy — HLT

S. Fiorendi
R. Manzoni
M. Verzetti



Tag B
w/ displaced μ



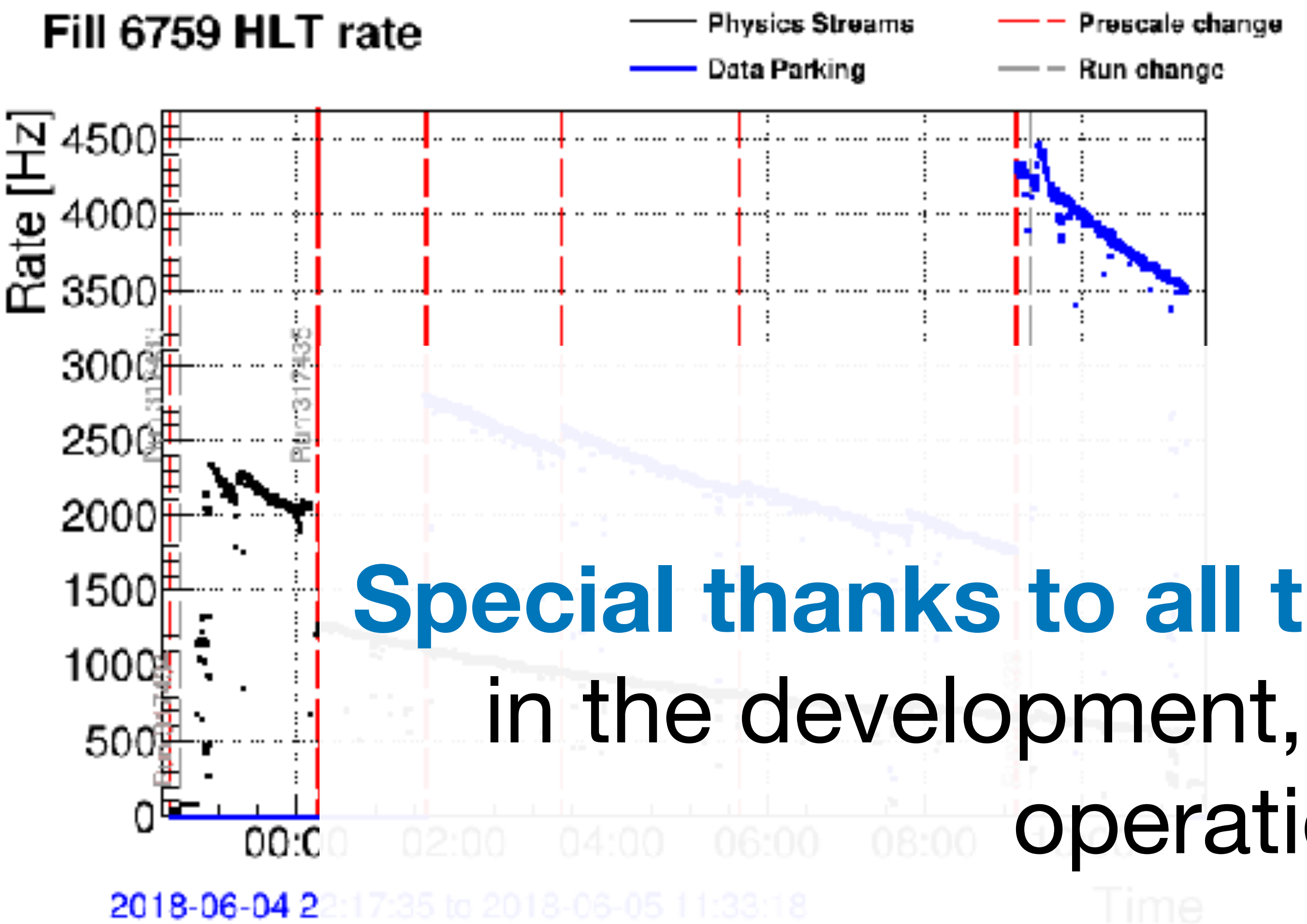
Probe B

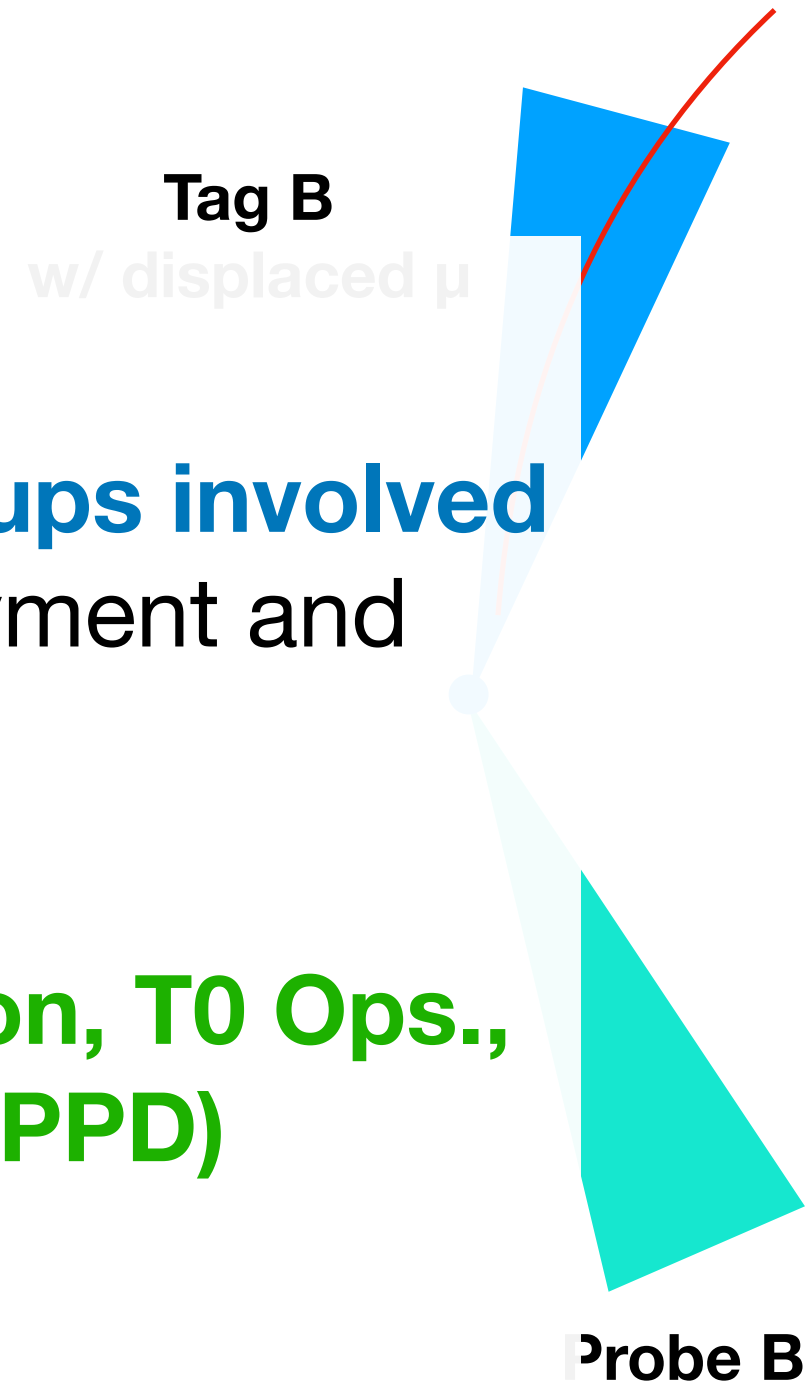
Lumi col. [E34]	FirstRun	Set1	Set2
1.6	-	-	HLT_Mu12_IP6
1.4	-	HLT_Mu9_IP6	HLT_Mu9_IP6
1.2	-	HLT_Mu9_IP6	HLT_Mu9_IP5
1	HLT_Mu9_IP6 HLT_Mu10p5_IP3p5 HLT_Mu8p5_IP3p5	HLT_Mu9_IP6	HLT_Mu9_IP5
0.8		HLT_Mu8_IP3	HLT_Mu7_IP4

Carefully tuned thresholds to maximise physics outcome: probe Bs in acceptance

Trigger strategy — HLT

S. Fiorendi
R. Manzoni
M. Verzetti





Special thanks to all the groups involved
in the development, deployment and operations!

(TSG, DAQ, Run Coordination, T0 Ops., Computing & Offline, PPD)

Lumi col. [E34]			
1.6	-		
1.4	-	HLT_Mu9_IP6	HLT_Mu9_IP6
1.2	-	HLT_Mu9_IP6	HLT_Mu9_IP5
1	HLT_Mu9_IP6 HLT_Mu10p5_IP3p5 HLT_Mu8p5_IP3p5	HLT_Mu9_IP6	HLT_Mu9_IP5
0.8		HLT_Mu8_IP3	HLT_Mu7_IP4

Trigger tuning

S. Fiorendi
R. Manzoni
M. Verzetti

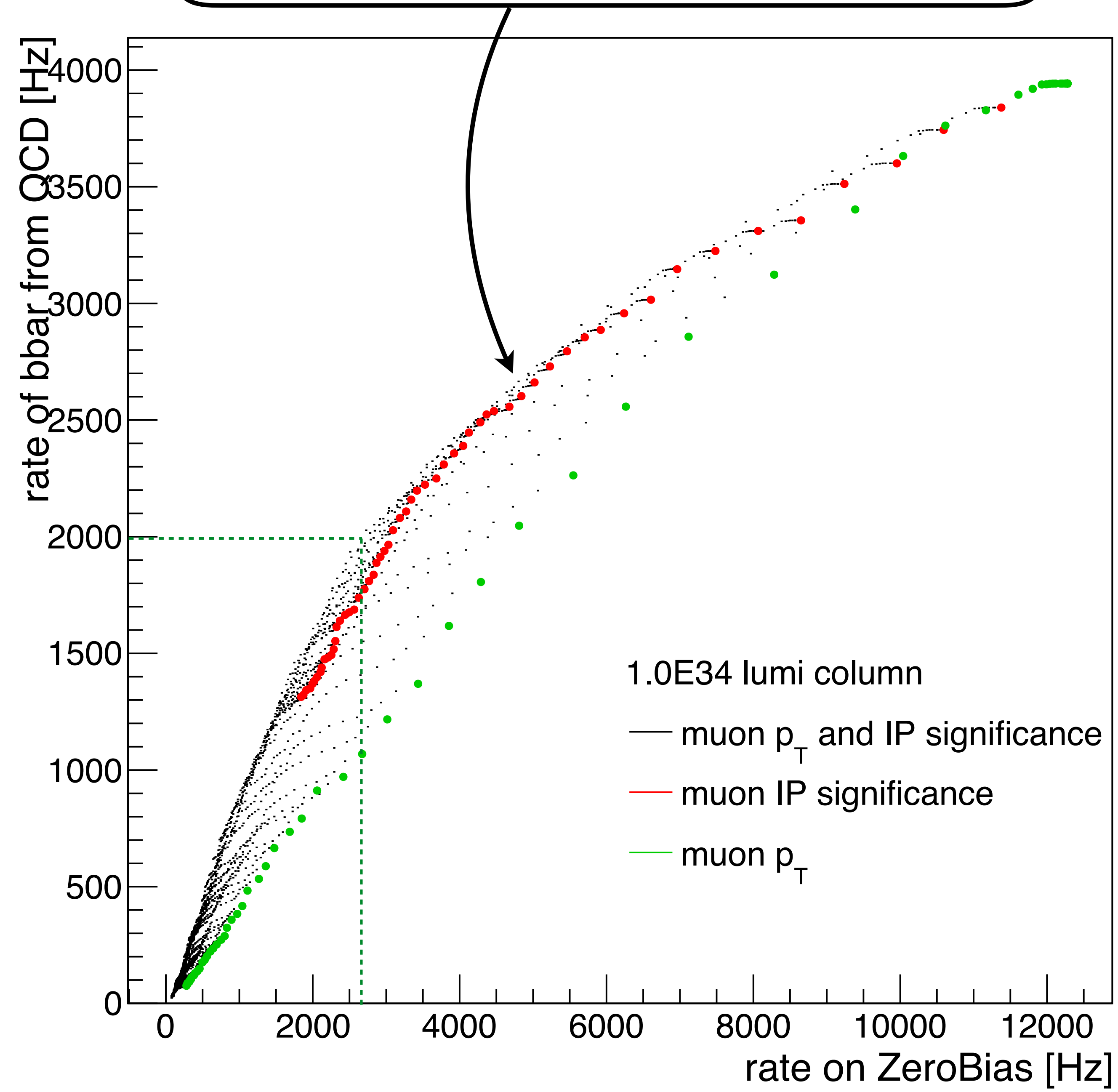
Trigger has been tuned computing the rate on ZeroBias and the B_{probe} rate on QCD (p_T 20-120) MC simulation.

