Rare Decays
& Heavy Flavor

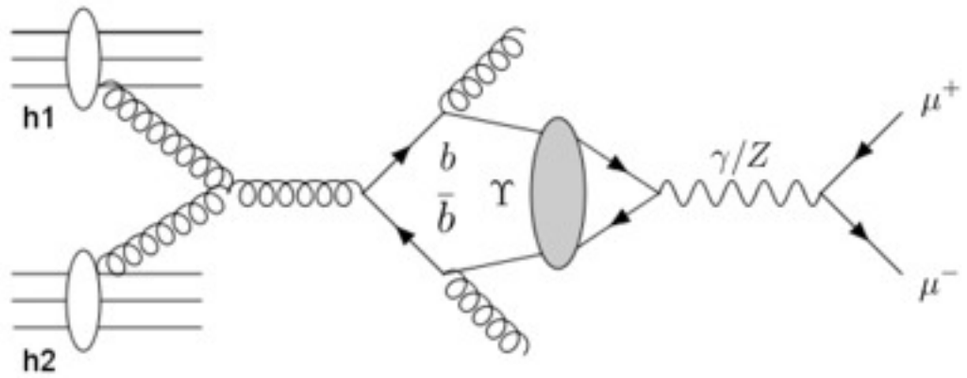
searches, measurements, prospects

Nuno Leonardo, Bruno Galinhas, Bruno Alves,
Júlia Silva, João Melo, Giorgio Ghillardi, Eliza Melo

Jornadas LIP 2018

Évora, Feb 16th, 2018

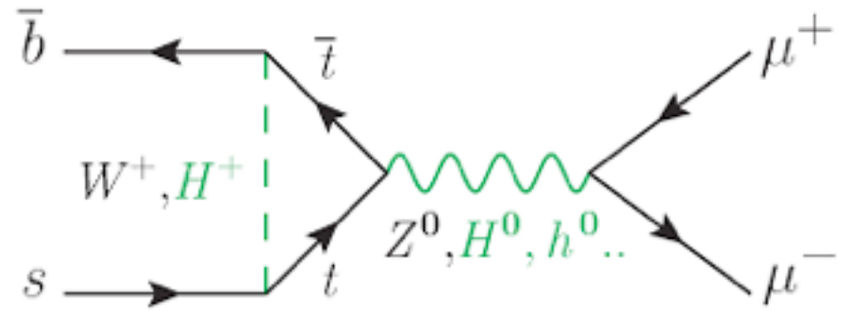
precision: Heavy Flavor



IJMP A32 19n20 (2017)

- precision tests of the SM
- understand QCD and its mechanisms of hadroproduction
- characterize the properties of the quark gluon plasma with novel probes

