BARD: B-Resonance Algorithm using Rare Decays

Hagen Möbius

57.Herbstschule HEP

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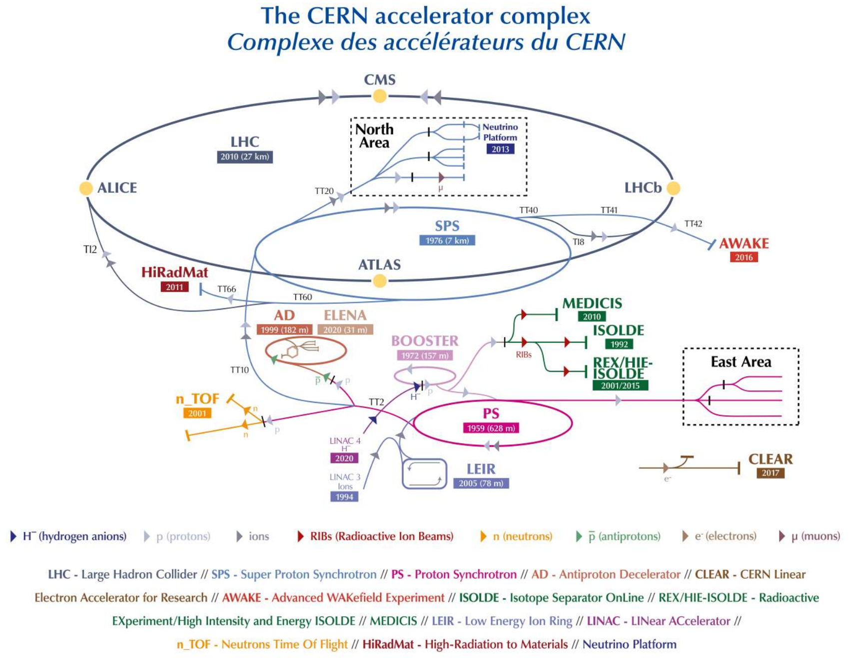
Large Hadron Collider

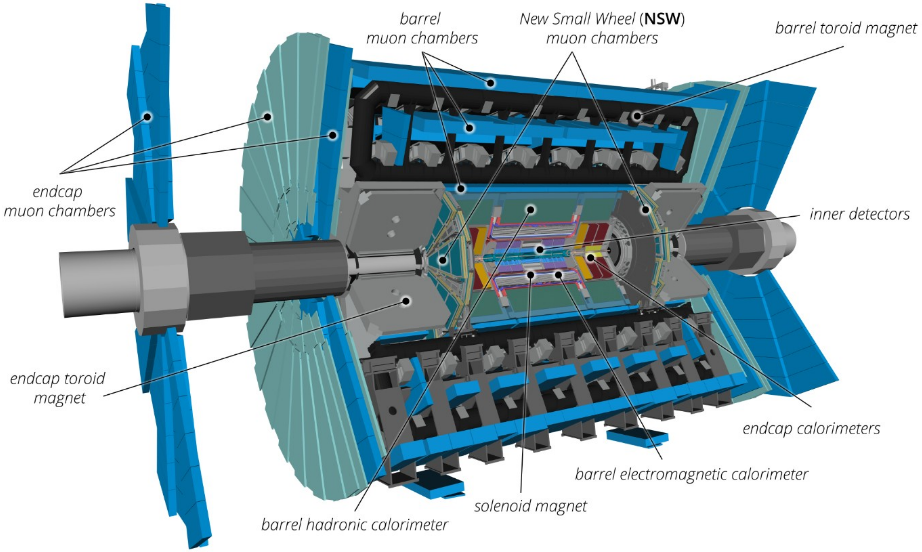
- Large Hadron Collider (LHC) is a proton-proton collider at CERN with a center of mass energy of $\sqrt{s}=13.6\,TeV$
- Four main experiments: ATLAS, CMS, ALICE, LHCb



https://cds.cern.ch/record/2800984

ATLAS

- General purpose detector at the LHC
- Multiple subdetector systems
  - Inner Detector:
    → tracking of charged particles
  - Calorimetry:
    → measure energy of particles
  - Muon spectrometer
    → measure minimal ionizing particles
  - Magnet system
    → momentum measurement and charged particle identification



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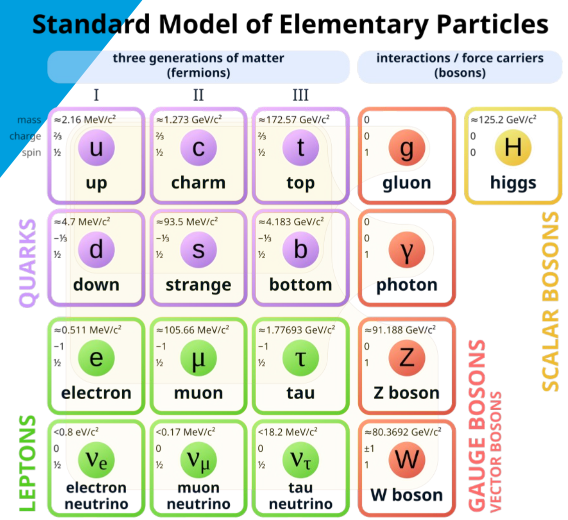
Standard Model of Elementary Particles
three generations of matter (fermions)
interactions / force carriers (bosons)
I
II
III
mass
charge
spin
≈2.16 MeV/c²
⅔
½
u
up
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charm
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Z boson
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±1
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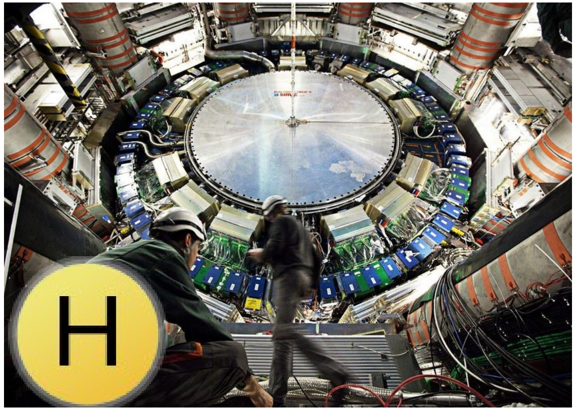
W boson
QUARKS
LEPTONS
GAUGE BOSONS
VECTOR BOSONS
SCALAR BOSONS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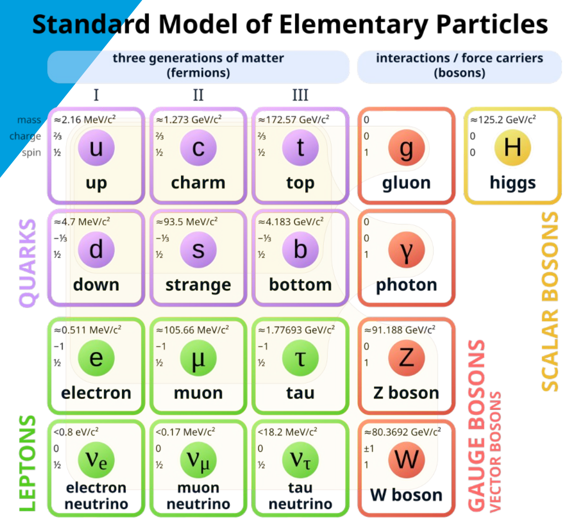

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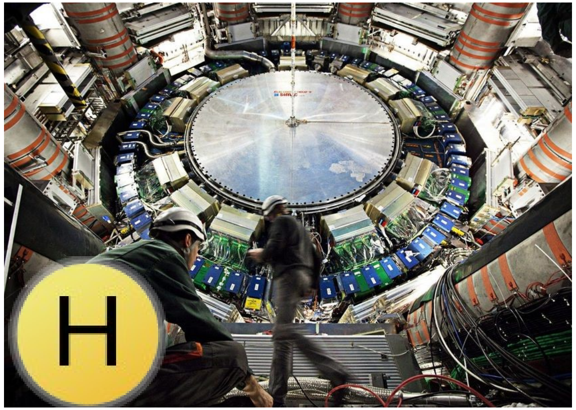

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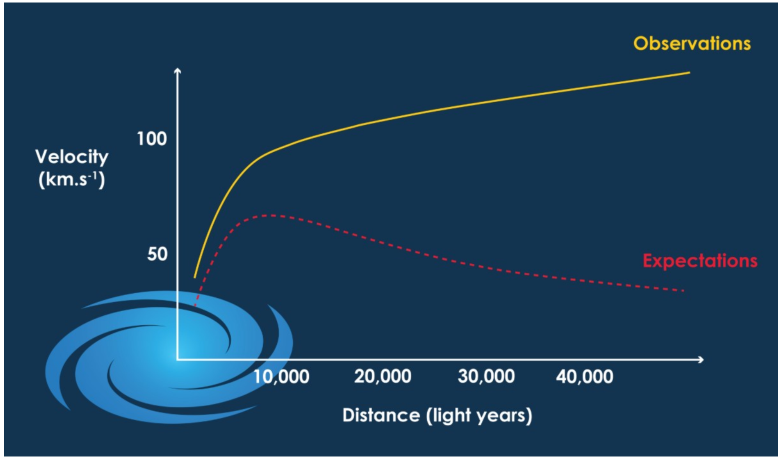
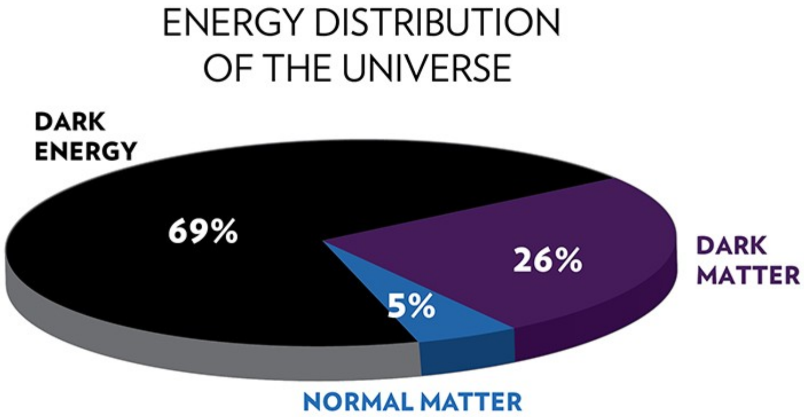
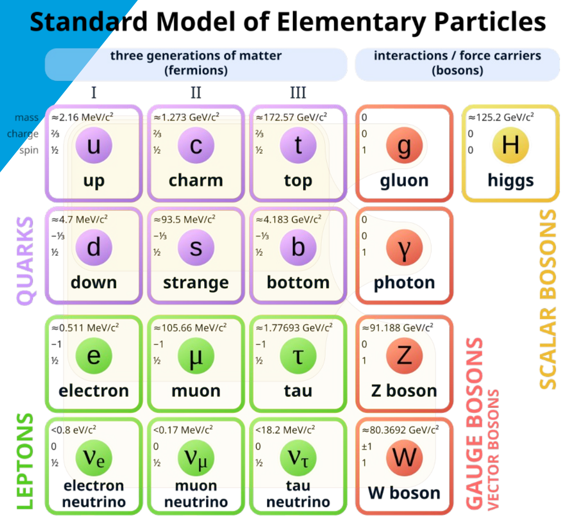


Observations
Expectations
Velocity (km.s⁻¹)
100
50
10,000
20,000
30,000
40,000
Distance (light years)