Very high "purity" estimate (up to ~80%).

Is it too optimistic?

$$\lambda = \frac{N_{MC}(\mathrm{B_{probe}\ in\ acceptance})}{N_{Data}(\mathrm{Zero\ Bias})}$$

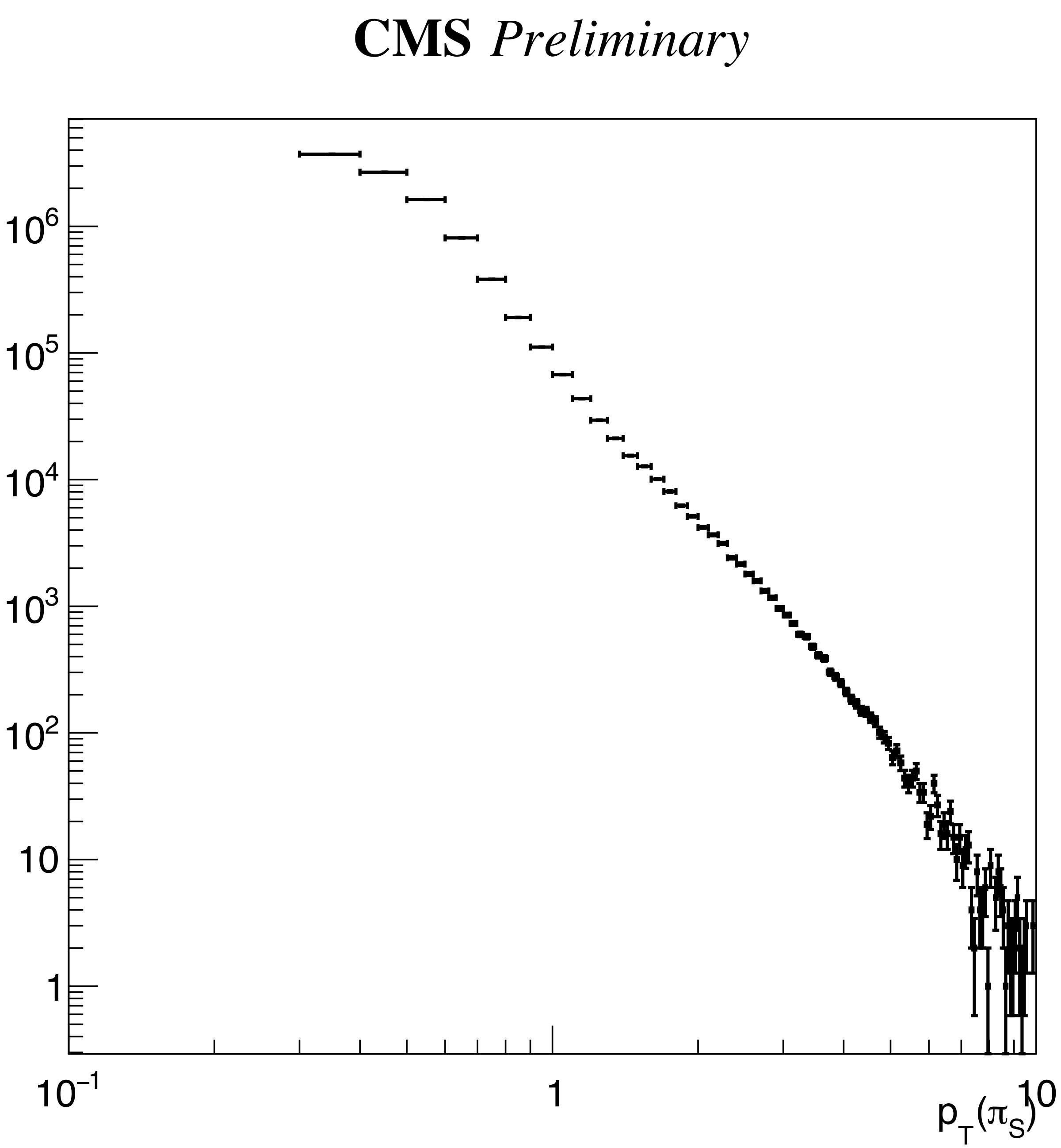
Each point in the cloud represent a tentative selection in $p_T(\mu)$ and IP significance

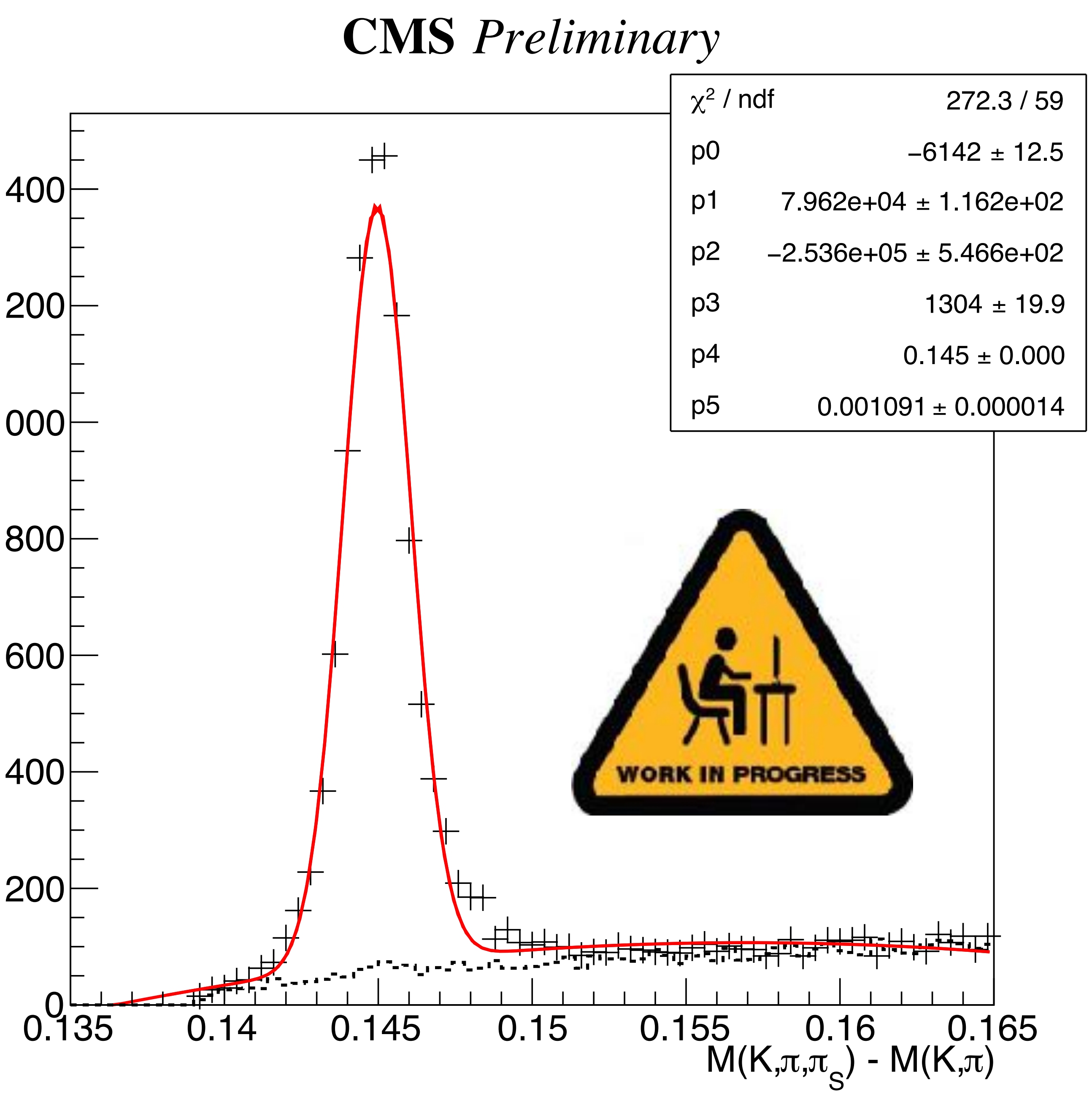


G. Karathanasis

Purity on data

$$B_{tag} \to D^{*+}(\to D^0(\to K\pi)\pi)\mu\nu$$





Extremely low-p_T pions (> 300MeV)

Purity on data

From data

$$N(b \to \mu X) = \frac{1}{\boxed{F_{corr}}} \frac{\boxed{N(B^0 \to D^{*+}\mu\nu)}}{\boxed{\alpha(D^{*+}) \times \varepsilon(D^{*+})} \times \boxed{\mathcal{B}(D^{*+} \to D^0(\to K\pi)\pi)}}$$

$$f_d \frac{\mathcal{B}(B^0 \to D^{*+}\mu\nu)}{\mathcal{B}(b \to \mu X)} \frac{\alpha(B^0 \to D^{*+}\mu\nu)}{\alpha(b \to \mu X)}$$

From MC

Acceptance x efficiency of the D*+ decay chain.

Computed on MC.