new physics: Rare Decays

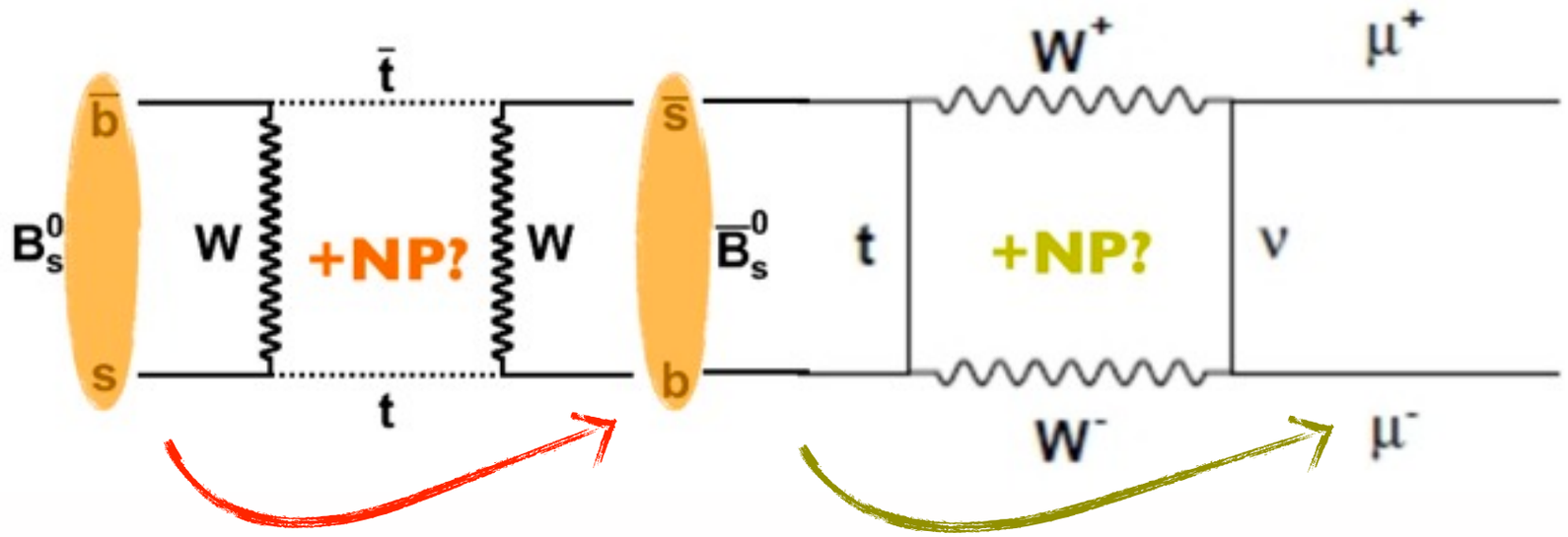


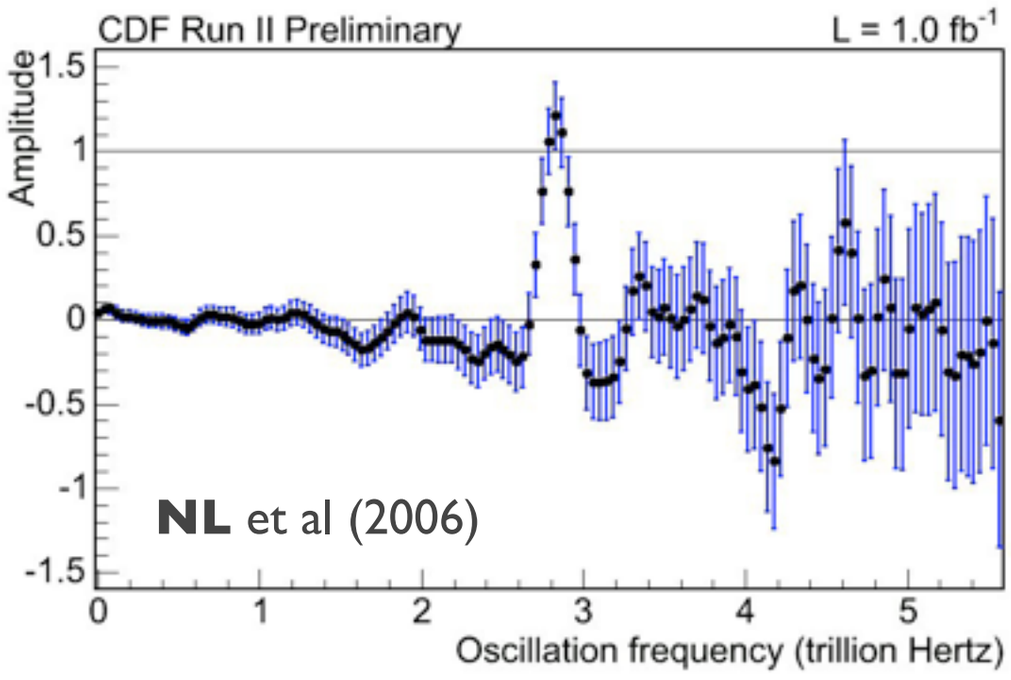
Nature 522 (2015) 68

- indirect search for BSM
- processes that are suppressed in the SM and highly sensitive to virtual contributions from BSM particles
- sensitive to higher NP scales

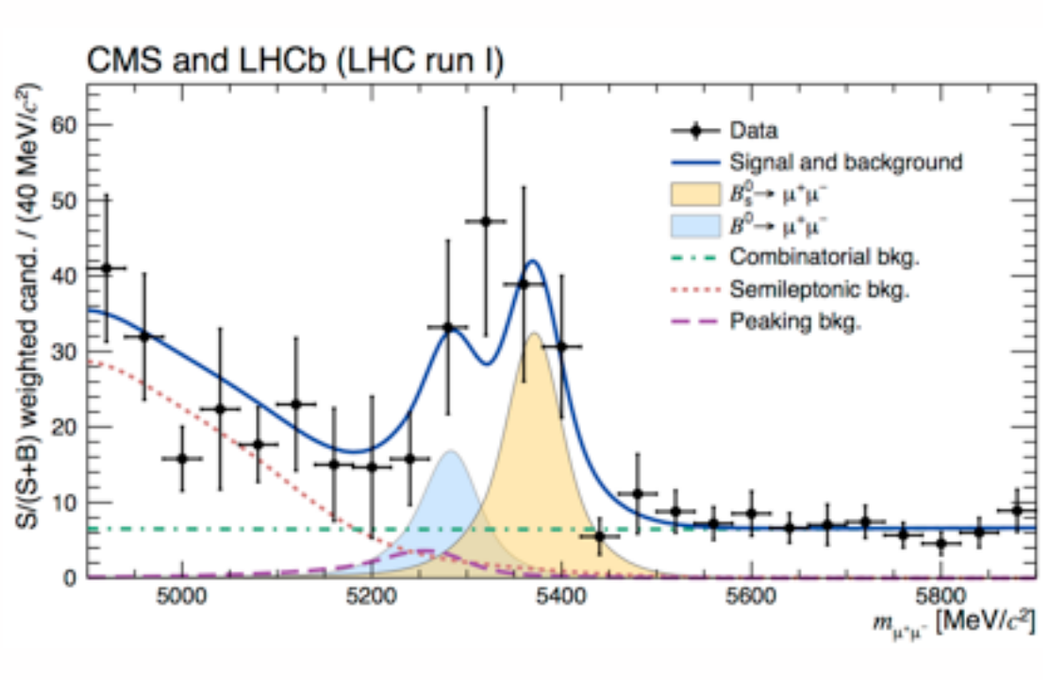
explore LHC's energy & luminosity frontiers

$B_s \to \mu\mu$ doubly-sensitive to NP





(1st) **Tevatron's Run2 flagship discovery**

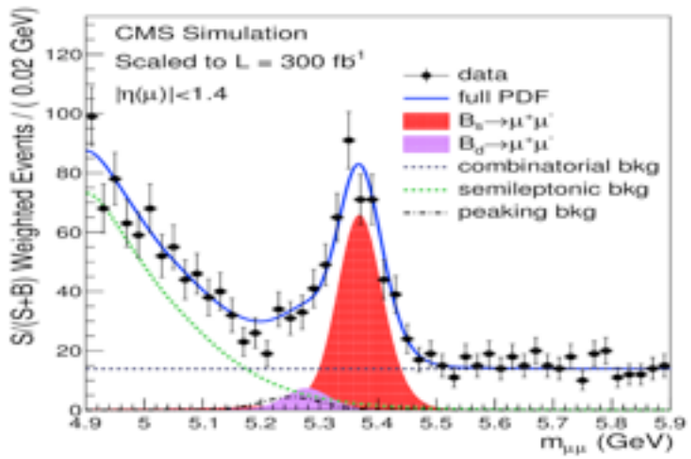


(2nd) **LHC's Run1 flagship discovery**

the B→μμ rare decays

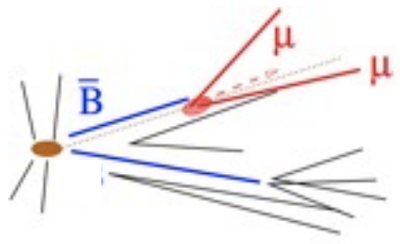
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \frac{N_S}{N_{obs}^{B^+}} \frac{f_u}{f_s} \frac{\varepsilon_{tot}^{B^+}}{\varepsilon_{tot}} \mathcal{B}(B^+)$$