ENERGY DISTRIBUTION OF THE UNIVERSE
DARK ENERGY
69%
26%
DARK MATTER
5%
NORMAL MATTER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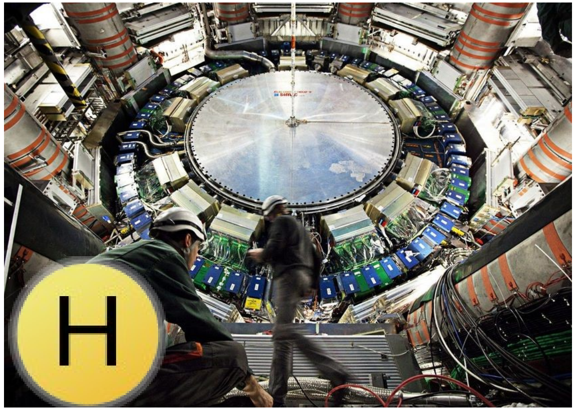
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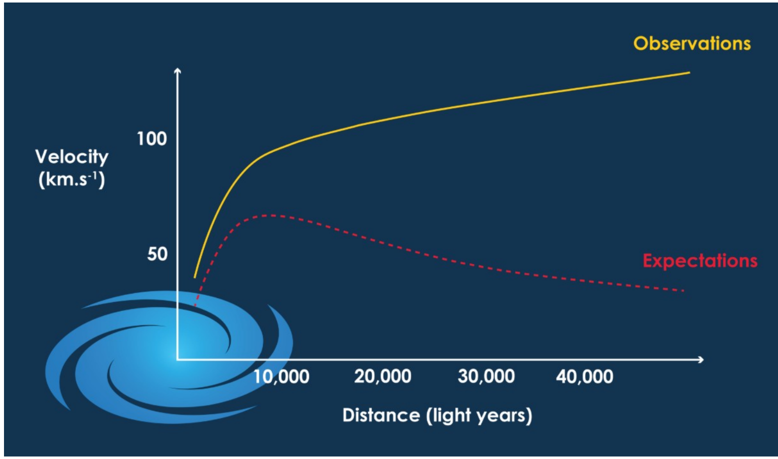
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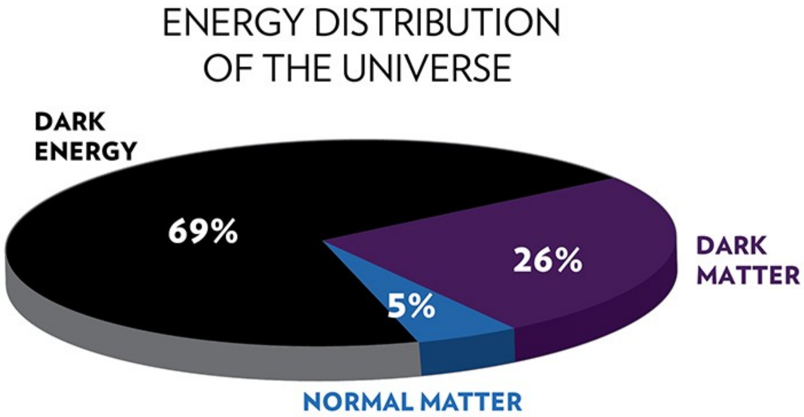
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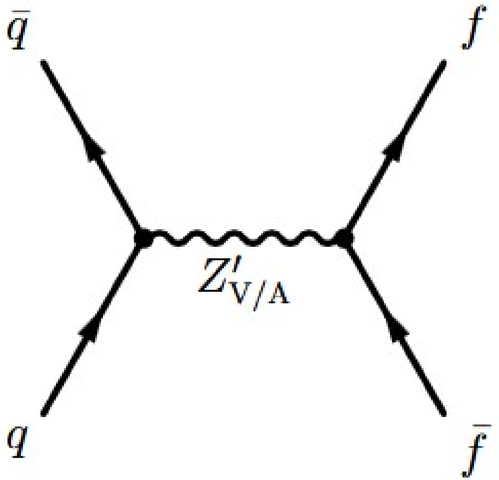
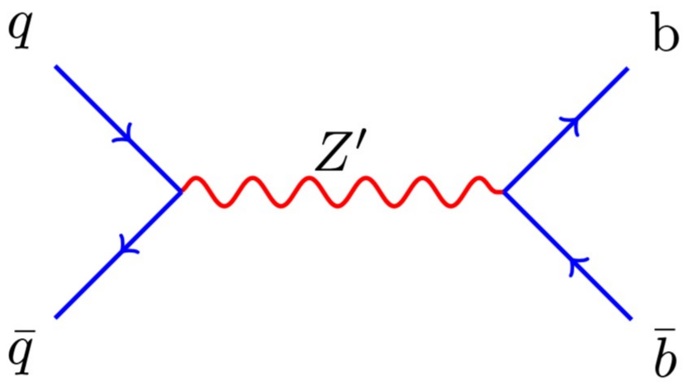

$\bar{q}$
f
$Z'_{V/A}$
q
$\bar{f}$

di-bjet searches

- B-resonance searches look for new particles decaying into a bb-pair



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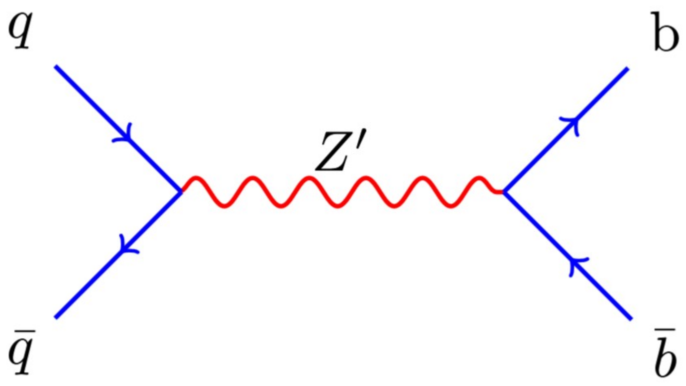
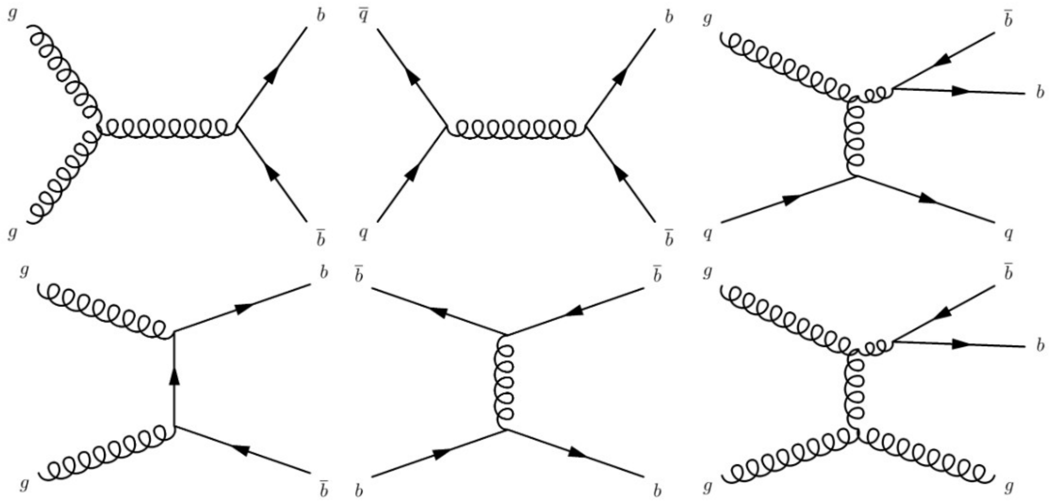
- Challenging:
  1. Huge amount of QCD background





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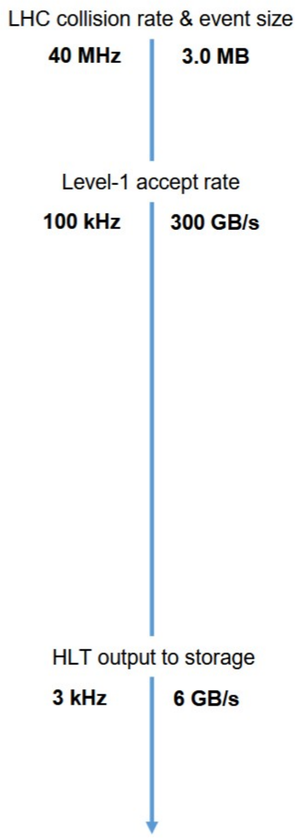

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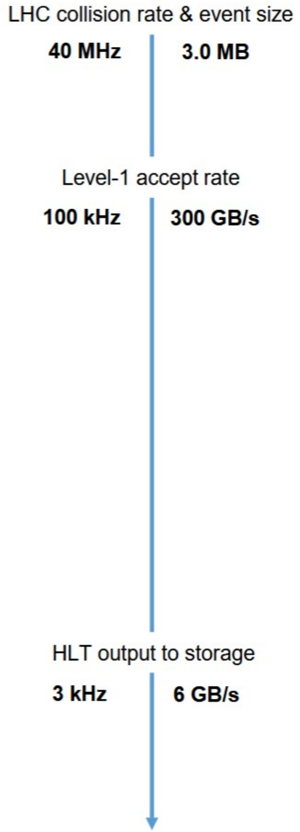
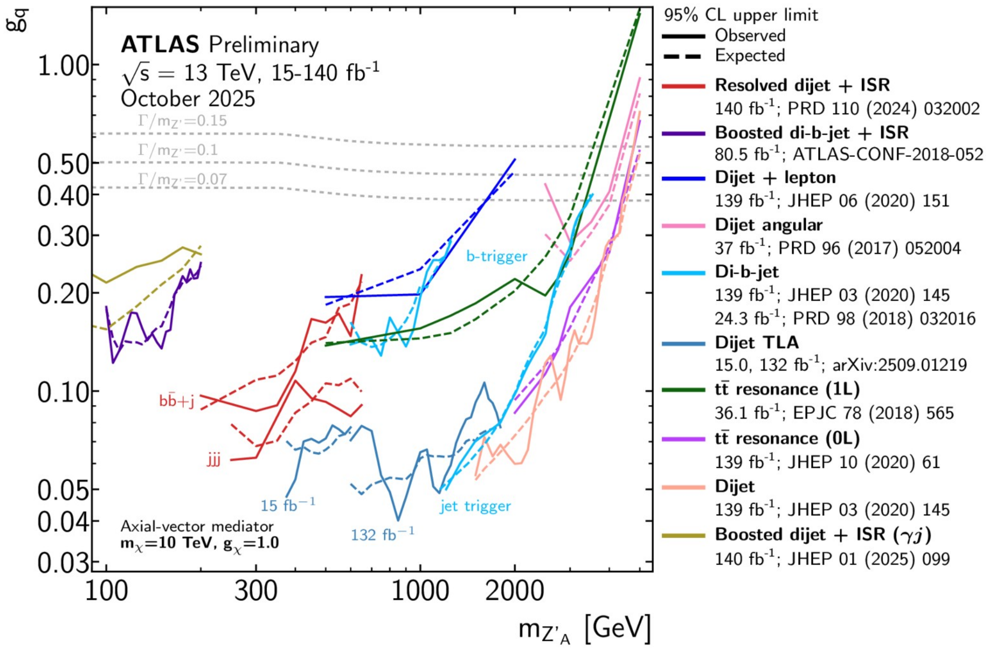
  → exceeds the disk rate available at ATLAS
- HLT output rate is 3kHz → Impossible to store all these events

  → You have to bring down the event rate



State of the art di-bjet searches

- Common procedures to reduce QCD background and event rate:



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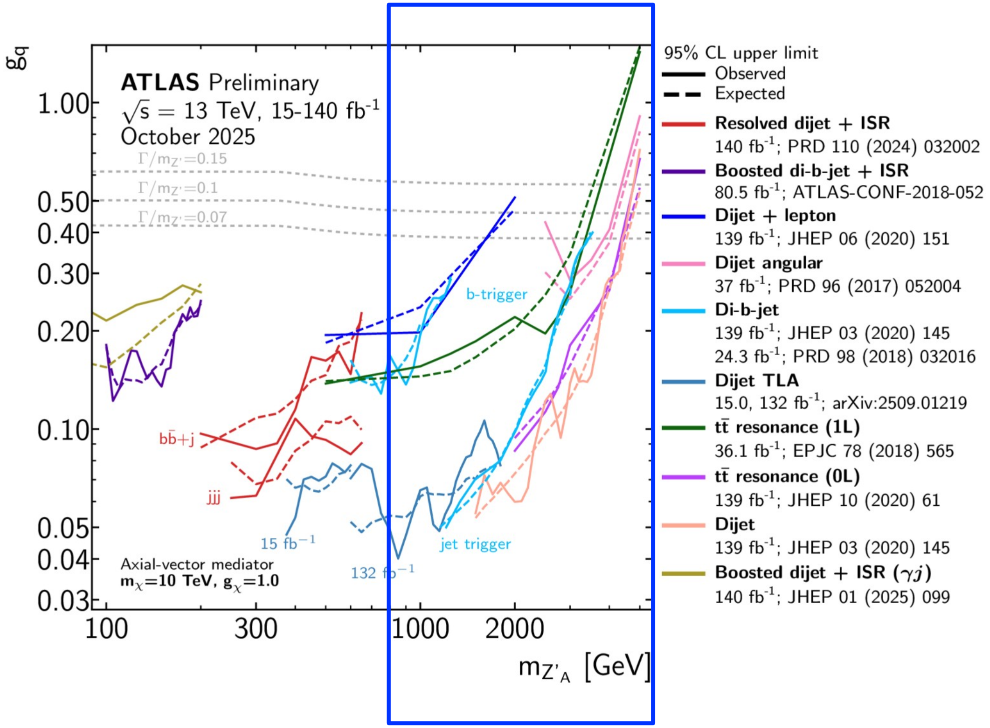