From literature: 2.6%

This value does **not** include any acceptance on the probe B

$$P_b = \frac{N(b \to \mu X)}{N(\mu)} \approx \mathbf{70\%}$$

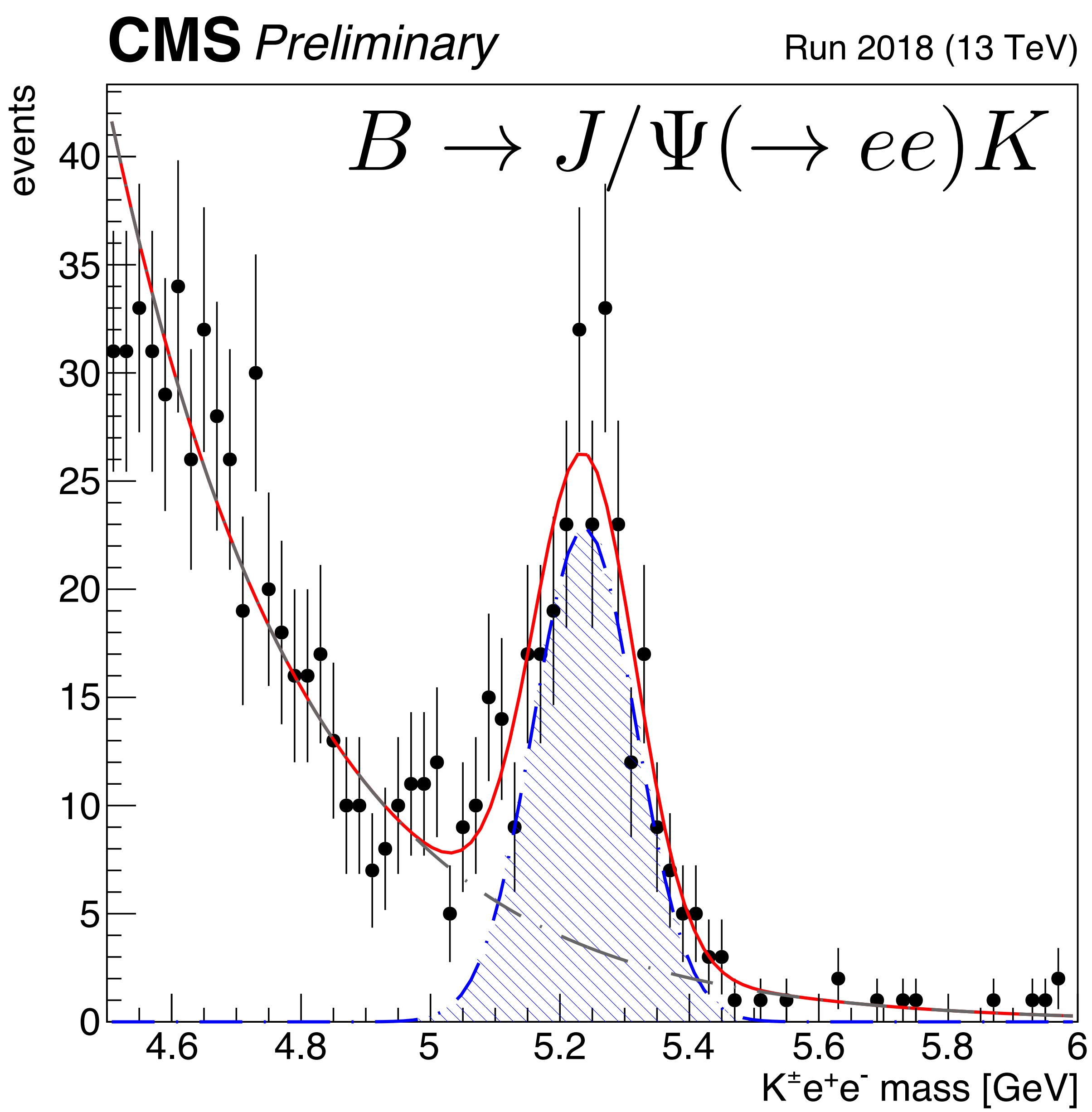
First look at data seems promising

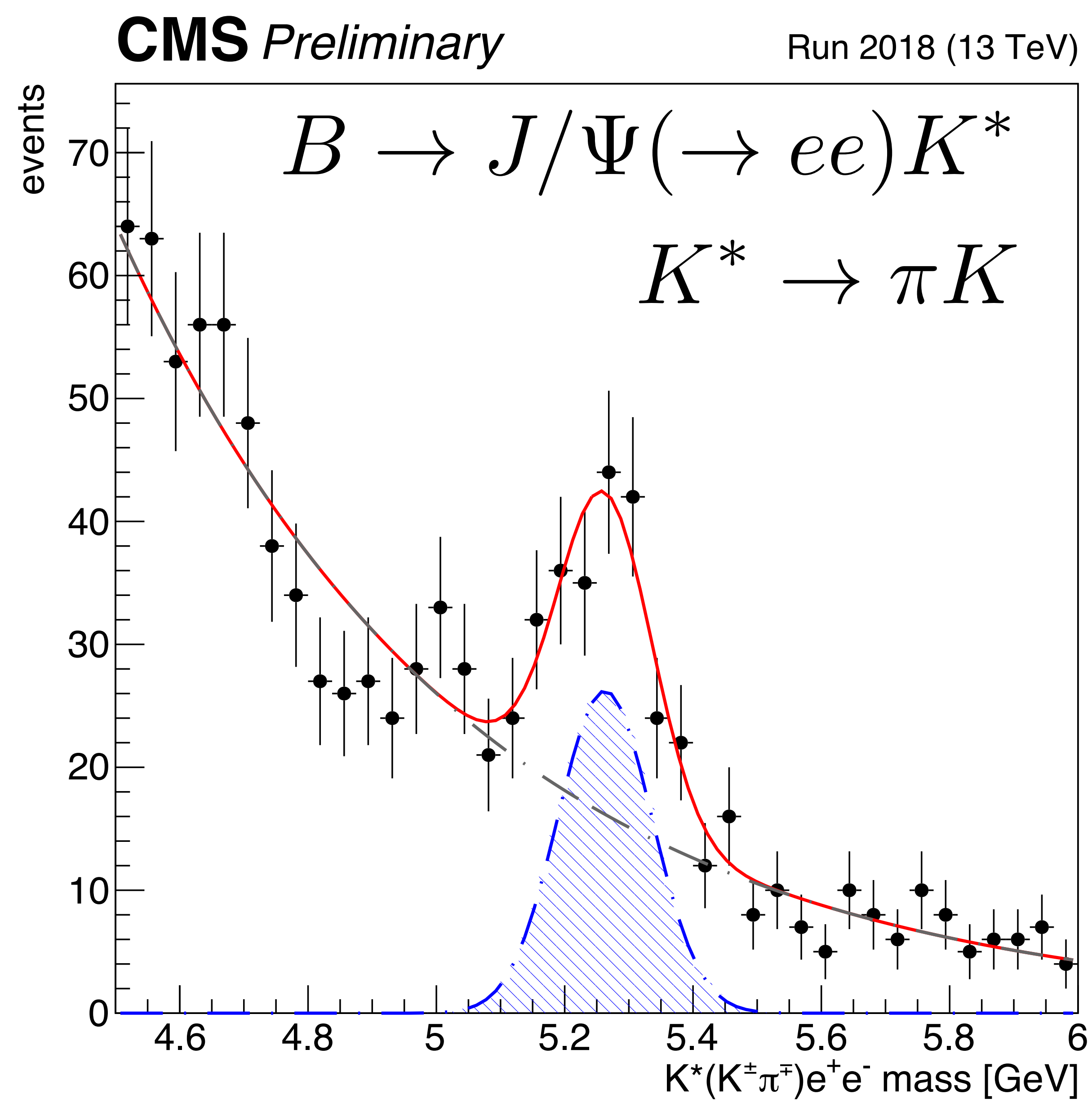
S. Fiorendi
R. Manzoni

Use 470e6 events from a dedicated processing
(**thanks PPD and O&C!**)

With **very simple** selection: 230 B→J/Ψ(→ee) K, 128 B→J/Ψ(→ee) K*

First observations in CMS!





First look at data seems promising

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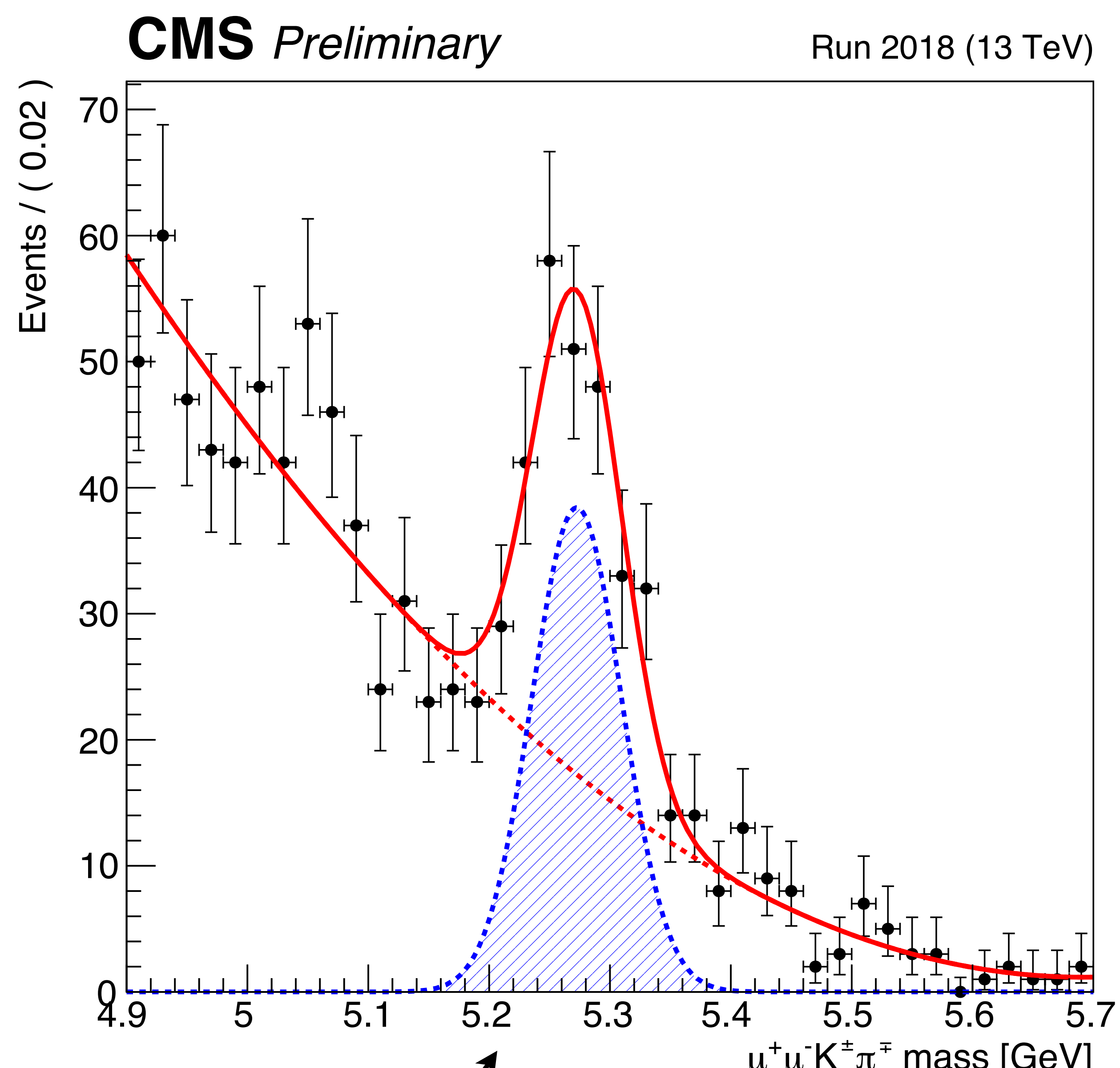
R. Manzoni

$$B \to J/\Psi(\to \mu\mu)K^*$$
$$K^* \to \pi K$$

Different dataset size with respect to the previous plots.