PhD thesis ongoing by **B.Galinhas**

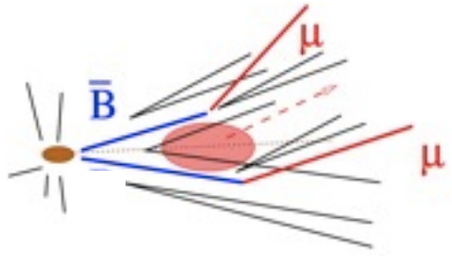


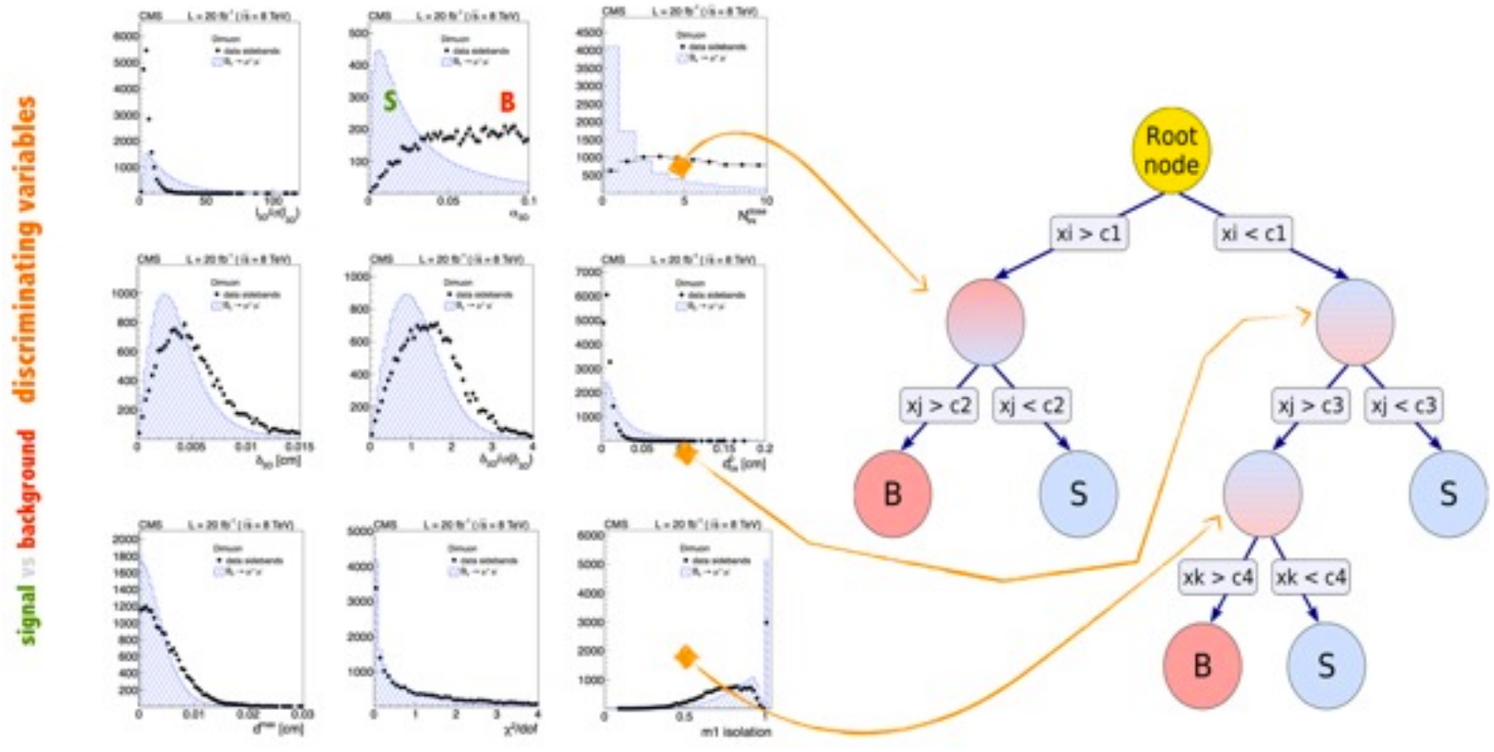
- 2015-2016 dataset
  - address dominant systematic source
- full Run2 dataset
  - explore alternative MVA method (DNN) for background rejection (focus on B^0)
  - explore additional observables with complementary sensitivity to NP (eg lifetime)

signal



background

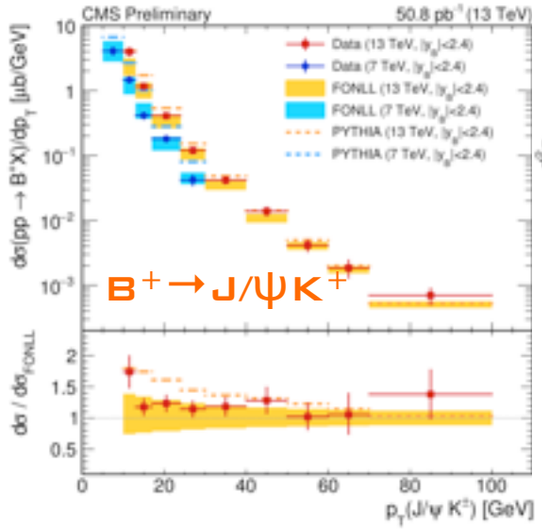




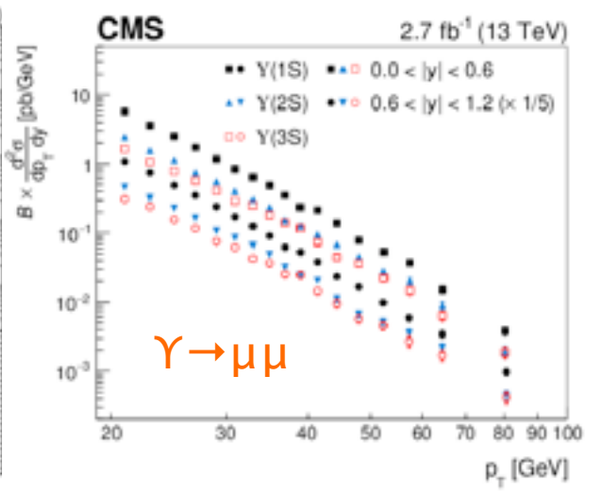
associated B production measurements

CMS task forces created & co-steered by NL

early data: HF production

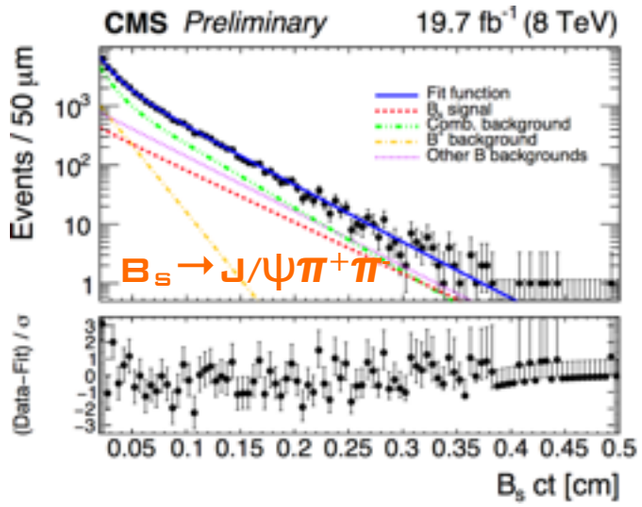


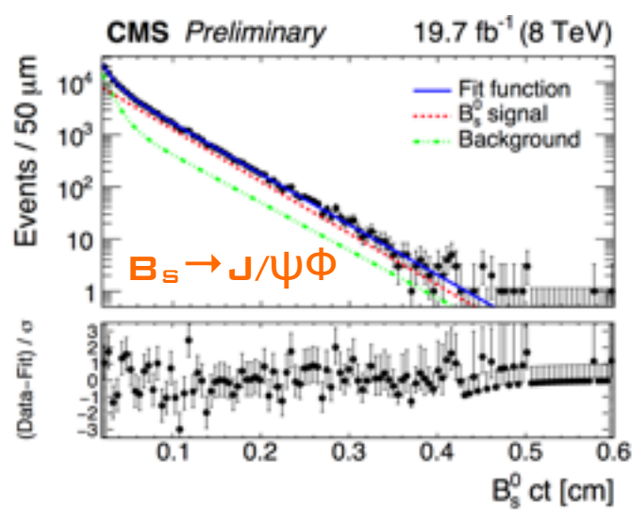
PLB 771 (2017) 435



just accepted by PLB

precision: b-hadron lifetimes





submitted to EPJC

production cross section measurement
of open and hidden beauty
at the new record energy of 13TeV