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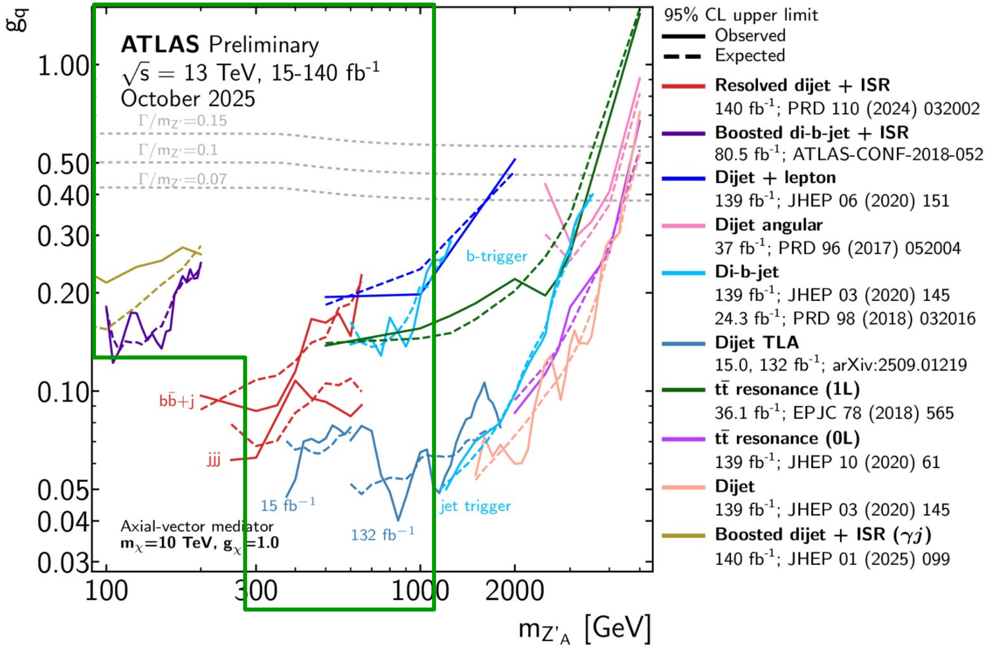

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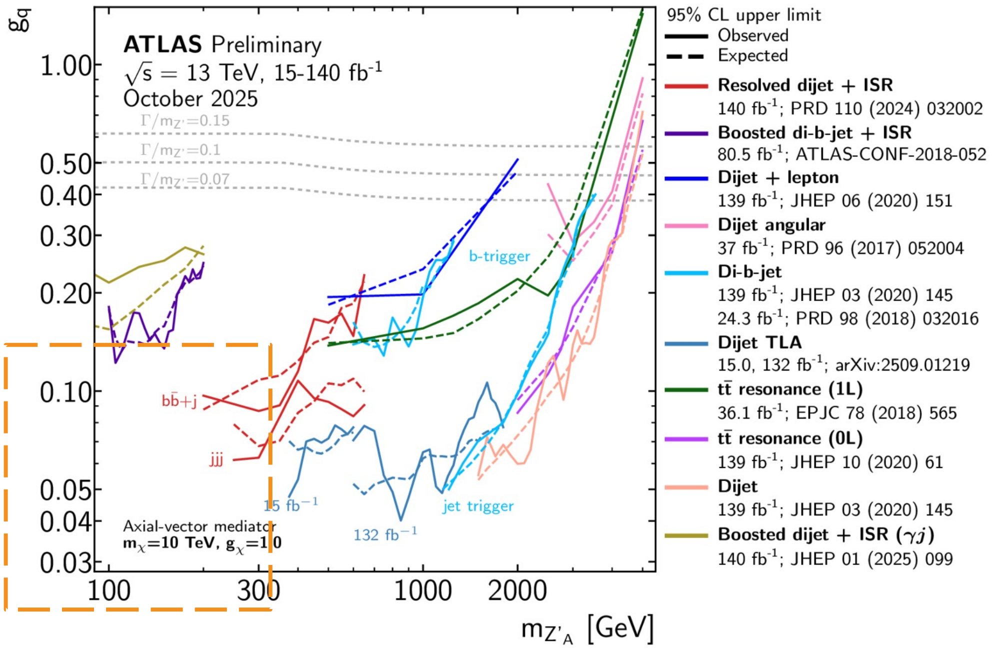
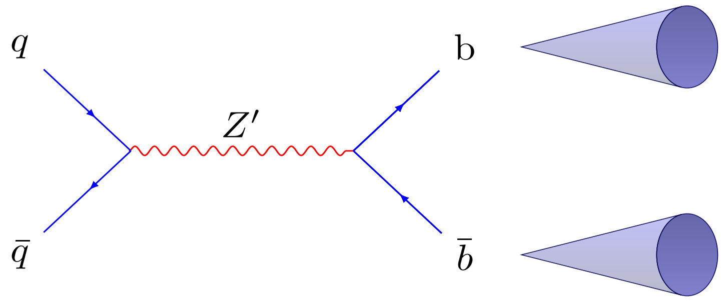
- **BARD idea**: Can something other than pT requirements achieve similar results?
  If yes: The low mass regime becomes more accessible



The idea of BARD

- Can a rare decay trigger suppress QCD while retaining enough signal to observe a resonance?



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- ≈ 1% of b-meson decays contain a J/ψ

	Channel	Branching Ratio		Channel	Branching Ratio
1	$B^{\pm} \to J/\psi\ K^{\pm}$	$(1.020 \pm 0.019) \cdot 10^{-3}$	7	$B^0 \to J/\psi\ K^+\pi^-$	$(1.15 \pm 0.05) \cdot 10^{-3}$
2	$B^{\pm} \to J/\psi\ K^0\pi^+$	$(1.14 \pm 0.11) \cdot 10^{-3}$	8	$B^0 \to J/\psi\ K^*(892)^0$	$(1.27 \pm 0.05) \cdot 10^{-3}$
3	$B^{\pm} \to J/\psi\ K^+\pi^-\pi^+$	$(8.1 \pm 1.3) \cdot 10^{-4}$	9	$B^0 \to J/\psi\ K^*(1270)^0$	$(1.3 \pm 0.5) \cdot 10^{-3}$
4	$B^{\pm} \to J/\psi\ K^*(892)^{\pm}$	$(1.43 \pm 0.08) \cdot 10^{-3}$	10	$B_s \to J/\psi\ \varphi$	$(1.08 \pm 0.08) \cdot 10^{-3}$
5	$B^{\pm} \to J/\psi\ K^*(1270)^{\pm}$	$(1.8 \pm 0.5) \cdot 10^{-3}$	11	$B_s \to J/\psi\ K^+K^-$	$(7.9 \pm 0.7) \cdot 10^{-4}$
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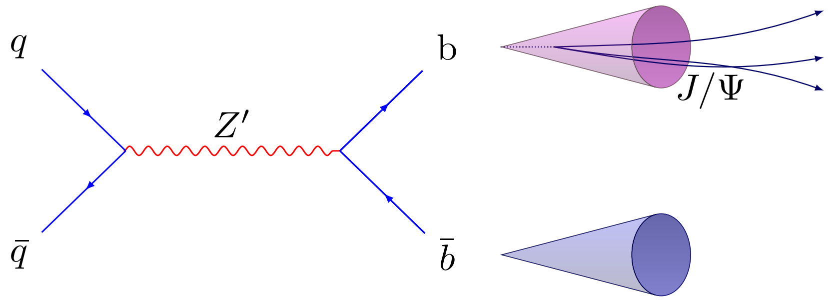

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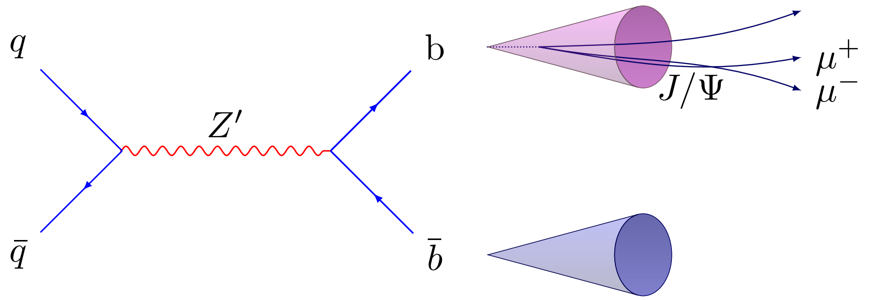

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- J/ψ decays to μ-μ+ pair with 6% branching fraction each → rare but easy-to-tag signal
- suppression of 0.01 * 0.06 ≈ 10^-4 → event rate reduced within acceptable levels

Proof of principle

- Can we find a known resonance?
- Proof-of-principle: Identify the SM Z above QCD background

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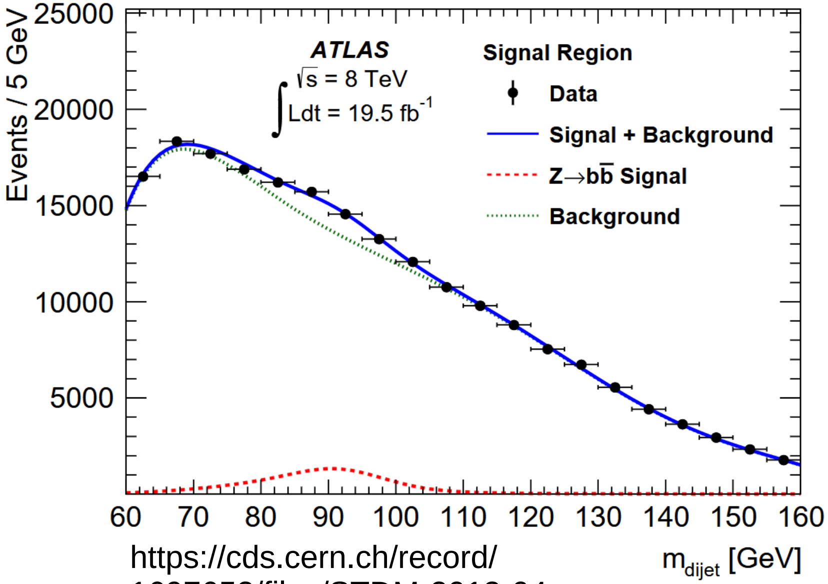
Boosted Z→bb analysis from 2014



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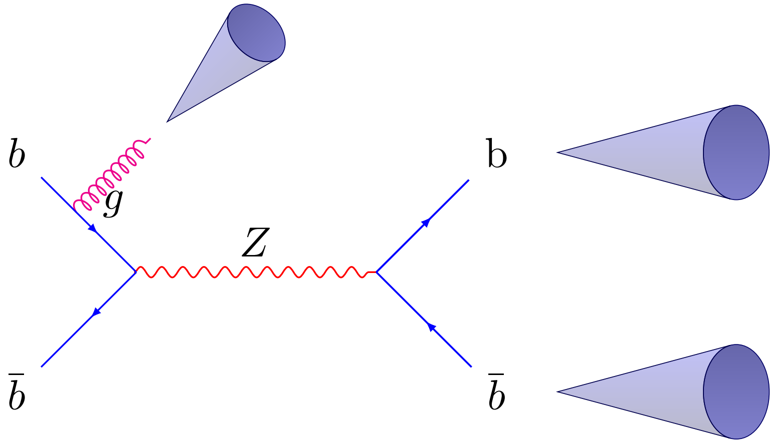