Still working on the muon anti-matching

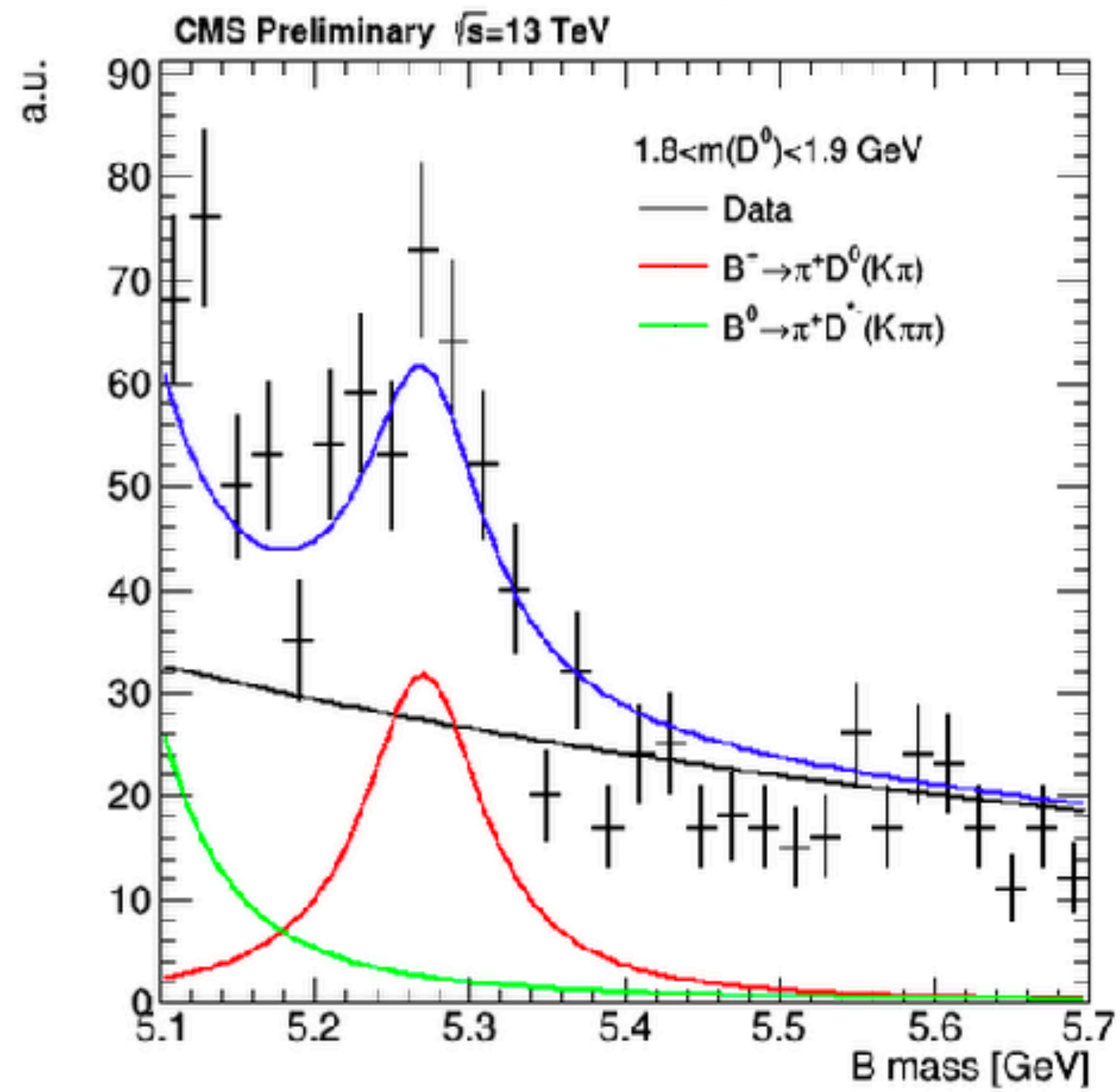
Muon channel yield is > 3 times the electron one



Mind the scale!

First look at data seems promising

$$B^+ \to D^0(\to K\pi)\pi^+$$



Different dataset size with respect to the previous plots.

Fully hadronic decay.

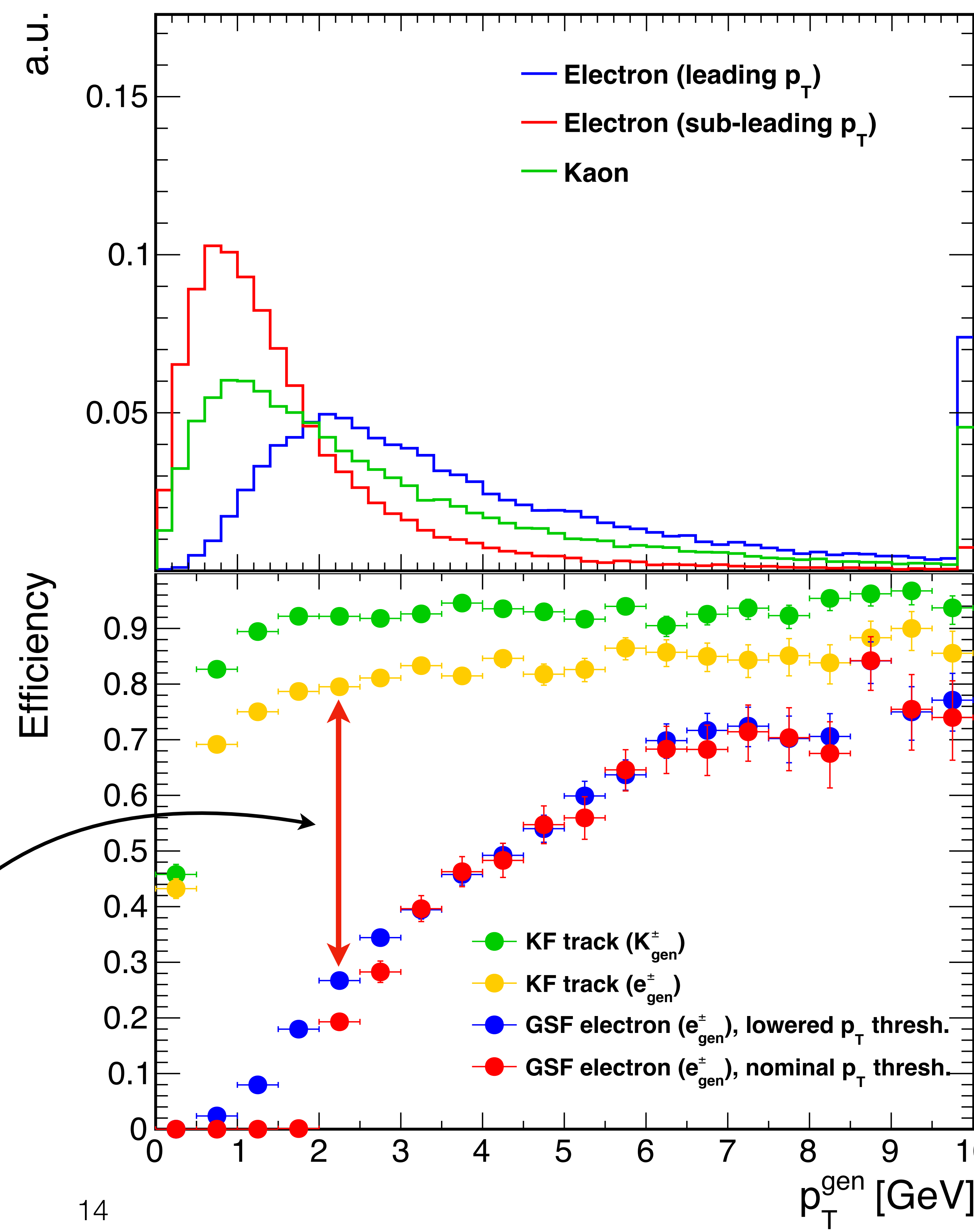
First observations in CMS!