baseline measurements at the new energy
first CMS HF publications with Run2 data

$$c\tau_{B_s^0} = 504.3 \pm 10.5\,(\text{stat}) \pm 3.7\,(\text{syst})\ \mu\text{m}$$
$$c\tau_{B_s^0} = 443.9 \pm 2.0\,(\text{stat}) \pm 1.2\,(\text{syst})\ \mu\text{m}$$

competitive set of precision lifetime
measurements of various b-hadrons

developed analysis techniques
being applied to measure the
$B_s \to \mu\mu$ effective lifetime

fragmentation fraction ratios

- the f_d/f_s ratio can be determined as

B.Galinhas, B.Alves, NL
MSc thesis ongoing by **B.Alves**

$$\frac{f_s}{f_d} = \frac{N_{B_s}}{N_{B^0}} \frac{\mathcal{B}(B^0 \to J/\psi\, K^{0*})\, \mathcal{B}(K^{0*} \to K\pi)}{\mathcal{B}(B_s \to J/\psi\, \phi)\, \mathcal{B}(\phi \to KK)} \frac{\epsilon_{B^0}}{\epsilon_{B_s}}$$

Ratio of signal yields

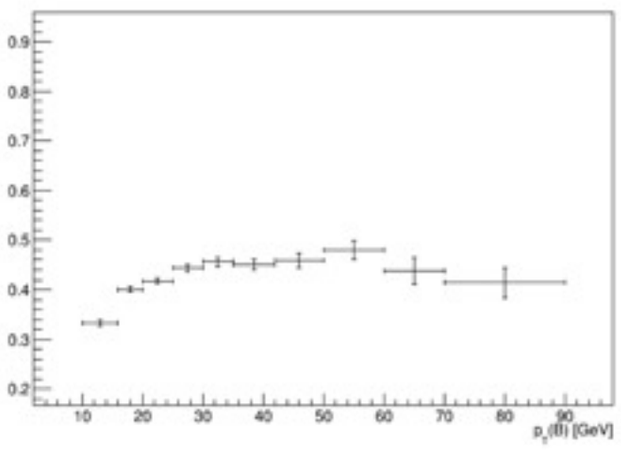
Ratio of branching fractions

(taken from PDG)

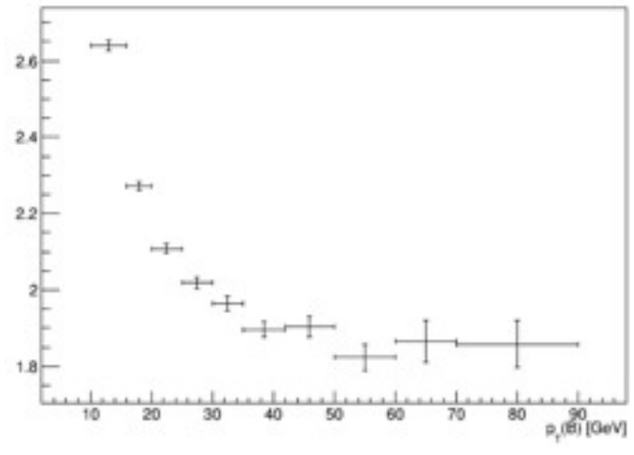
Ratio of efficiencies

from the data

from simulation



x



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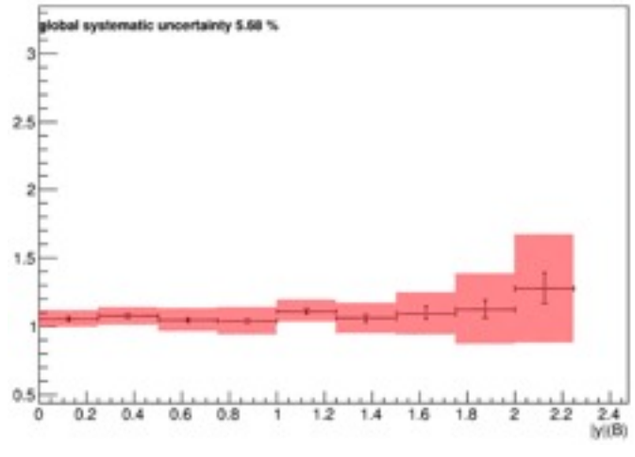
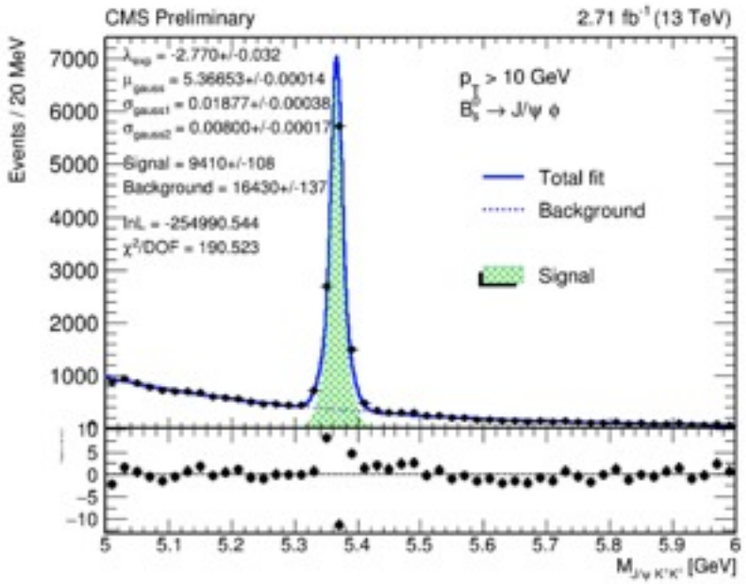


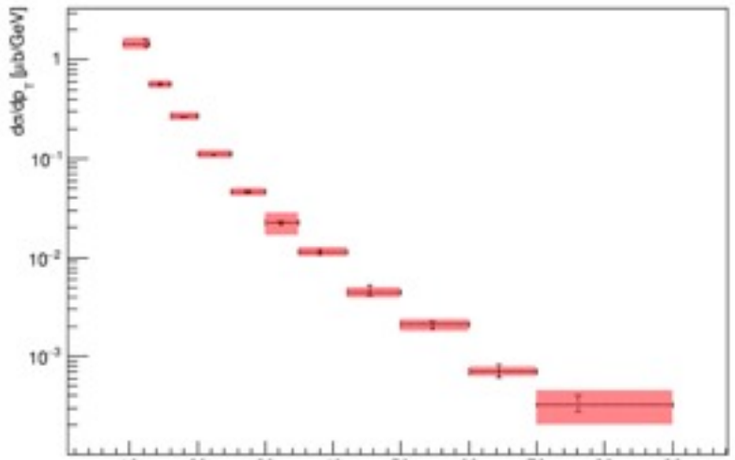
➠ measurement exclusively ***made in LIP*** from A to Z (see Bruno's poster!)