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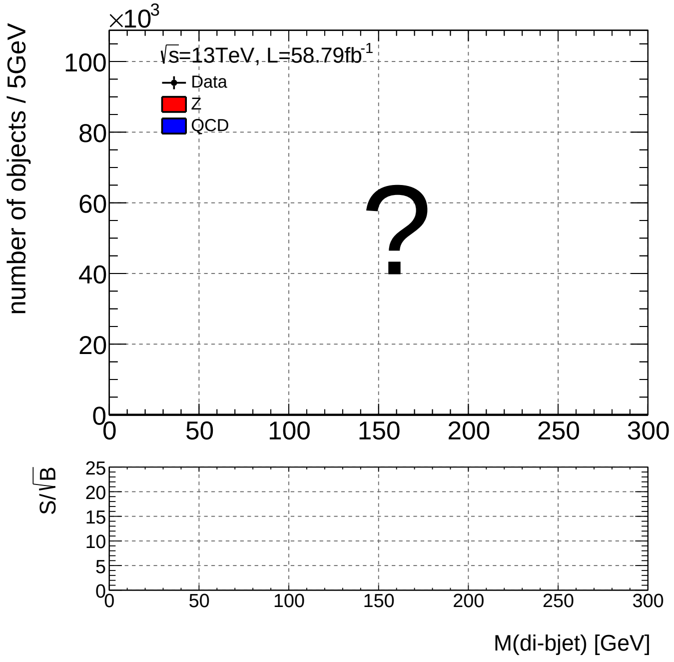

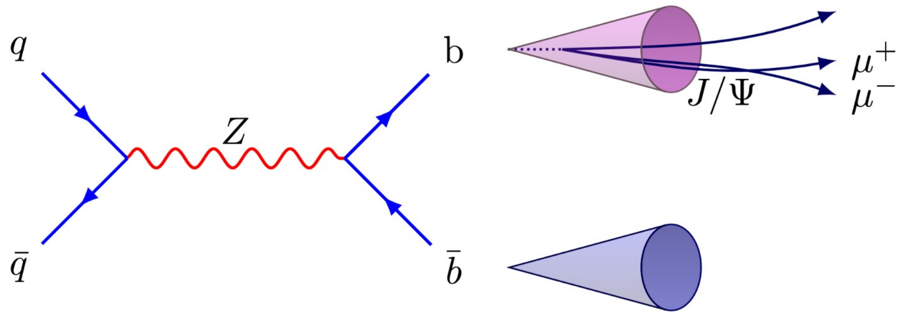

BARD triggers

- First step: Identify optimal trigger list

Trigger
$J/\psi \to \mu\mu$
HLT_2mu6_bJpsimumu_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_2mu6_bJpsimumu_Lxy0_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_mu11_mu6_bJpsimumu_L1LFV_MU11
HLT_mu11_mu6_bJpsimumu
HLT_mu11_mu6_bJpsimumu_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bJpsimumu_Lxy0
HLT_2mu10_bJpsimumu
Generic
HLT_mu11_mu6_bDimu_L1LFV_MU11
HLT_mu11_mu6_bDimu
HLT_mu11_mu6_bDimu_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bDimu_Lxy0
HLT_mu11_mu6_bDimu2700_L1LFV_MU11
HLT_mu11_mu6_bDimu2700
HLT_mu11_mu6_bDimu2700_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bDimu2700_Lxy0
Bmumu
HLT_mu11_mu6_bBmumu_L1LFV_MU11
HLT_mu11_mu6_bBmumu
HLT_mu11_mu6_bBmumuxv2_L1LFV_MU11
HLT_mu11_mu6_bBmumuxv2
HLT_2mu6_bBmumux_BpmumuKp_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_mu11_mu6_bBmumux_BpmumuKp_L1LFV_MU11
HLT_mu11_mu6_bBmumux_BpmumuKp
Bphysics
HLT_2mu6_bBmumu_Lxy0_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_2mu6_bBmumux_BsmumuPhi_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
Multi-muon low p_T
HLT_mu6_2mu4_bJpsi
HLT_3mu4_bJpsi
HLT_3mu6_bJpsi
$\Upsilon \to \mu\mu$
HLT_2mu6_bUpsimumu_L1BPH_8M15_2MU6_BPH_0DR22_2MU6
HLT_mu11_mu6_bUpsimumu_L1LFV_MU11
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Single-muon
HLT_mu26_ivarmedium
HLT_mu50
HLT_mu60_0eta105_msonly
Multi-muon
HLT_2mu14
HLT_mu22_mu8noL1
HLT_mu20_2mu4noL1
HLT_3mu6

BARD triggers

- First step: Identify optimal trigger list
- Many different triggers already exist that target dimuon topology

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HLT_2mu10_bJpsimumu
Generic
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HLT_mu11_mu6_bDimu2700_Lxy0
Bmumu
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HLT_mu11_mu6_bBmumuxv2
HLT_2mu6_bBmumux_BpmumuKp_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_mu11_mu6_bBmumux_BpmumuKp_L1LFV_MU11
HLT_mu11_mu6_bBmumux_BpmumuKp
Bphysics
HLT_2mu6_bBmumu_Lxy0_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_2mu6_bBmumux_BsmumuPhi_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
Multi-muon low p_T
HLT_mu6_2mu4_bJpsi
HLT_3mu4_bJpsi
HLT_3mu6_bJpsi
$\Upsilon \to \mu\mu$
HLT_2mu6_bUpsimumu_L1BPH_8M15_2MU6_BPH_0DR22_2MU6
HLT_mu11_mu6_bUpsimumu_L1LFV_MU11
HLT_mu11_mu6_bUpsimumu
Single-muon
HLT_mu26_ivarmedium
HLT_mu50
HLT_mu60_0eta105_msonly
Multi-muon
HLT_2mu14
HLT_mu22_mu8noL1
HLT_mu20_2mu4noL1
HLT_3mu6

BARD triggers

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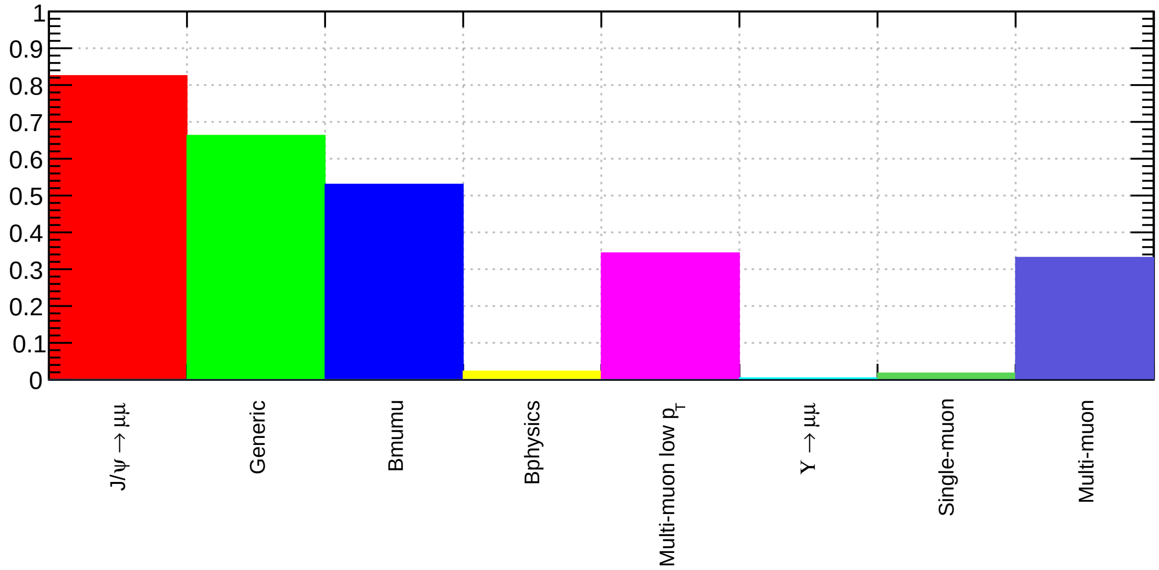
- Many different triggers already exist that target dimuon topology
- Trigger acceptance has been studied



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$J/\psi \to \mu\mu$
HLT_2mu6_bJpsimumu_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_2mu6_bJpsimumu_Lxy0_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_mu11_mu6_bJpsimumu_L1LFV_MU11
HLT_mu11_mu6_bJpsimumu
HLT_mu11_mu6_bJpsimumu_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bJpsimumu_Lxy0
HLT_2mu10_bJpsimumu
Generic
HLT_mu11_mu6_bDimu_L1LFV_MU11
HLT_mu11_mu6_bDimu
HLT_mu11_mu6_bDimu_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bDimu_Lxy0
HLT_mu11_mu6_bDimu2700_L1LFV_MU11
HLT_mu11_mu6_bDimu2700
HLT_mu11_mu6_bDimu2700_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bDimu2700_Lxy0
Bmumu
HLT_mu11_mu6_bBmumu_L1LFV_MU11
HLT_mu11_mu6_bBmumu
HLT_mu11_mu6_bBmumuxv2_L1LFV_MU11
HLT_mu11_mu6_bBmumuxv2
HLT_2mu6_bBmumux_BpmumuKp_L1BPH_2M9_2MU6_BPH_2DR15_2MU6
HLT_mu11_mu6_bBmumux_BpmumuKp_L1LFV_MU11
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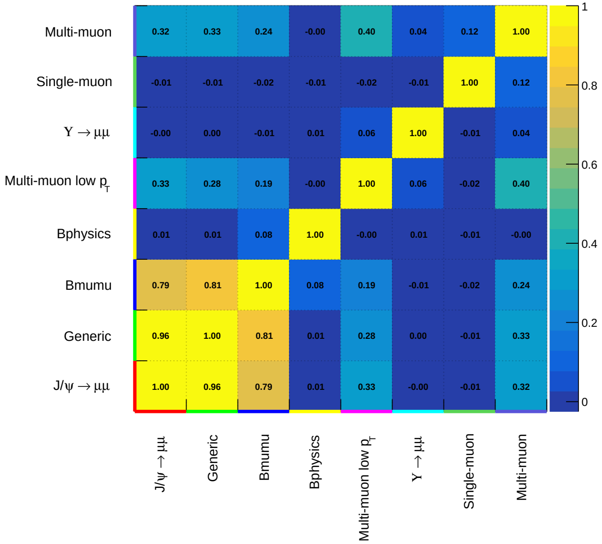
- Many different triggers already exist that target dimuon topology
- Trigger acceptance has been studied
- correlations between trigger families were analysed



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HLT_2mu10_bJpsimumu
Generic
HLT_mu11_mu6_bDimu_L1LFV_MU11
HLT_mu11_mu6_bDimu
HLT_mu11_mu6_bDimu_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bDimu_Lxy0
HLT_mu11_mu6_bDimu2700_L1LFV_MU11
HLT_mu11_mu6_bDimu2700
HLT_mu11_mu6_bDimu2700_Lxy0_L1LFV_MU11
HLT_mu11_mu6_bDimu2700_Lxy0
Bmumu
HLT_mu11_mu6_bBmumu_L1LFV_MU11
HLT_mu11_mu6_bBmumu
HLT_mu11_mu6_bBmumuxv2_L1LFV_MU11
HLT_mu11_mu6_bBmumuxv2
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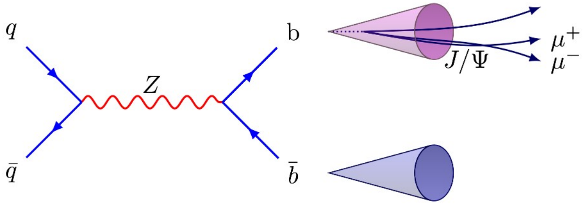
Monte Carlo samples