R. Bainbridge

Low-p_T electron reconstruction is fundamental for our program

Track p_T thresholds	Aε [%]	
	B→Kee	B^0→K*ee
Nominal	5.0	4.2
Lowered	6.7	5.2

Loss in efficiency due to electron seeding

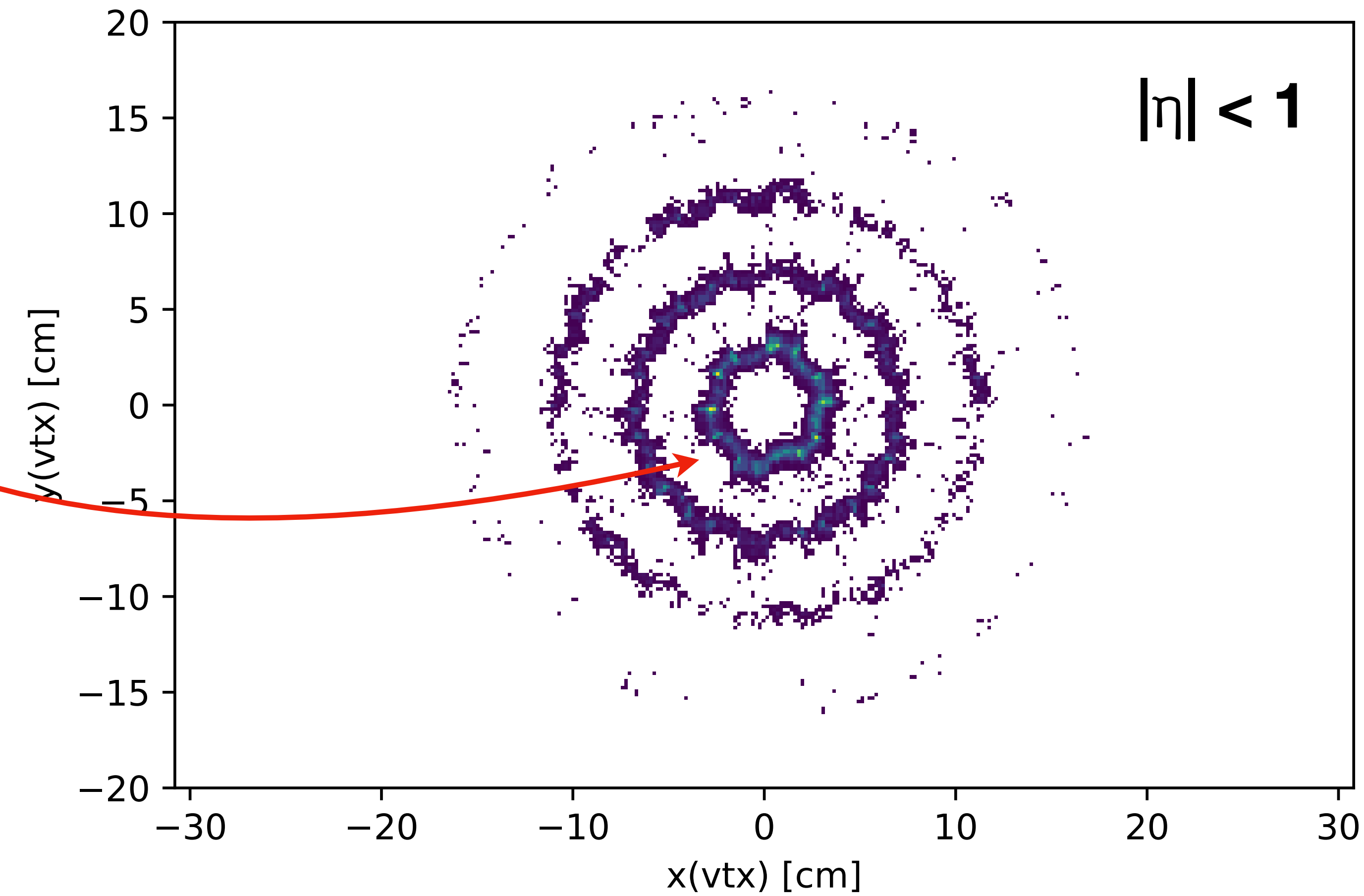


Conversions can be used to study low p_T electrons

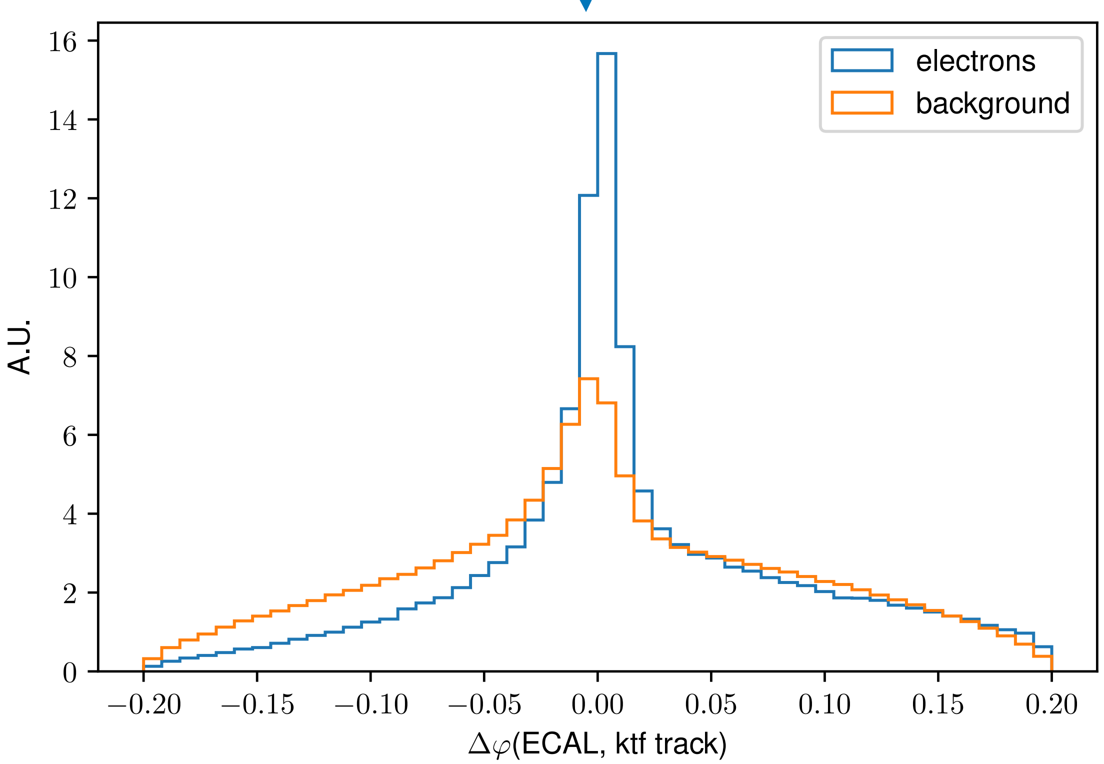
N. Marinelli
M. Verzetti

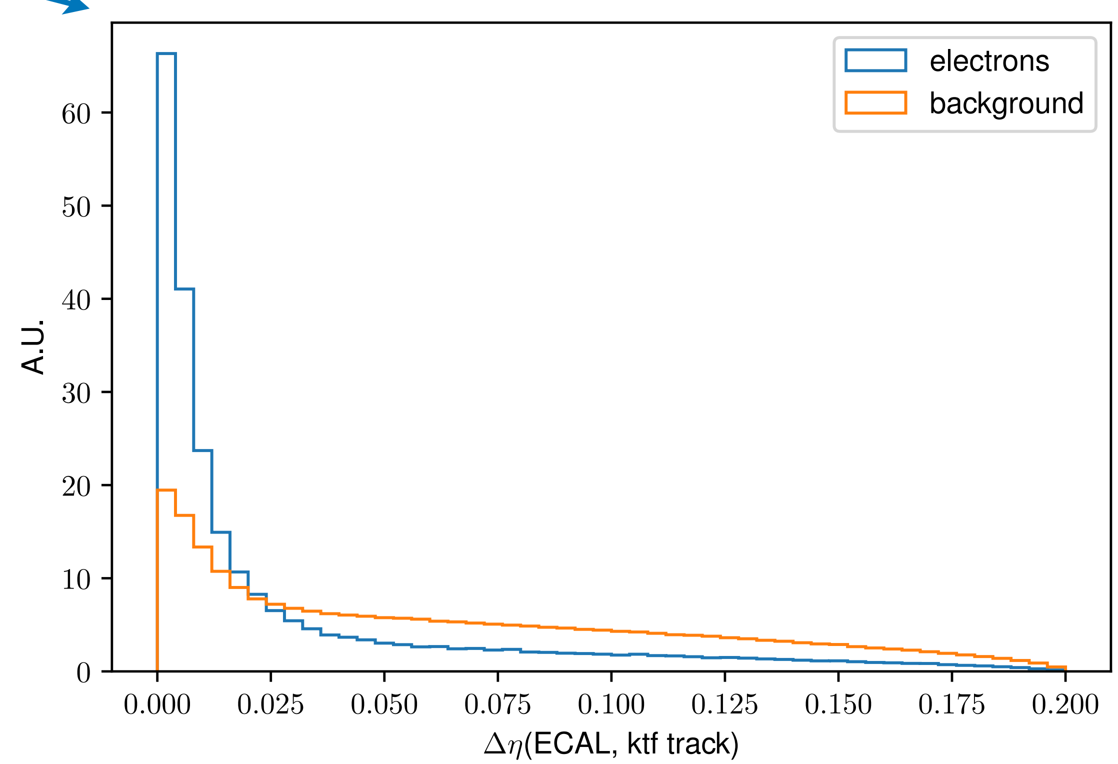
Other datasets are also being considered

Use conversions stemming from the first pixel layer/beampipe



Example of discriminating variables used in the seeding





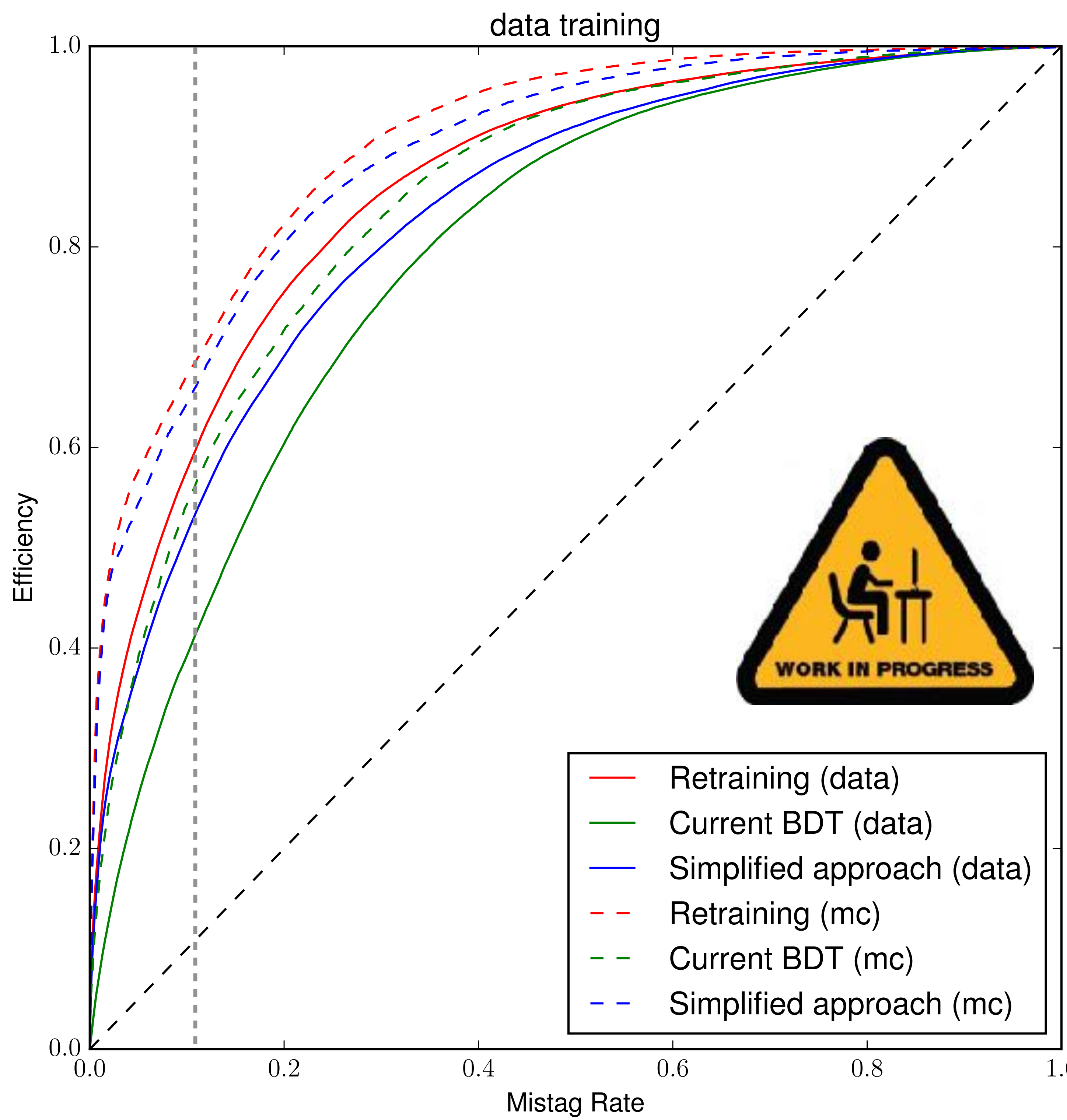
Very preliminary results look promising

N. Marinelli
M. Verzetti

From a preliminary study a simplified approach outperforms the current selection, both for **conversion data** (solid) and **B→Kee MC** (dashed).

We are currently investigating the performance difference between data and MC

Even better performance might come from more/better features and/or deep learning



With O(10^{10}) un-biased B-hadrons CMS could do…

- R(K) and R(K*)
- R(D*)?
- Search for very rare B decays like $B_s \to \tau\tau$
- LFV decays B(s) $\to \tau\mu$ and τe
- And much much more

2/Mar/2018

… but to get there we need

- A 5-10 kHz set of L1 seed(s) targeting $B \to X\mu(\mu)$
- A dedicated HLT aiming at high B purity
- Park 2 kHz (or more, if data compression is possible) of data
- Refinement in the reconstruction and ID of low-p_T electrons

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… but to get there we ~~need~~ have

- A 5-10 kHz set of L1 seed(s) targeting $B \to X\mu(\mu)$
- A dedicated HLT aiming at high B purity

… getting there …

- Park >2 kHz of data until the end of the run —3e9 events so far
- Refinement in the reconstruction and ID of low-p_T electrons

BACK-UP

We can use EFT to describe the unknown NP

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i [\underbrace{\mathcal{C}_i(\mu)\mathcal{O}_i(\mu)}_{\text{left handed}} + \underbrace{\mathcal{C}'_i(\mu)\mathcal{O}'_i(\mu)}_{\substack{\text{right handed} \\ \text{(suppressed in the SM)}}}]$$

i=1, 2	Tree
i=3-6, 8	Gluon penguin
i=7	Photon penguin
i=9, 10	Electroweak penguin
i=S	Higgs (scalar) penguin
i=P	Pseudoscalar penguin

- Four-fermion vertex, a-la Fermi
  - $\mathcal{C}_i$: Wilson coefficients. Perturbative, short distance, sensitive to high scales
  - $\mathcal{O}_i$: new operators, effect of non-perturbative QCD

We can use EFT to describe the unknown NP

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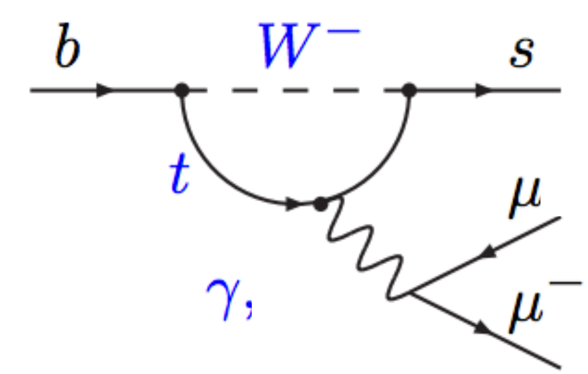
New physics can affect the values of the Wilson coefficients (of particular interest are $\mathcal{C}_7$, $\mathcal{C}_9$, $\mathcal{C}_{10}$)

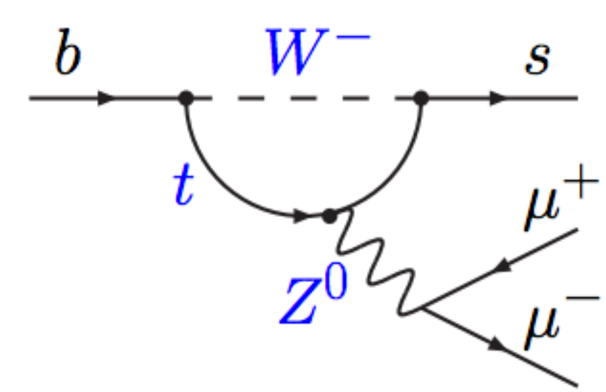
… or …

Introduce totally new operators $\mathcal{O}$' and $\mathcal{O}_P$

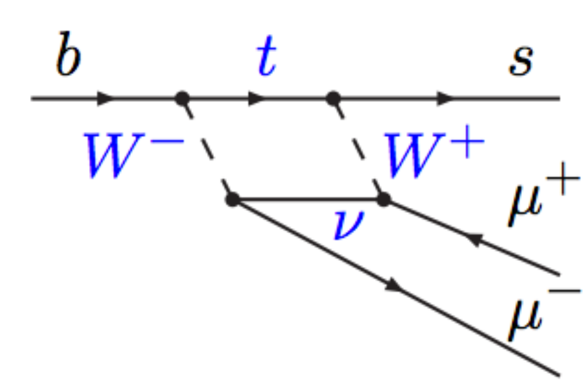
$\mathcal{O}_7$



$\mathcal{O}_9$



$\mathcal{O}_{10}$



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$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i [\underbrace{\mathcal{C}_i(\mu)\mathcal{O}_i(\mu)}_{\text{left handed}} + \underbrace{\mathcal{C}'_i(\mu)\mathcal{O}'_i(\mu)}_{\text{right handed (suppressed in the SM)}}]$$