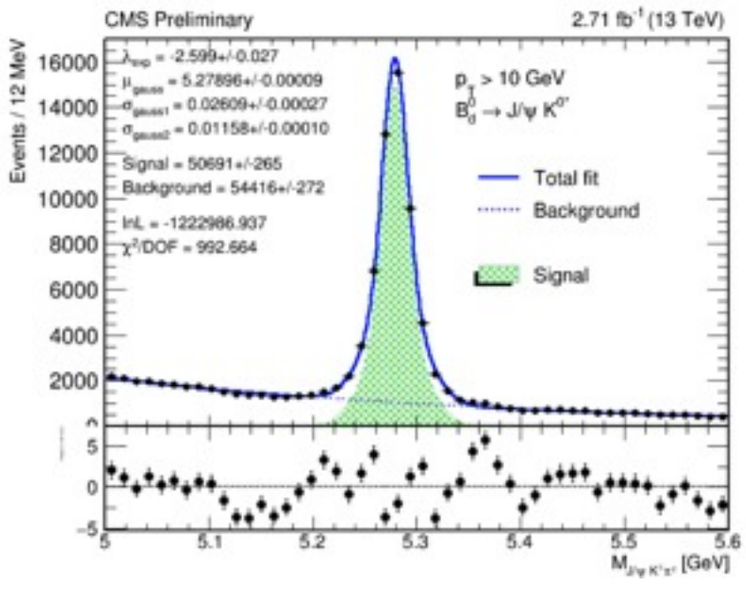
cross sections: B_s^0 and B^0 @13TeV

J.Melo, J.Silva
internship 2016: 2015 data

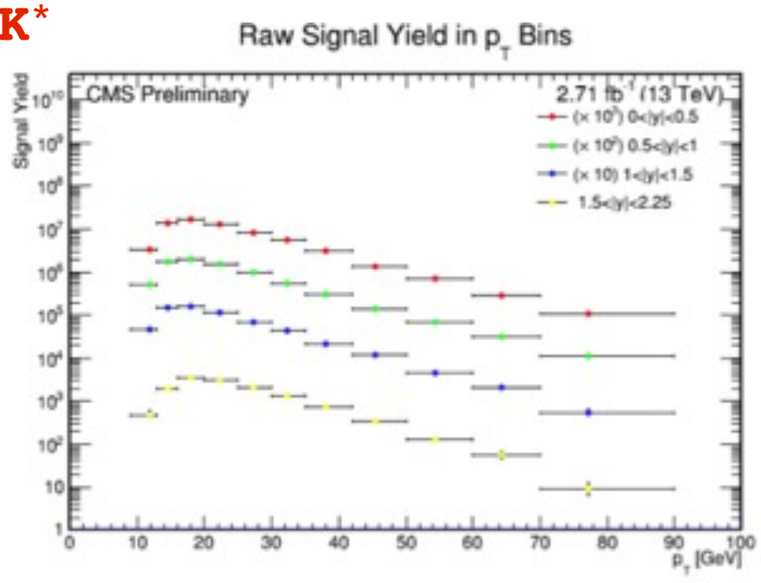


$B_s \to J/\psi\phi$





$B^0 \to J/\psi K^*$



early Run2 data (2015)

- selection optimization

- data-MC validation
  with sideband subtraction

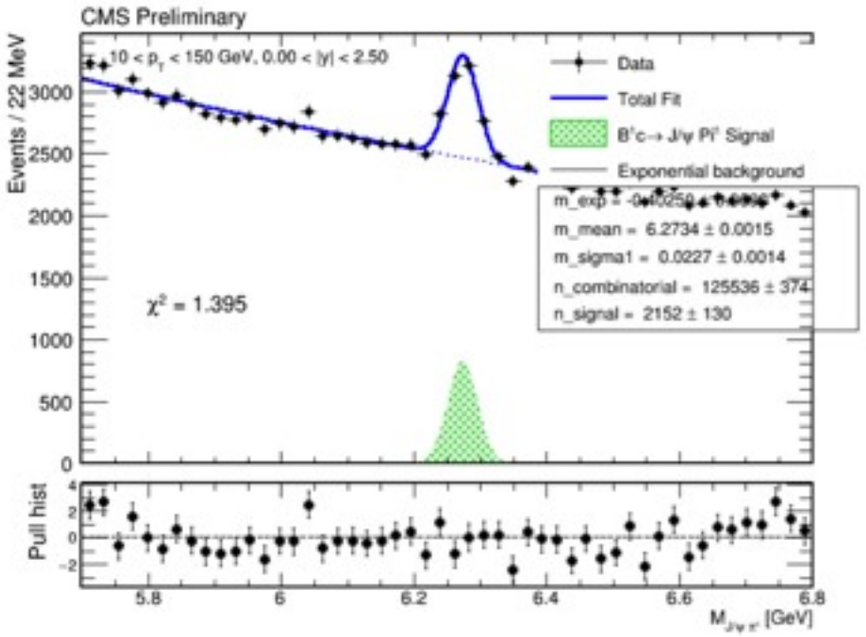
- yield extraction
  and systematics

- fit validation
  with pseudo experiments

➠ delivered first production measurement at 13 TeV with Bs and B0

cross sections: B_c^+ and B^+ @13TeV

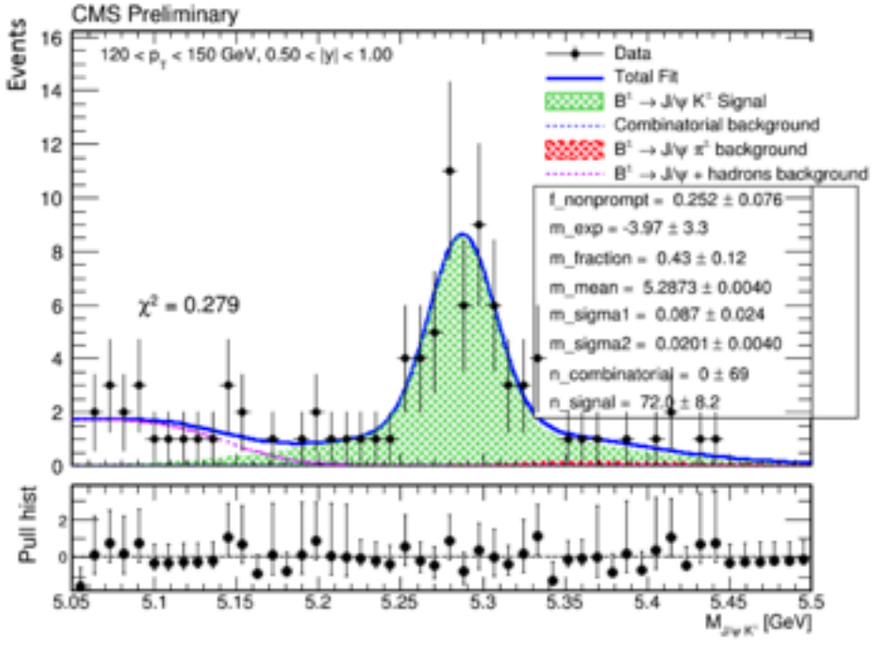
G.Ghillardi, B.Alves
internship 2017: 2016 data