- Created Pythia Z sample to simulate Z→bb →[Jpsi→μμ]+X



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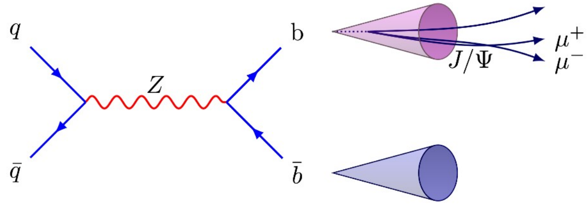

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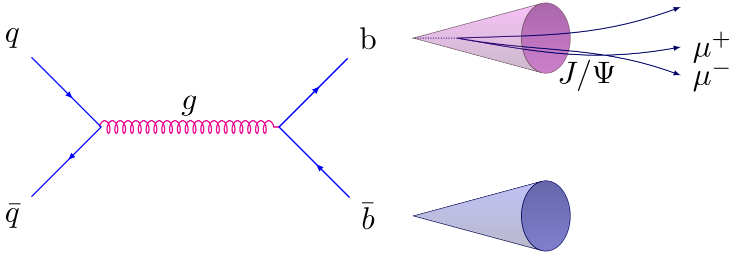

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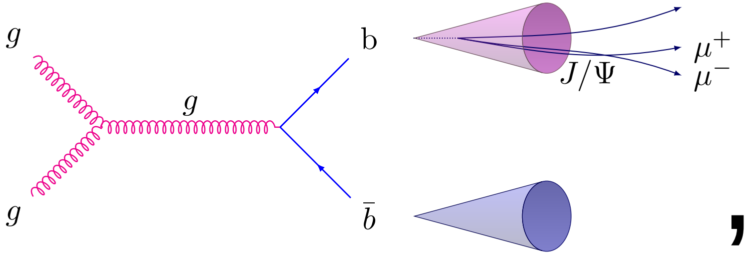
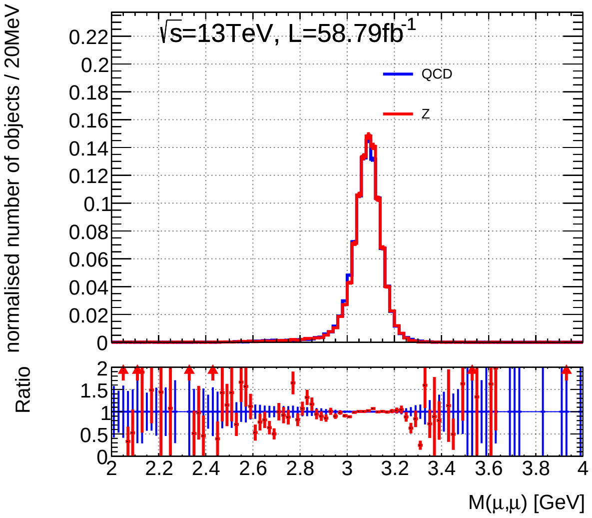


, ...

Reconstruction of J/ψ

- Muons with pT≥4GeV and |η|≤2.7, Identification WP: Loose, Isolation WP: NonIso
- ΔR-method: - Find the muon-pair with the smallest ΔR and d0sig > 3
  - calculate the sum of their 4-vectors to get J/ψ 4-vector



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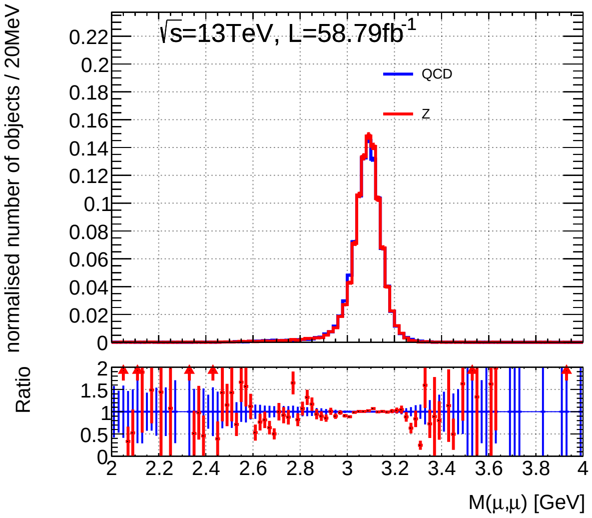

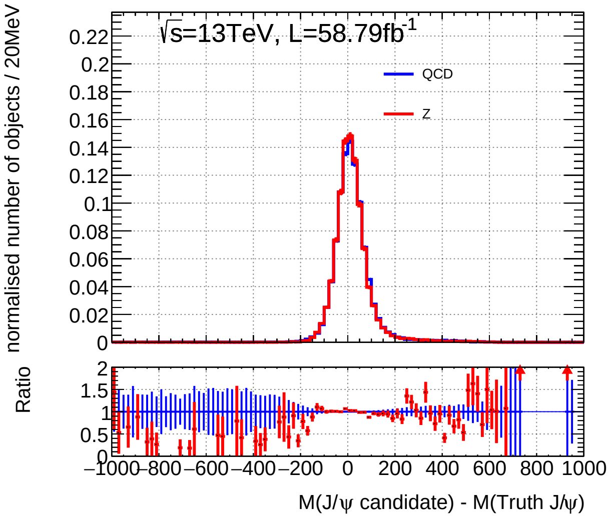

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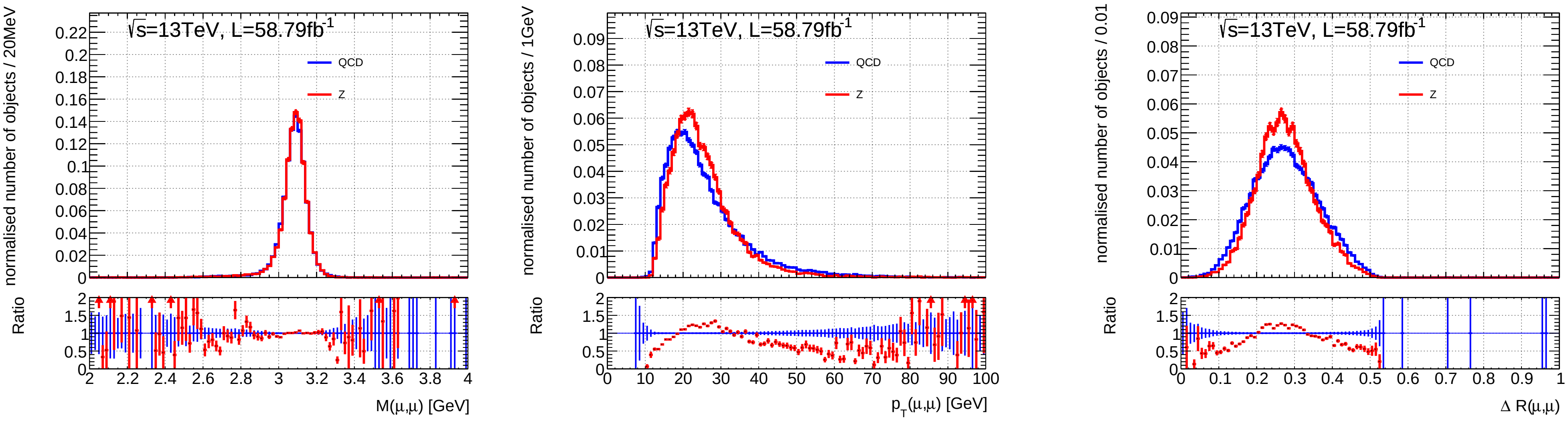
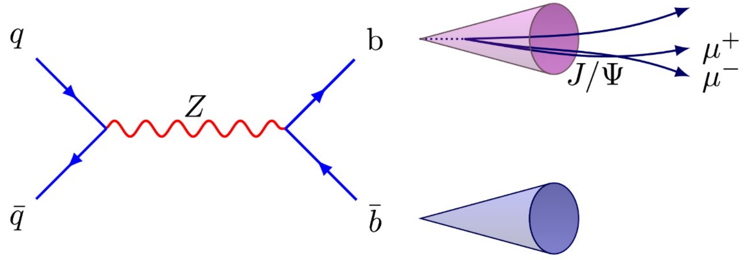
$$\Delta R = \sqrt{(\eta_1 - \eta_2)^2 + (\phi_1 - \phi_2)^2}$$



Reconstruction of the Z

- Jets with pT≥20GeV and |η|≤2.5
- Jet with ΔR(J/ψ candidate,jet)<0.4 gets assigned as $b_{J/\psi}$ - jet
- Check that there is a second non-overlapping GN2 b-tagged jet in the event → b_{GN2} - jet



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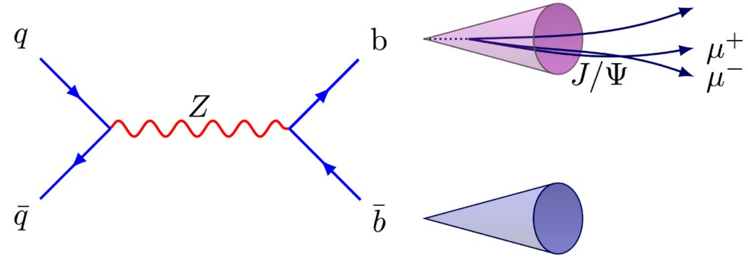

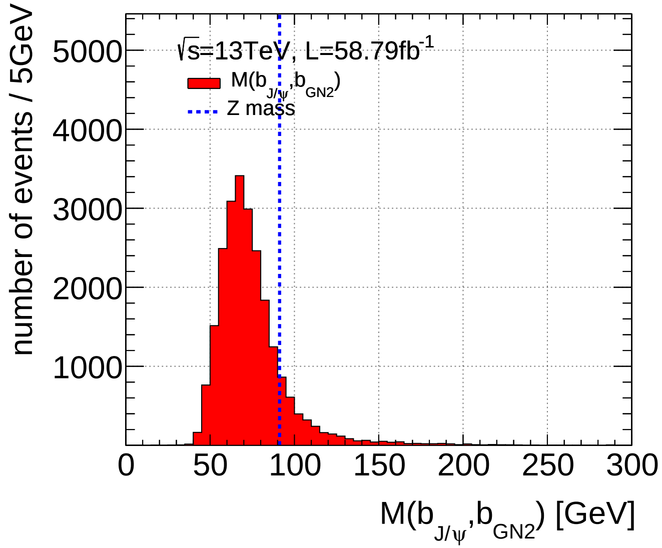

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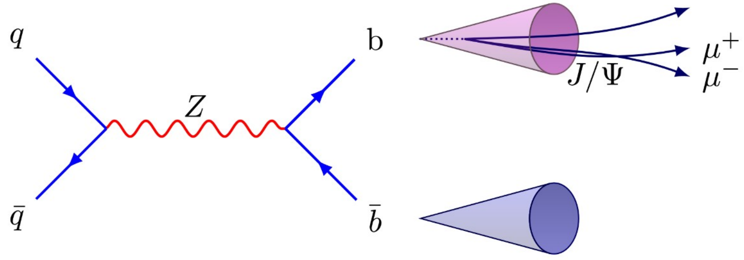
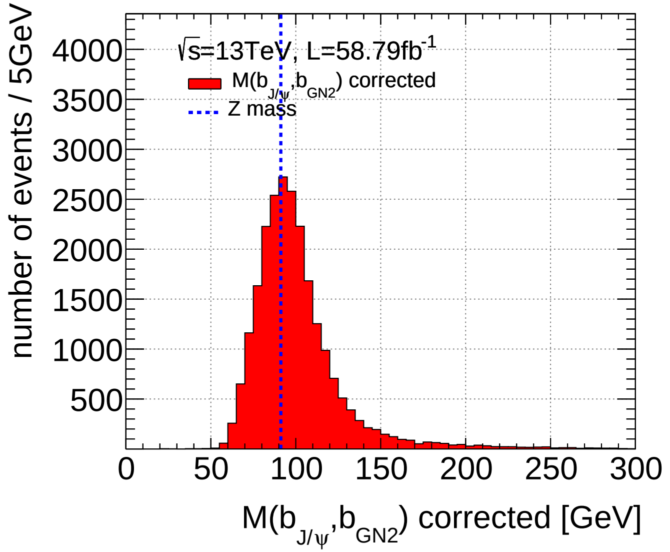
- $M\left(\mathrm{b}_{J/\psi}, \mathrm{b}_{\mathrm{GN2}}\right)$ corrected → Add 4-vector of the J/ψ-candidate (di-muon-system) to $\mathrm{b}_{J/\psi}$ -jet and recalculate $M\left(\mathrm{b}_{J/\psi}, \mathrm{b}_{\mathrm{GN2}}\right)$