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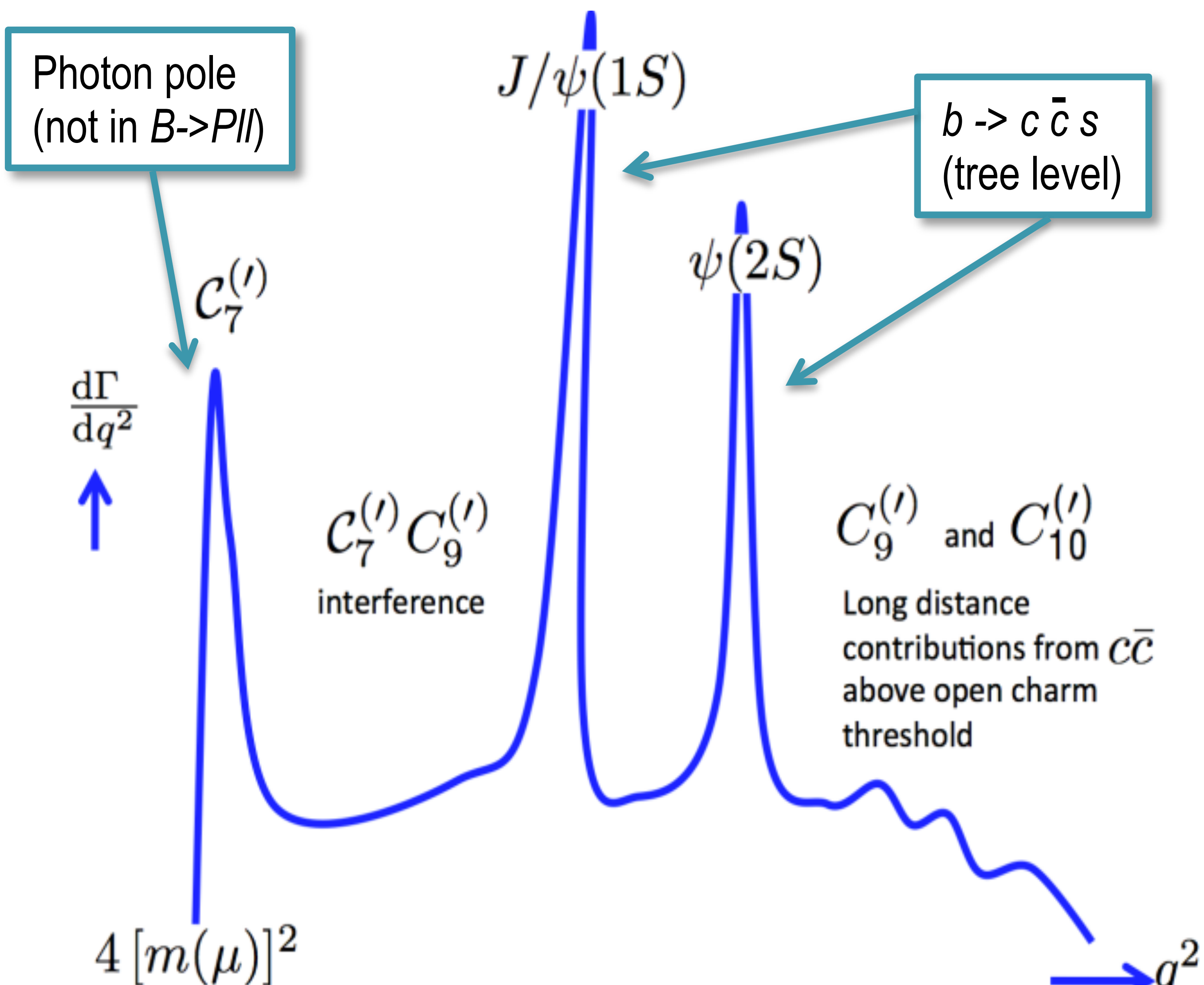


Different q², i.e. m(ℓℓ), are sensitive to different coefficients

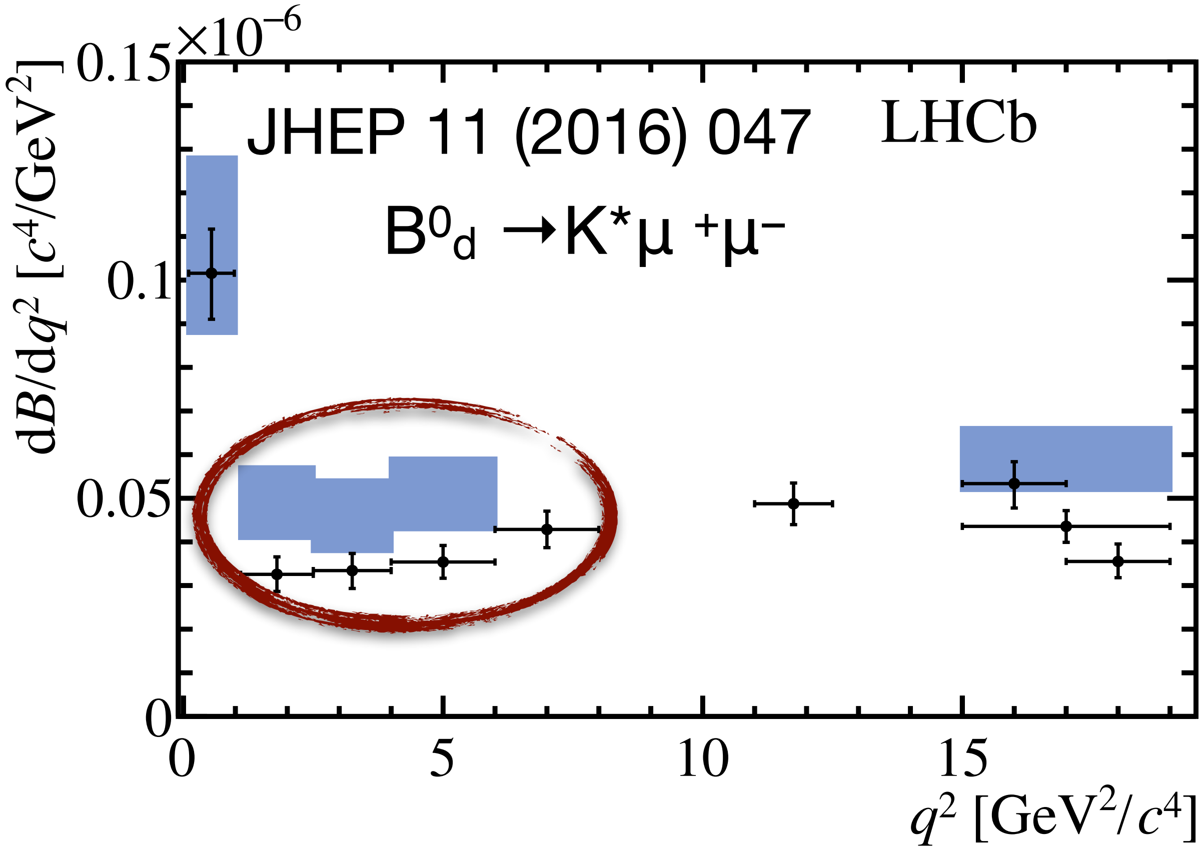
There are different ways of searching deviations

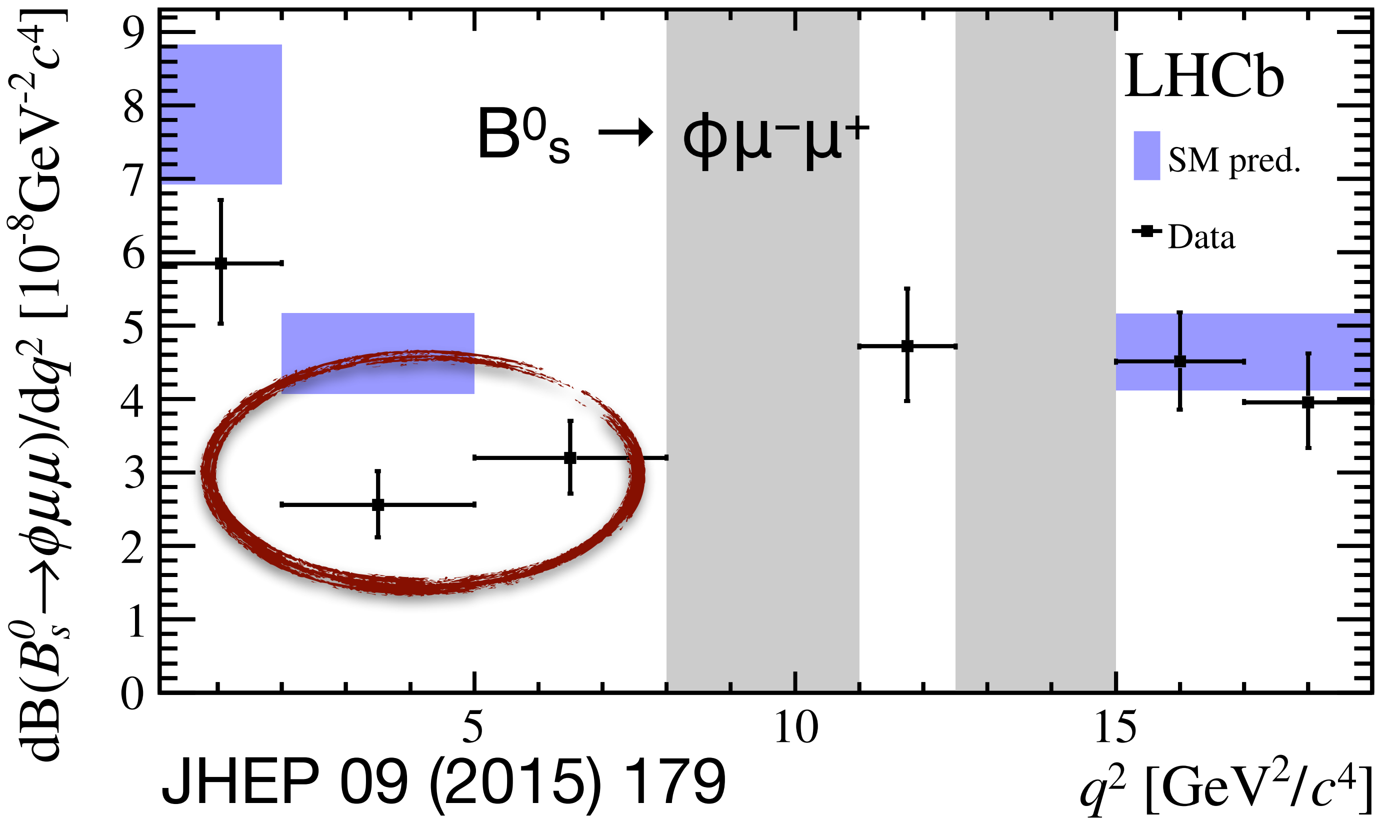
- Measure differential branching fractions (as function of q^2)
  - E.g.: $B \to K^{(*)}\mu\mu$, $\Lambda_b \to \Lambda\mu\mu$, $B_s \to \phi\mu\mu$, $B \to \pi\mu\mu$
  - Large theory uncertainties on form factors