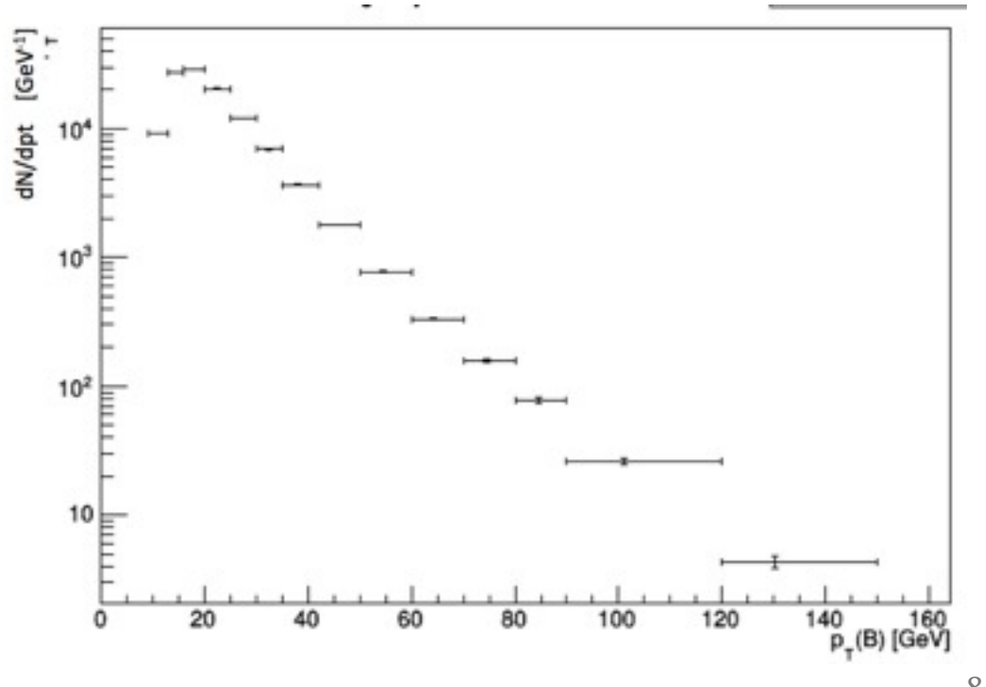
$B_c \to J/\psi\pi$

processed the 2016 dataset
- ported analysis code to new CMS software release
- access and process the data using the global GRID infrastructure
- generated and processed MC simulation