Preliminary sensitivty studies

- Selection:
  - Event triggered by the $J/\psi \rightarrow \mu\mu$ trigger family
  - A J/ψ candidate with 3.0GeV < M(J/ψ candidate) < 3.2GeV
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  - An additional GN2 b-tagged jet
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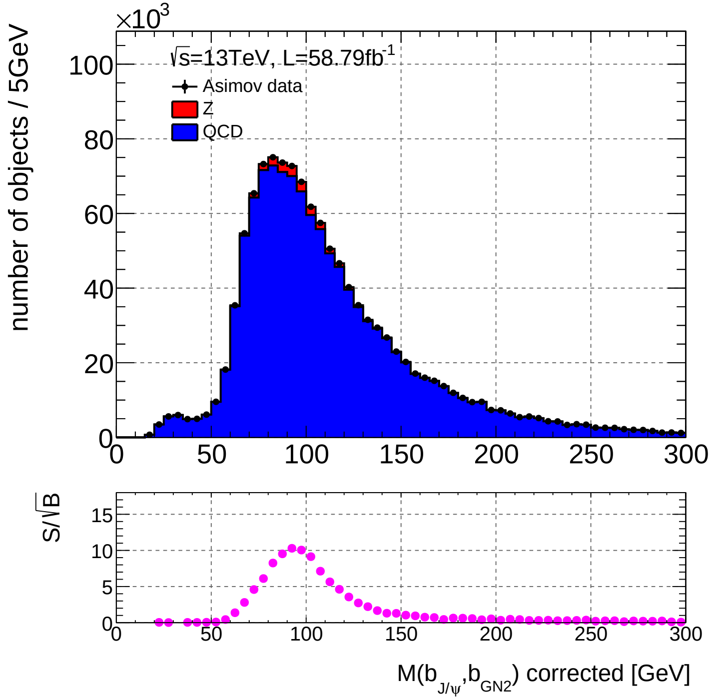
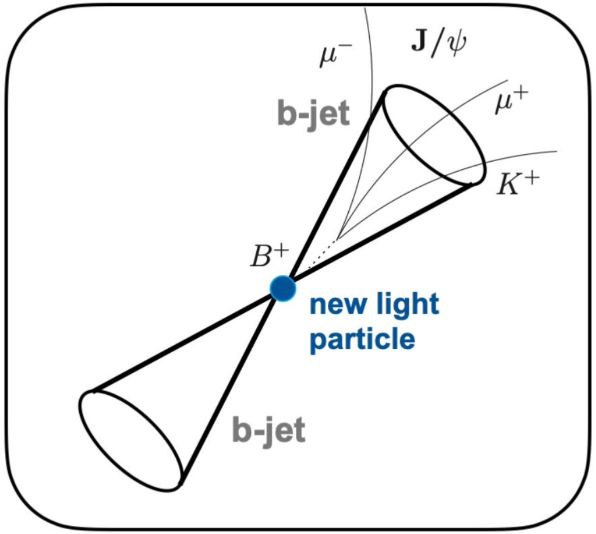
- Very preliminary stat-only sensitivity looks promising
  → modelling uncertainties need to be considered



Conclusion

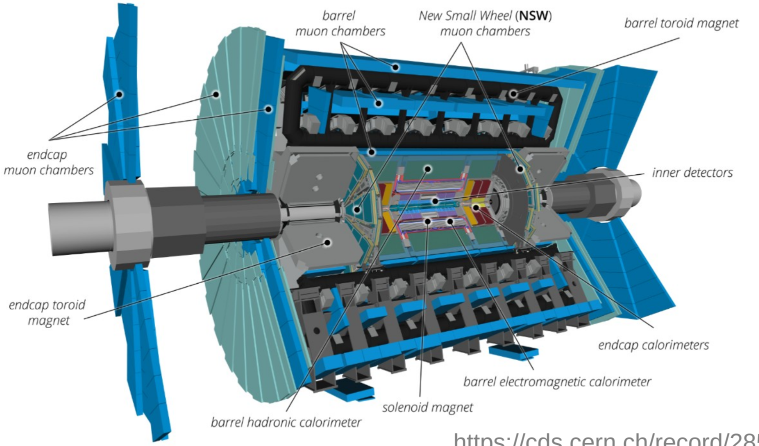
- BARD: B-Resonance Algorithm using rare decays
- Current B-resonances searches limited to high masses because high energetic objects are needed to trigger the event
- BARD is a new approach to trigger these events using a rare but clean B-hadron→J/ψ→μμ decay
- Ongoing proof of principle to identify the Z
  - Trigger acceptance and correlations studied
  - Z signal and QCD background samples created
  - Construction of J/ψ candidate and bb-system set up
  - First sensitivity studies on mass spectrum look promising



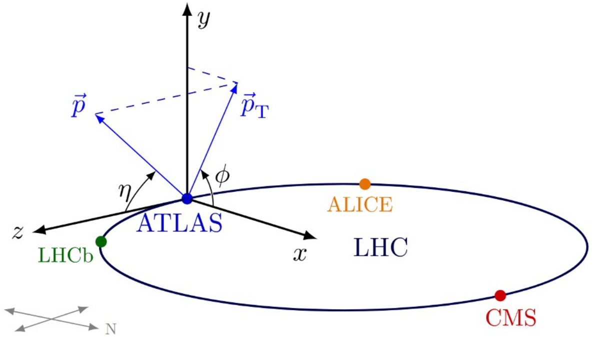
Backup

ATLAS

- General purpose detector at the LHC
- Multiple subdetector systems
  - Inner Detector:
    → tracking of charged particles
  - Calorimetry:
    → measure energy of particles
  - Muon spectrometer
    → measure minimal ionizing particles
  - Magnet system
    → momentum measurement and charged particle identification

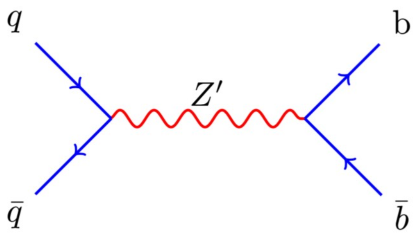


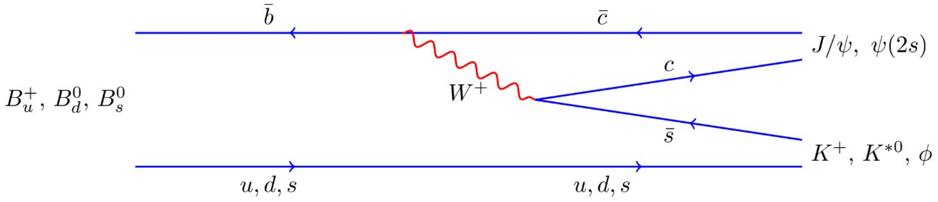
https://cds.cern.ch/record/2859916?ln=de

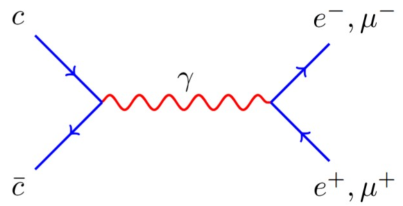


BARD

- Idea of BARD: Instead of requiring high pT objects at trigger level require a rare but clean b-hadron decay to trigger the event







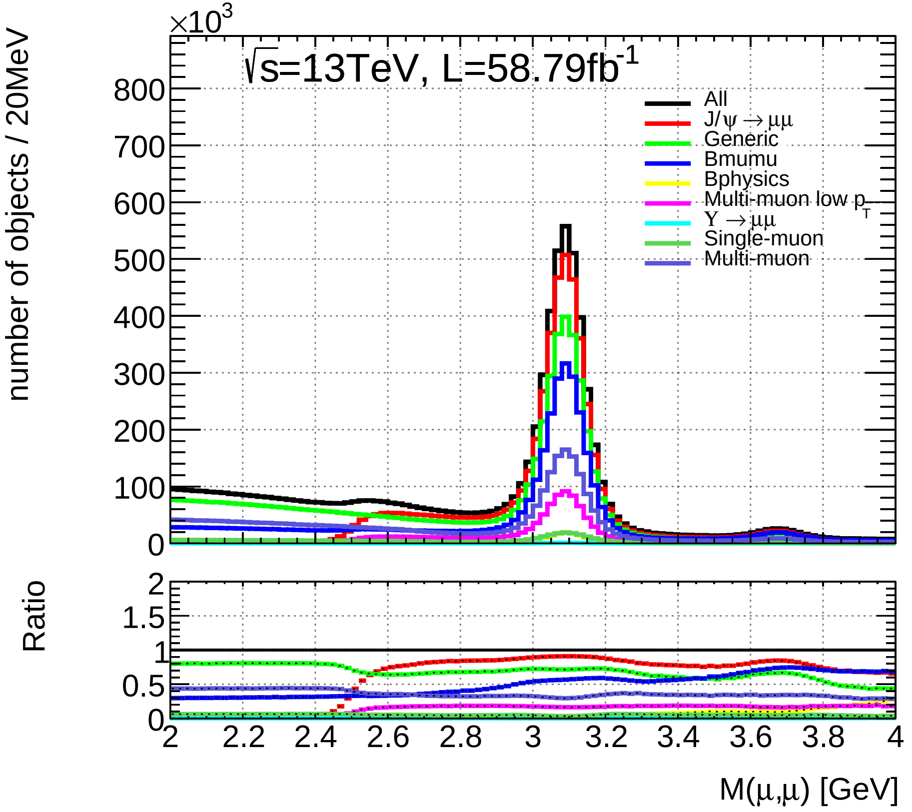
- B-meson to Jpsi decay has branching fraction of order 10^-3

	Channel	Branching Ratio		Channel	Branching Ratio
1	$B^{\pm} \to J/\psi\ K^{\pm}$	$(1.020 \pm 0.019) \cdot 10^{-3}$	7	$B^0 \to J/\psi\ K^+\pi^-$	$(1.15 \pm 0.05) \cdot 10^{-3}$
2	$B^{\pm} \to J/\psi\ K^0\pi^+$	$(1.14 \pm 0.11) \cdot 10^{-3}$	8	$B^0 \to J/\psi\ K^*(892)^0$	$(1.27 \pm 0.05) \cdot 10^{-3}$
3	$B^{\pm} \to J/\psi\ K^+\ \pi^-\pi^+$	$(8.1 \pm 1.3) \cdot 10^{-4}$	9	$B^0 \to J/\psi\ K^*(1270)^0$	$(1.3 \pm 0.5) \cdot 10^{-3}$
4	$B^{\pm} \to J/\psi\ K^*(892)^{\pm}$	$(1.43 \pm 0.08) \cdot 10^{-3}$	10	$B_s \to J/\psi\ \varphi$	$(1.08 \pm 0.08) \cdot 10^{-3}$
5	$B^{\pm} \to J/\psi\ K^*(1270)^{\pm}$	$(1.8 \pm 0.5) \cdot 10^{-3}$	11	$B_s \to J/\psi\ K^+K^-$	$(7.9 \pm 0.7) \cdot 10^{-4}$
6	$B^0 \to J/\psi\ K^0$	$(8.91 \pm 0.21) \cdot 10^{-4}$	12	$B_s \to J/\psi\ K^0K^-\pi^+ + cc$	$(9.5 \pm 1.3) \cdot 10^{-4}$

- Jpsi → μμ has branching fraction of 6%
  - → Signal of two muons is easy to identify

- Rare B-meson to Jpsi decay reduces the event rate within acceptable levels

BARD triggers



Data streams in ATLAS

- Trigger system routes accepted events into multiple data streams:
  Main stream, Express stream, delayed streams, calibration streams, ...