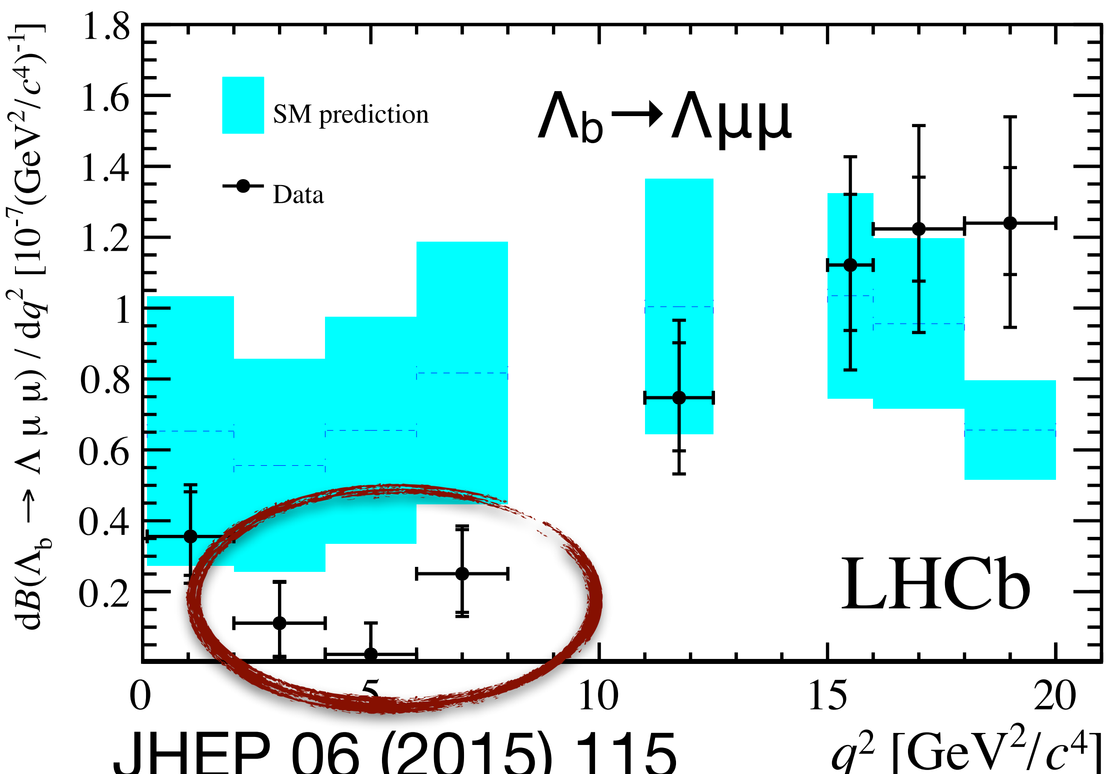
- Angular analysis:
  - E.g.: $B \to K^{(*)}\mu\mu$, $B_s \to \phi\mu\mu$

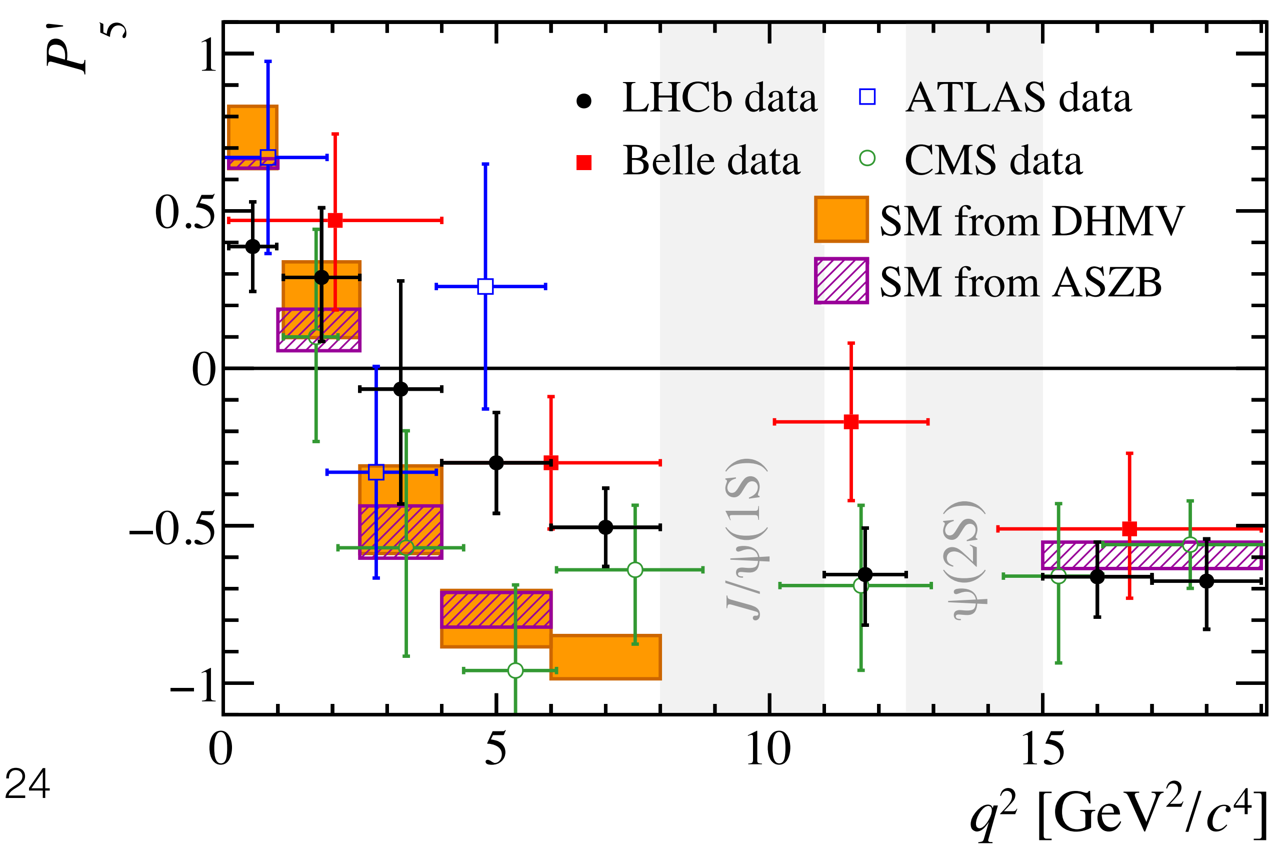
- Tests of lepton universalities: $R(X) = B \to X\ell(\ell) / B \to X\ell'(\ell')$
  - E.g.: $R(K) = B \to K\mu\mu / B \to Kee$, $R(K^*) = B \to K^*\mu\mu / B \to K^*ee$, $R(D^*) = B \to D^*\tau\nu_\tau / B \to D^*\mu\nu_\mu$
  - Cancellation of theory uncertainties in the predictions