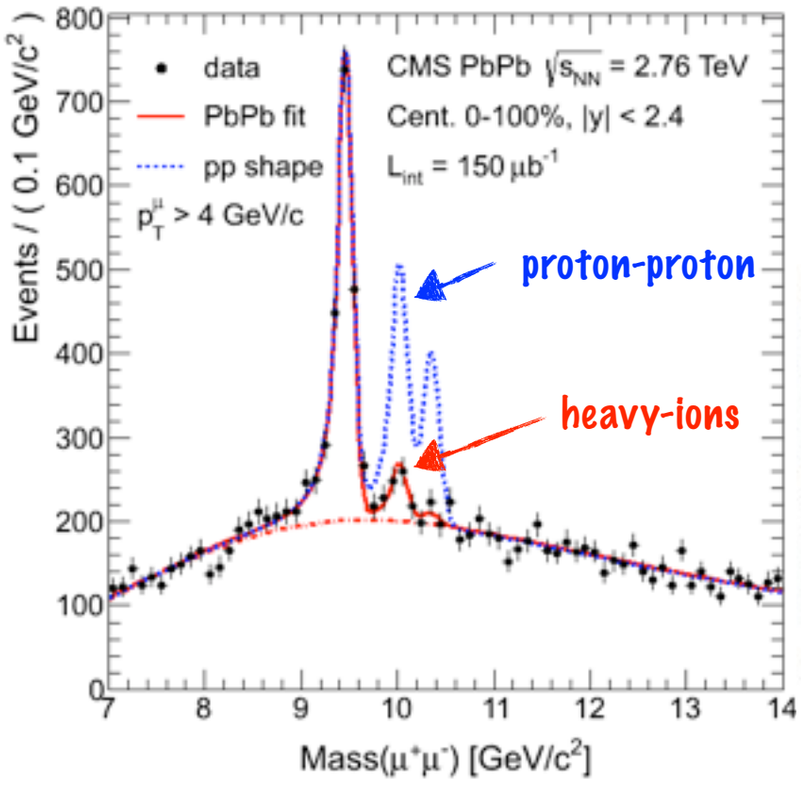
➠ obtained first Bc analysis in Run2



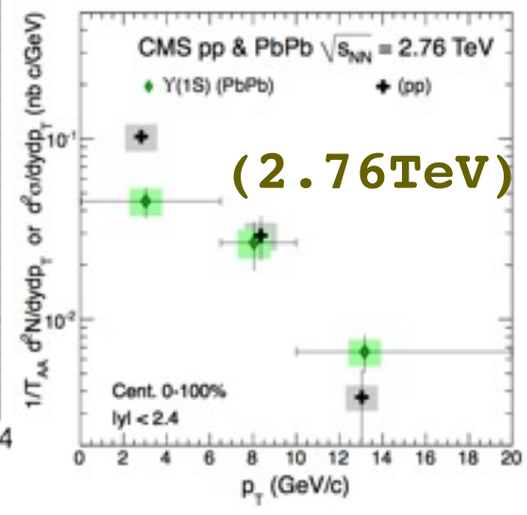
$B^+ \to J/\psi K^+$



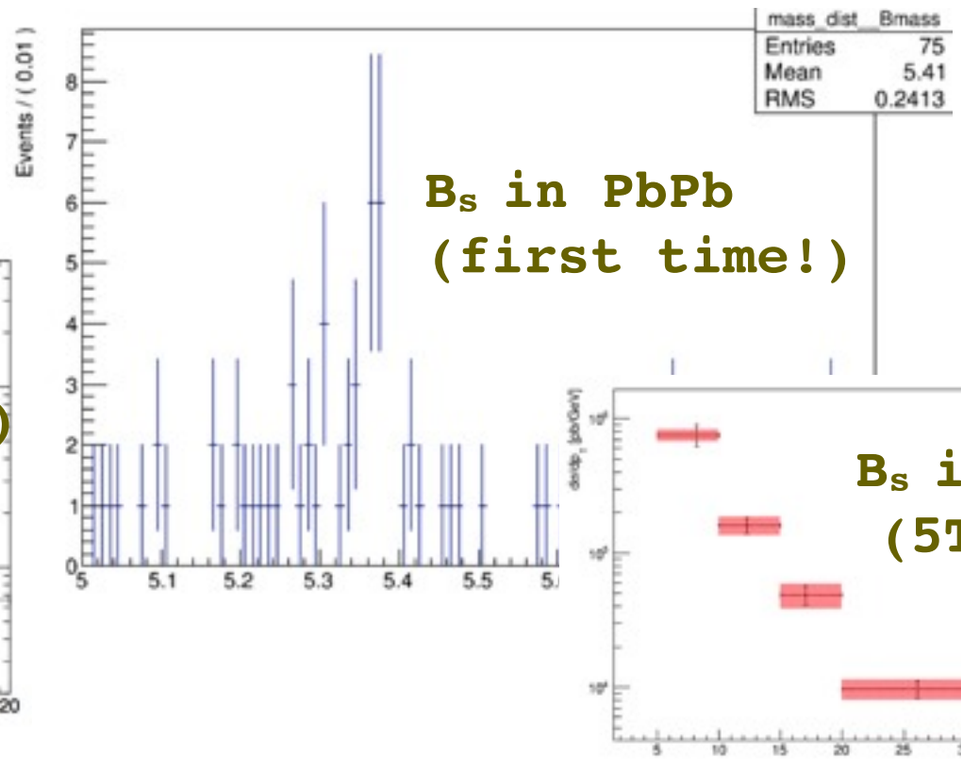
novel probes of the QGP



NL et al
(2011, 2012)



J.Silva (2017)



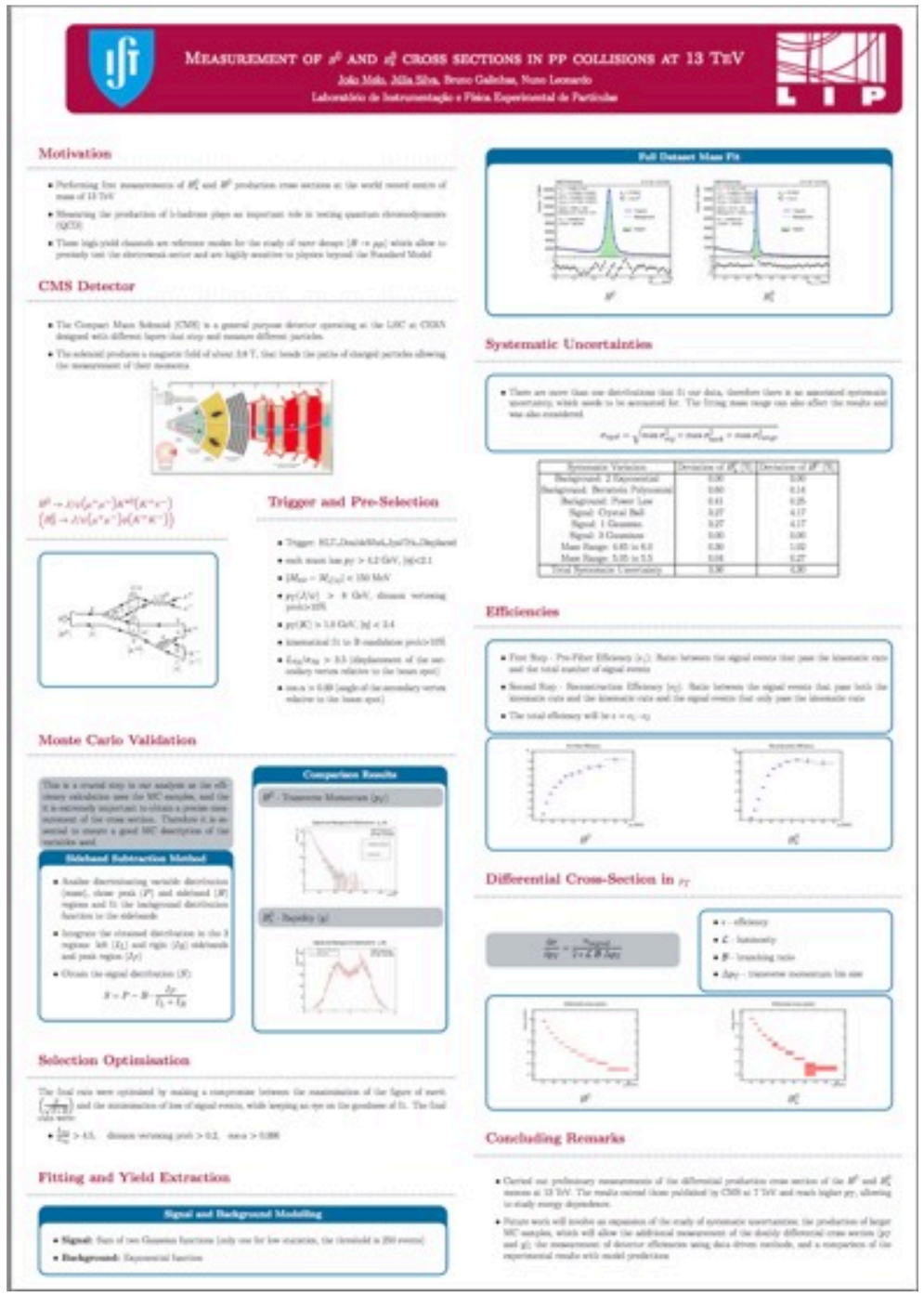
First Υ(nS) in heavy ions
seen with first PbPb Run1 data