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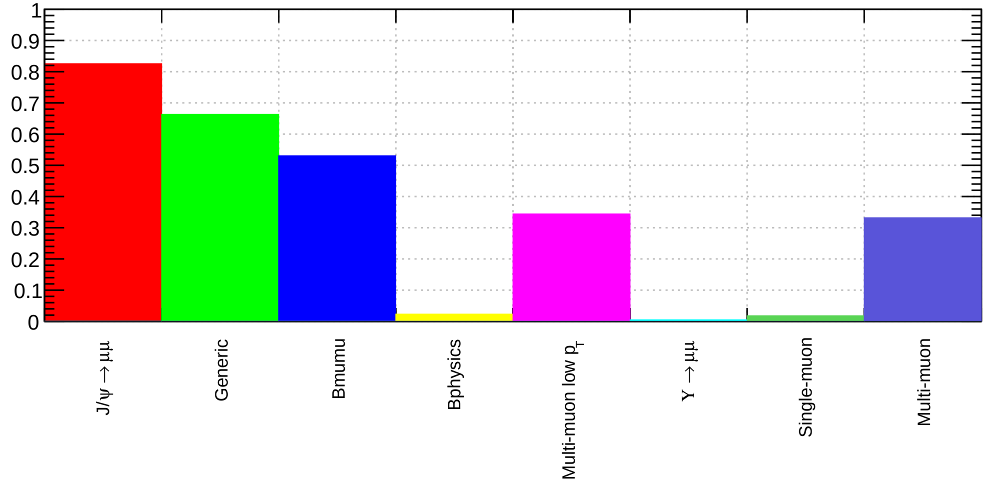

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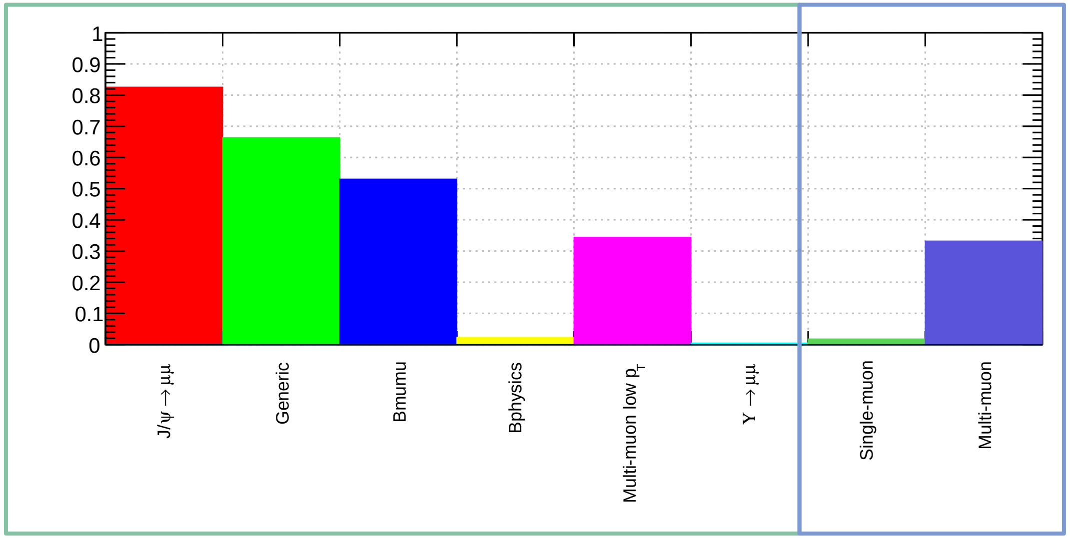
Delayed stream



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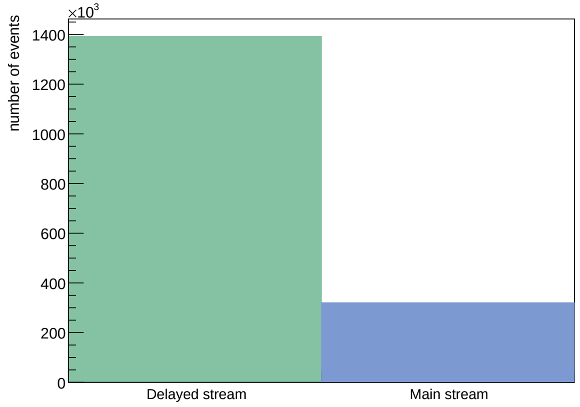
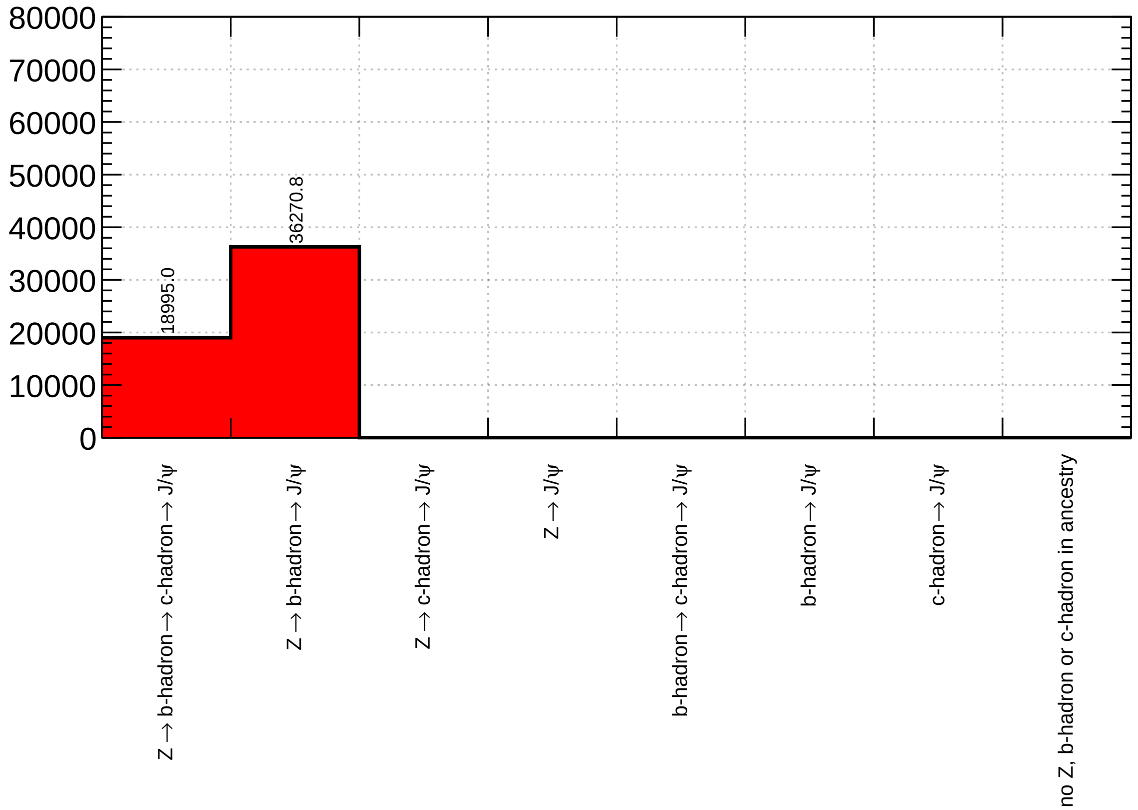
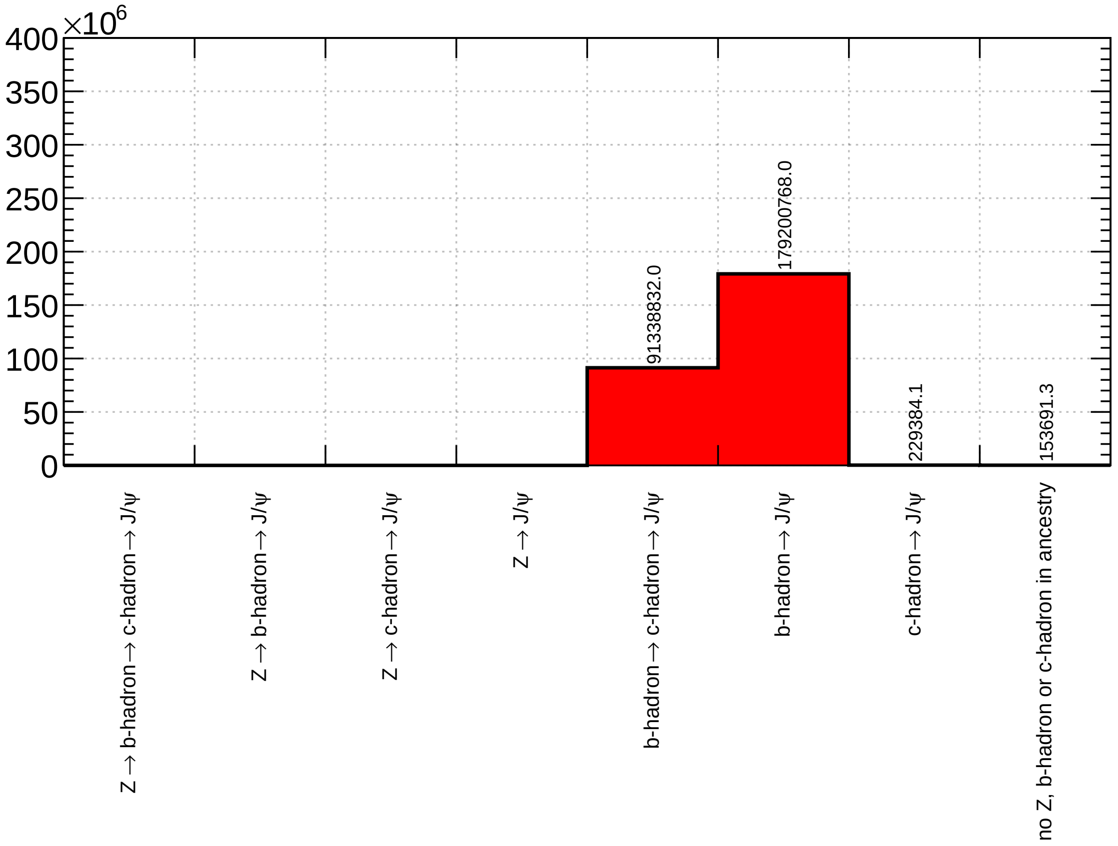
Important for BARD: Relevant $J/\psi \to \mu\mu$ triggers are writing to B-physics delayed stream, much more events



TruthJpsi origin in Z sample



TruthJpsi origin in QCD sample



TruthJpsi categories in Z sample

0: both muons have the same TruthJpsi parent

1: both muons have a TruthJpsi parent but they are actually different TruthJpsi

2: one of the muons has a parent that is not a TruthJpsi

3: both muons have parents that are not TruthJpsi

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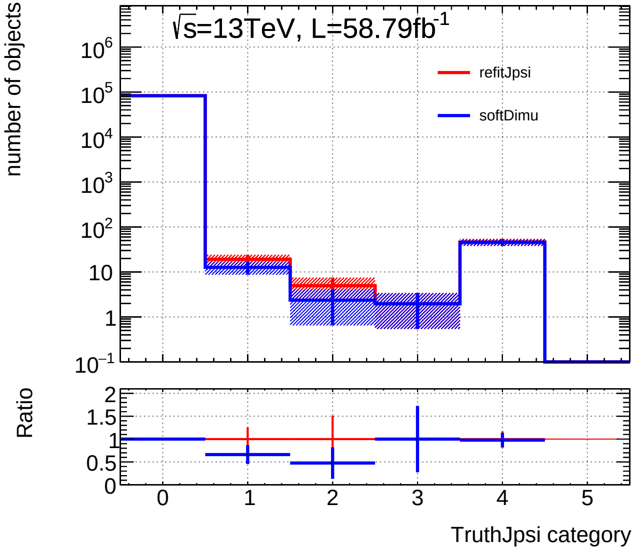