Other Remarkable deviations so far

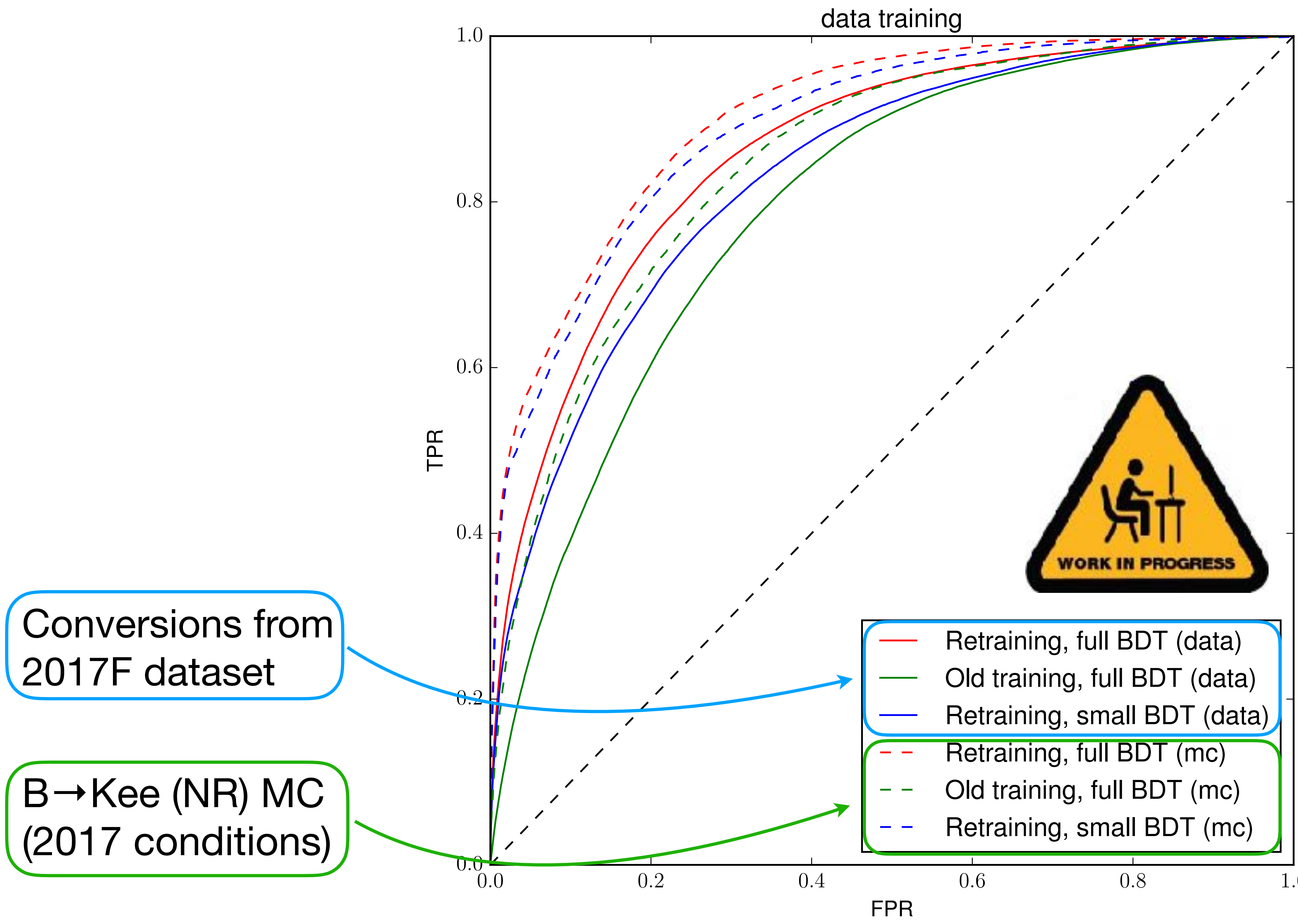








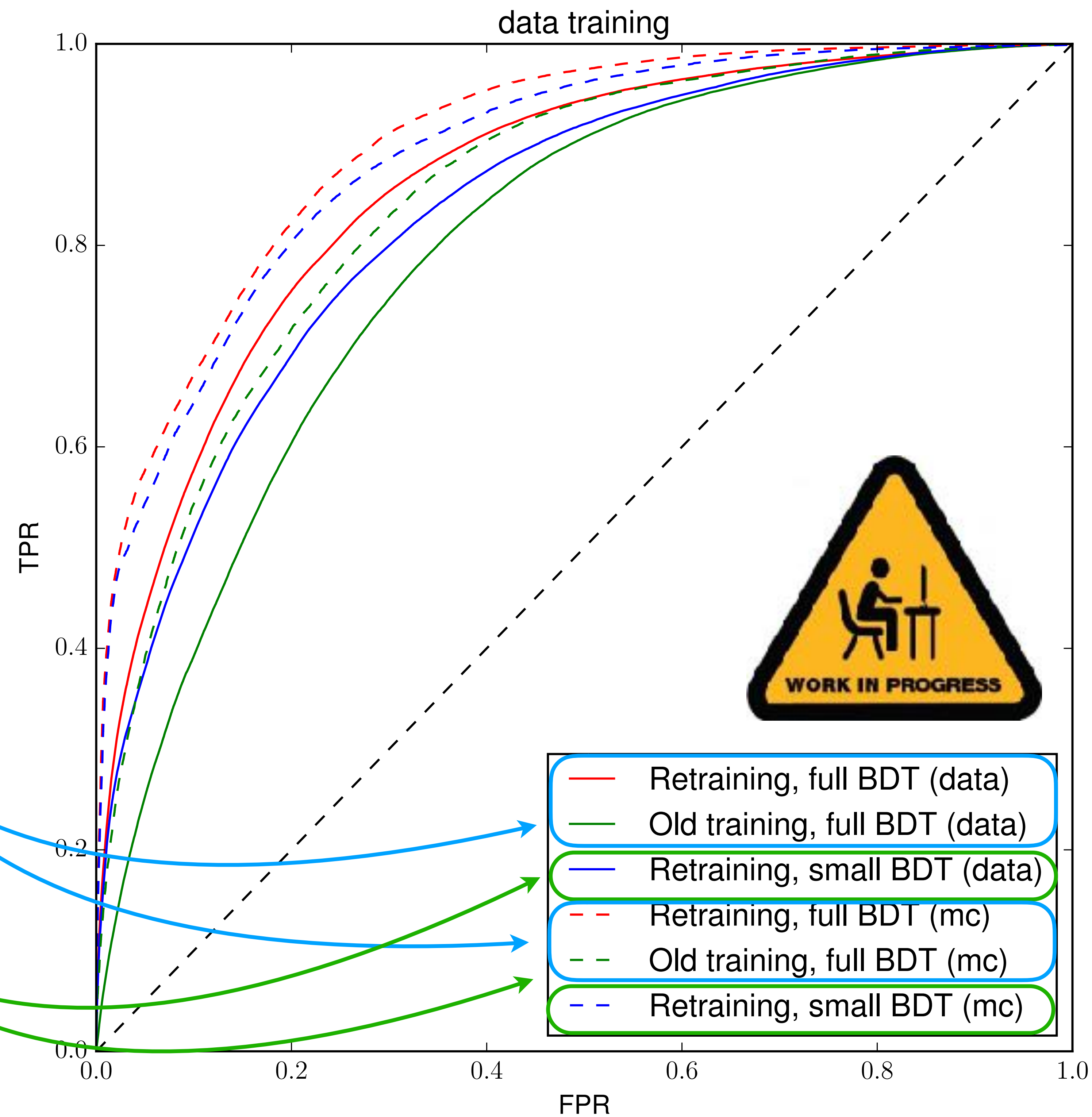
Very preliminary results look promising

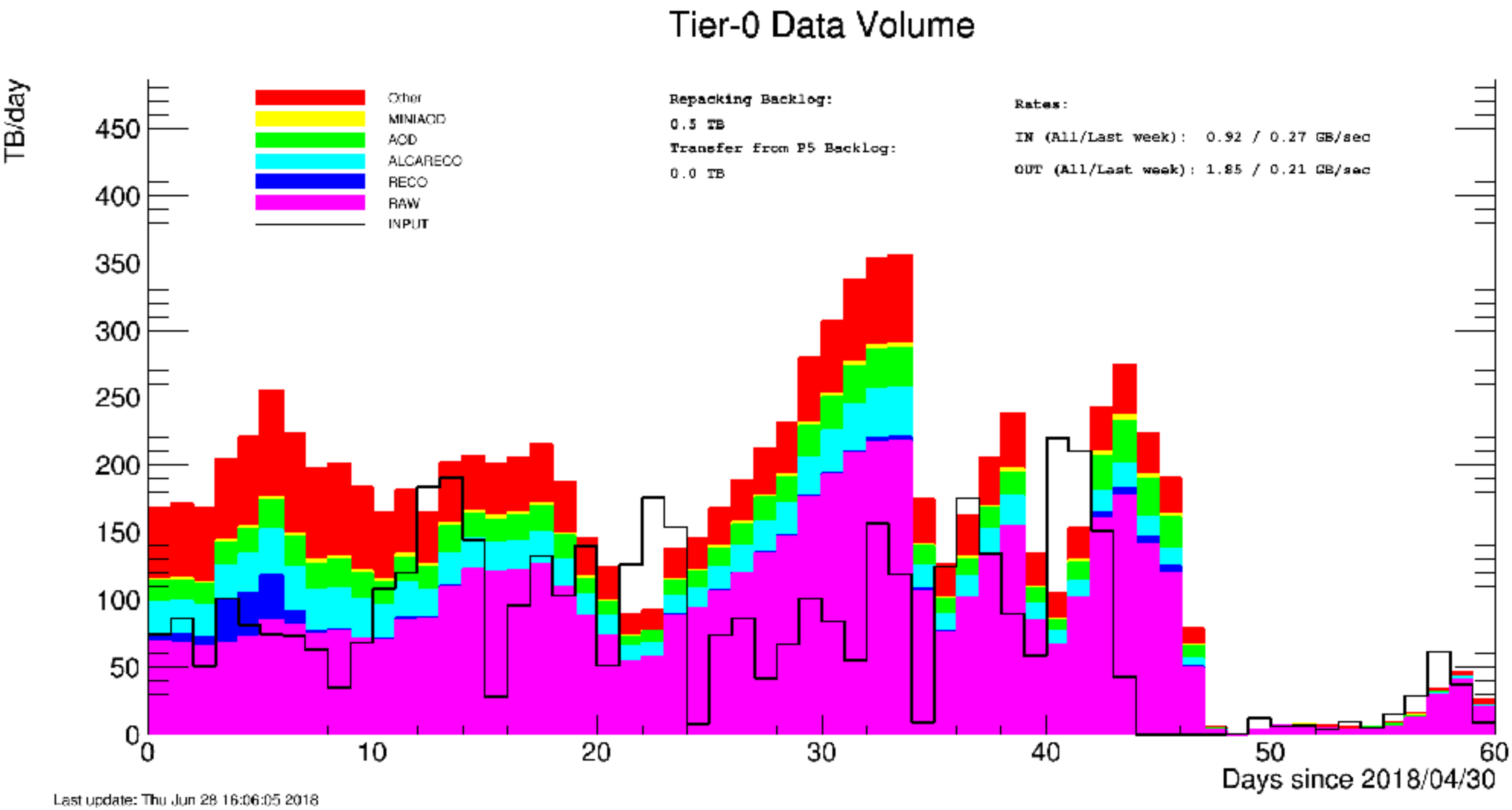


Very preliminary results look promising

Full information. Requires simplified GSF (= CPU time)

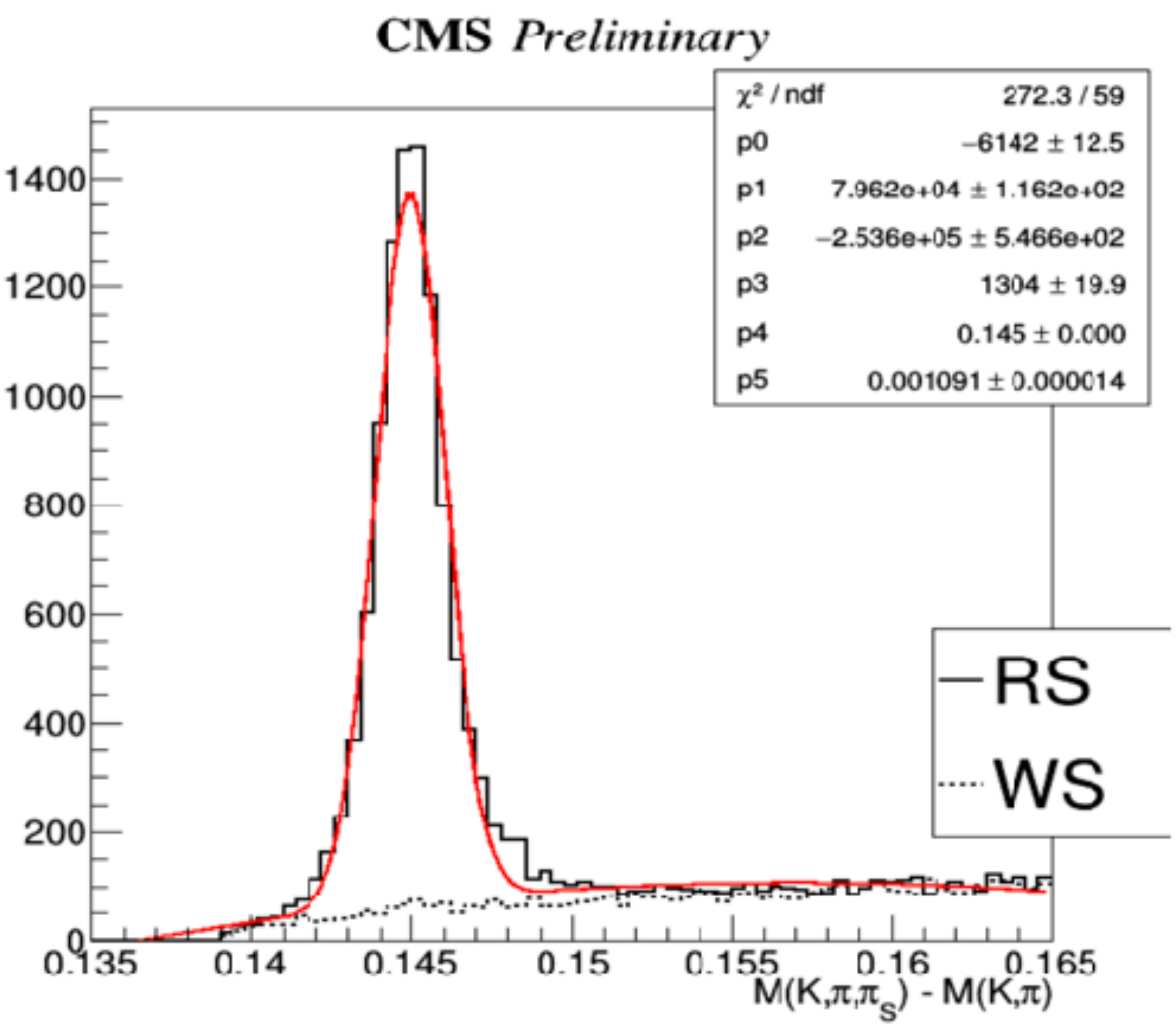
Simplified information, less CPU needed





Tier-0 Data Volume
TB/day
Other
MINIAOD
AOD
ALCARECO
RECO
RAW
INPUT
Repacking Backlog:
0.5 TB
Transfer from P5 Backlog:
0.0 TB
Rates:
IN (All/Last week): 0.92 / 0.27 GB/sec
OUT (All/Last week): 1.85 / 0.21 GB/sec
0
50
100
150
200
250
300
350
400
450
0
10
20
30
40
50
60
Days since 2018/04/30
Last update: Thu Jun 28 16:06:05 2018

- **This is the η restricted B purity from events that pass HLT_Mu9_IP6 and not uniquely fired from L1_SignleMuon22**
- Plot: $M(K,\pi,\pi_s)-M(K,\pi)$; Fit: Gaussian+2nd order pol. ; RS: $Q(\mu)\neq Q(\pi_s)$; WS: $Q(\mu)=Q(\pi_s)$
- $N(\mu)$: calculated from events that passed HLT_Mu9_IP6 .AND. fired from the Low p_T seeds



Factor	Value
$\alpha*\varepsilon$	0.10
F_{cor}	0.22
$N(\mu)$	20161145
Fit	8331

$$P_b = \frac{1}{N(\mu)\times F_{corr}} \frac{N(B^0 \rightarrow D^{*+}\mu\nu\,;\,\mathrm{data})}{\alpha(D^{*+})\times\varepsilon(D^{*+})\times 0.026} \Longrightarrow$$

$$\boldsymbol{P_b = 0.73}$$