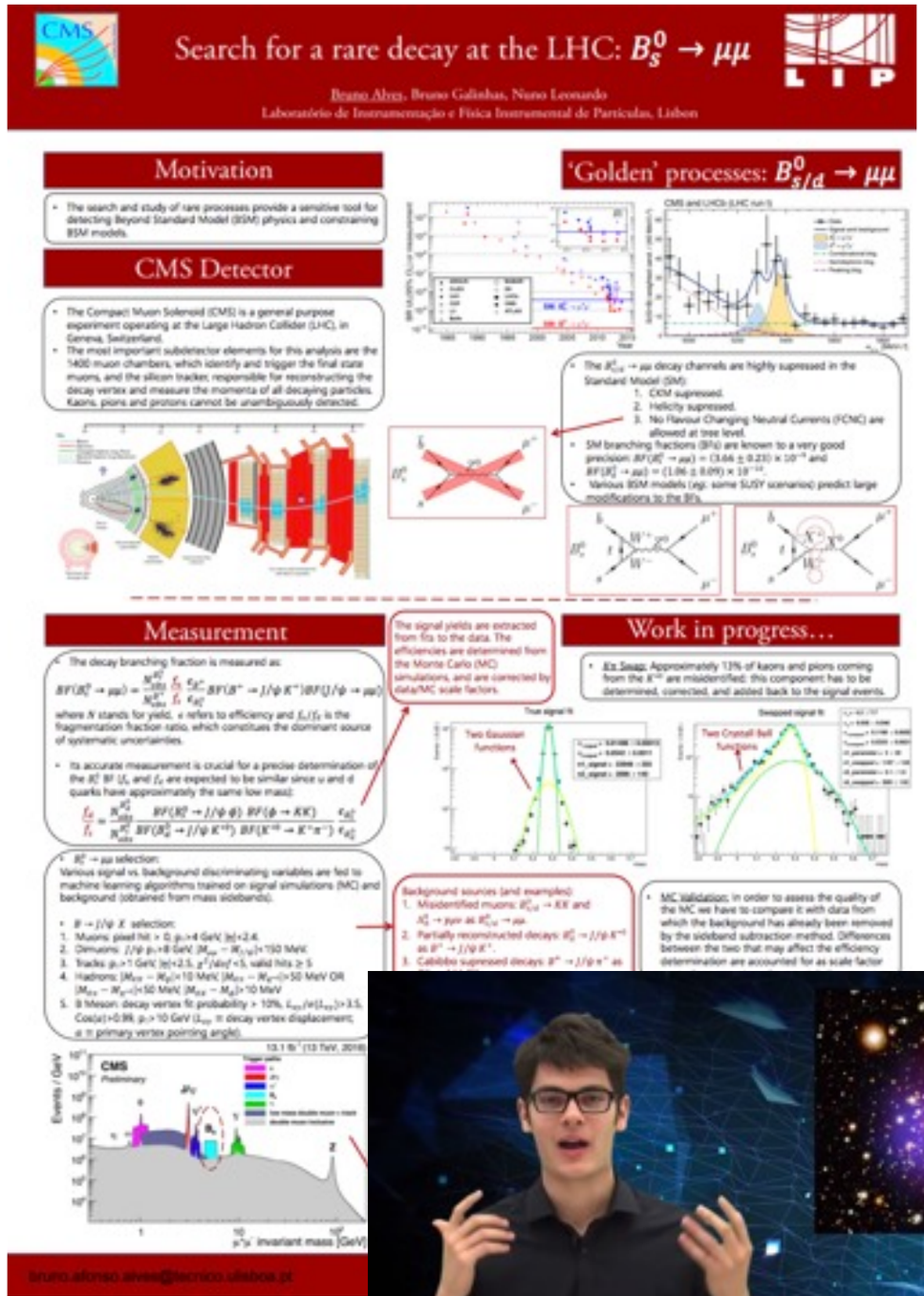
➠ found spectacular indication of QGP formation (onia sequential suppression)

First B mesons in heavy ions
seen with first PbPb Run2 data

➠ novel probe, used to study flavor dependency of energy loss

Distinguished posters @ IST's JEF'2017





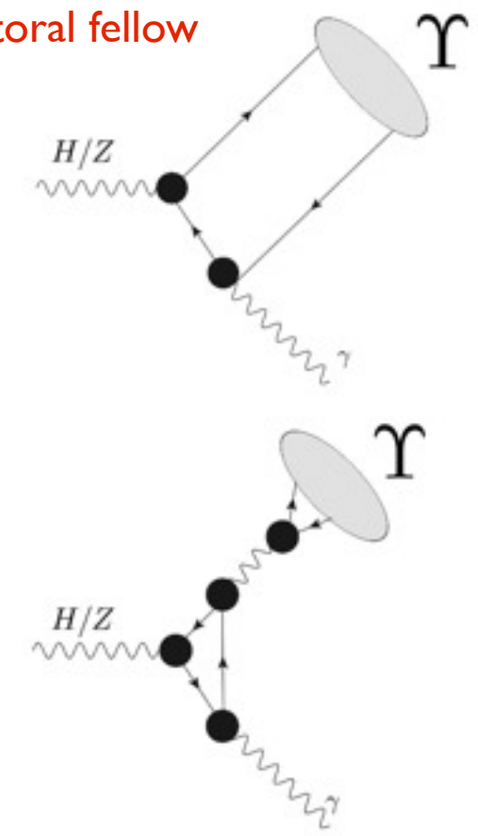
... and a cool outreach video:

João Melo Júlia Silva Giogio Ghillardi Bruno Alves

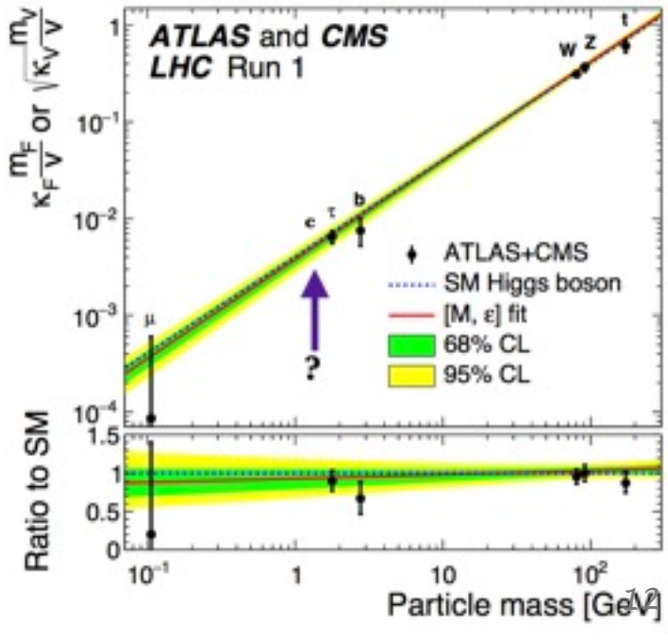
1st LIP Summer Student Program, Final Workshop
Photo credit: R.Gonçalo

Higgs (and Z) rare decays

NL, **E.Melo**
postdoctoral fellow



- rare processes in the SM (BR: 10^{-7}-10^{-9})
  - sensitive to NP
- allows to measure quark Yukawa couplings
  - alternative to H→qq (challenging due to QCD)
- Z provides experimental benchmark for the H decay
  - larger production cross section, nearby mass
- valuable tool for probing nature of quarkonium production
  - a topic LIP has been leadingly exploring
- dedicated trigger has been deployed
- analysis of the collected data started



summary

- **Rare Decays**
  - $B \to \mu\mu$: analysis being pursued with partial and full Run2 data
  - $H,Z \to Q\gamma$: analysis being started with existing data, targeting full dataset

- **Heavy Flavor**
  - fragmentation fractions
  - production cross sections
  - B mesons as novel QGP probes
  - not covered: top cross section, quarkonium polarization

✓ Physics area with **LIP leadership** in CMS
  - B and Quarkonium Physics Analysis Group (NL, 2014-16)
  - Working Subgroups: Exclusive decays (NL, 2011), Quarkonium (PF, 2012-13), Top Mass (PS, 2013), Rare Decays & CP Violation (NL, 2013)