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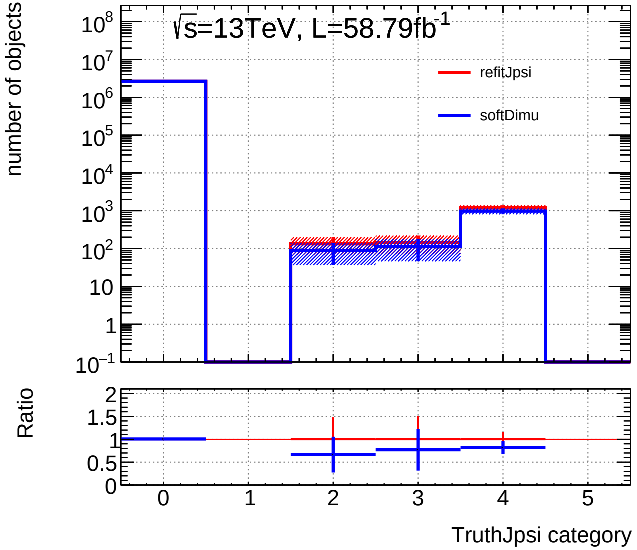

QCD vs Z

- Z difficult to see above QCD background
  → Find selections to improve signal to background ratio
- Useful to quantify discrimination power: Separation

$$\langle S^2 \rangle = \frac{1}{2} \int \frac{\left(y_S(x) - y_B(x)\right)^2}{\left(y_S(x) + y_B(x)\right)} dx$$

$$y_S = \text{signal pdf (Z)}$$

$$y_B = \text{background pdf (QCD)}$$

- separation = 0 means signal and background are identical
- separation = 1 means signal and background have no overlap

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$$y_B = \text{background pdf (QCD)}$$

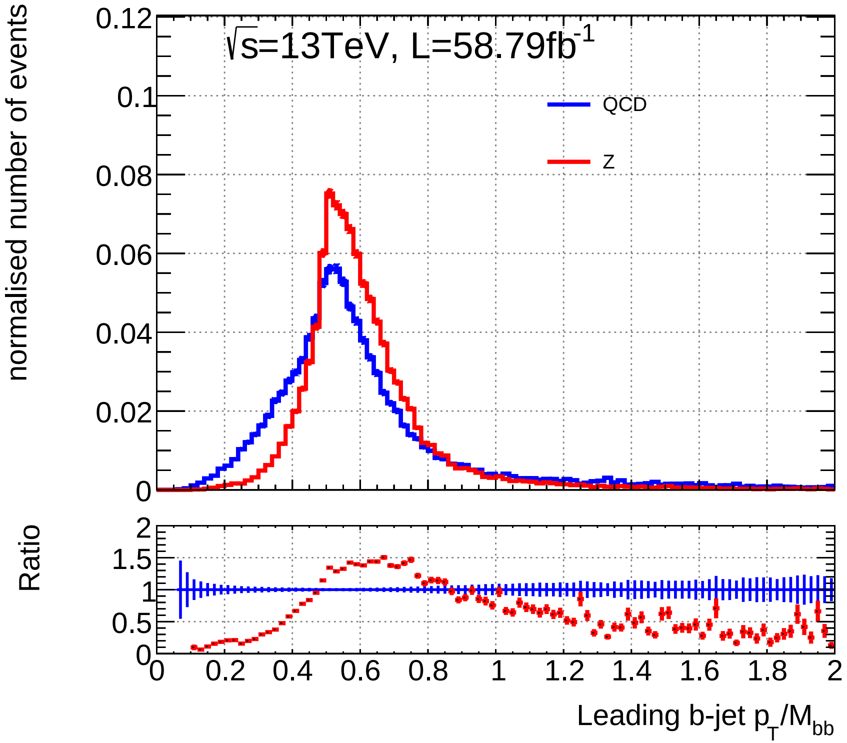
- separation = 0 means signal and background are identical
- separation = 1 means signal and background have no overlap

→ Investigated many different variables

Variable	Separation
Mbb_corrected_softDimu_R	0.1218
Mbb_softDimu	0.0881
leading_bjet_pt_Mbb_ratio	0.0568
jpsi_tagged_jet_cos_theta_Collins_Soper	0.0564
btagged_jet_cos_theta_Collins_Soper	0.0564
cos_theta_collins_soper_from_function	0.0544
DeltaEta_bb_softDimu	0.0521
dibjet_centrality	0.0518
sorted_passed_leading_bjet_pt	0.0245
btagged_jet_cos_theta_Collins_Soper_2D	0.0216
jpsi_tagged_jet_cos_theta_Collins_Soper_2D	0.0216
Is_leading_jet_btagged	0.0204
etabb_softDimu_asymmetry	0.0201
leading_jet_that_is_not_bbsystem_tlv_pt	0.0173
pTbb_softDimu	0.0142
pT_mumu	0.0139
A_ZBB	0.0064
Jpsi_jet_fragmentation_pt	0.0053
dibjet_rapidity	0.0052
DR_between_jet_and_jpsi_softDimu	0.0046
pTbb_softDimu_asymmetry	0.0043
Jpsi_jet_fragmentation_pt_2	0.0039
JPSI_softDimu_tau	0.0035
number_of_jets	0.0034
JPSI_softDimu_d0sig2	0.0021
JPSI_softDimu_d0sig1	0.0020
massbb_softDimu_asymmetry	0.0019
JPSI_softDimu_simpleLxy	0.0016

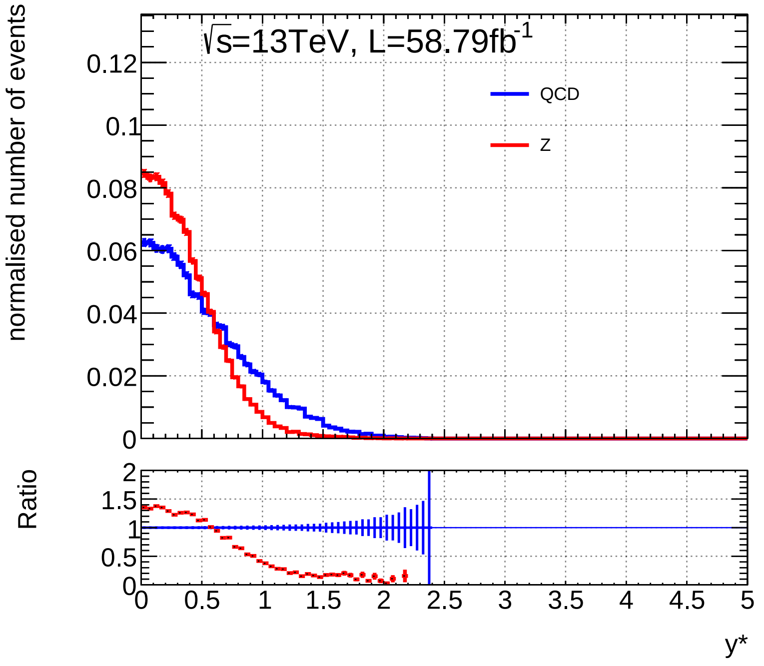
Discriminating variables

- Leading bjet pT/Mbb currently has the best separation of 0.0568



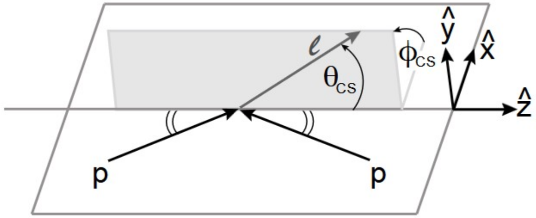
Discriminating variables

- Leading bjet pT/Mbb currently has the best separation of 0.0568
- Centrality defined as $|y^*| = \frac{|y_{jet,0} - y_{jet,1}|}{2}$



cos(θ*) in Collins-Soper frame

- Collins Soper frame is for example defined here: https://arxiv.org/pdf/1606.00689
- z-axis defined as the bisector of the incoming proton beams in the Z-mass restframe
- calculate cos(θ*) of boosted b-jet and boosted jpsi-jet with respect to this z-axis

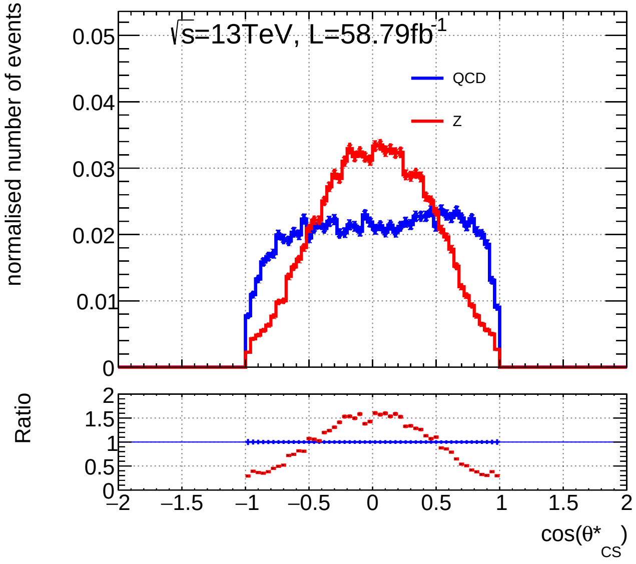


$$\cos\theta^* = \frac{p_{z,\ell\ell}}{m_{\ell\ell}|p_{z,\ell\ell}|}\frac{p_1^+p_2^- - p_1^-p_2^+}{\sqrt{m_{\ell\ell}^2 + p_{T,\ell\ell}^2}}$$

- https://arxiv.org/pdf/1710.05167 has a direct formula to calculate cos(θ*)
- Usually used for leptons where the charge of the lepton is known
  → Charge not known for jets but can still apply the formula

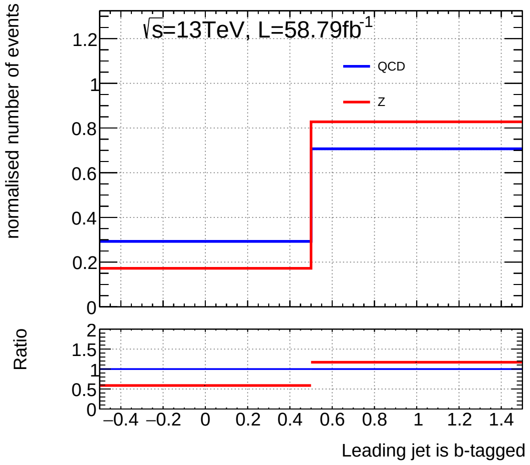
Discriminating variables

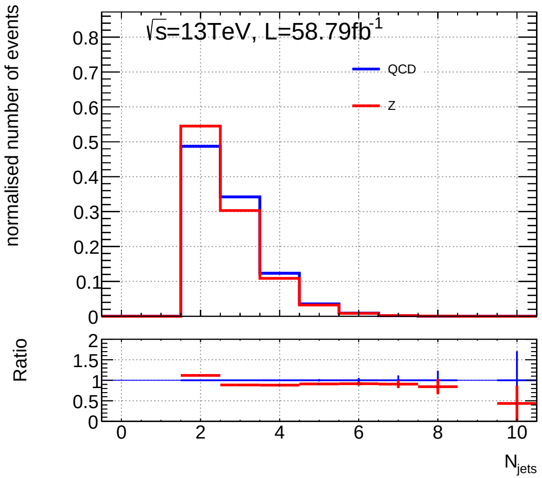
- Leading bjet pT/Mbb currently has the best separation of 0.0568
- Centrality defined as $|y^*| = \frac{|y_{jet,0} - y_{jet,1}|}{2}$
- Cos(θ*) usually used for Z→ll measurements but could also be applied here



Discriminating variables

- Leading bjet pT/Mbb currently has the best separation of 0.0568
- Centrality defined as $|y^*| = \frac{|y_{jet,0} - y_{jet,1}|}{2}$
- Cos(θ*) usually used for Z→ll measurements but could also be applied here
- Requiring number of jets equal to 2 or that the leading jet in the events i b-tagged reduces the low Mbb contribution → Mbb turn on can be fitted easier





Trigger naming for L1 Muon

Naming for L1Muon

- MUxx + "V", "F", "C", "H", "R", "BO", "EC", "M"
  - xx : measured-pT value (**Different definition from Run-2.**). E.g. The pT distribution of muons which fire MU10, but not MU11, peaks at 10 GeV. The plateau starts around 12.5 GeV for endcap. See slide 10 onwards of these slides for details.
  - "V" : **V**ariable thresholds with eta (e.g. different between barrel and endcap). TGC pT value is used for **xx** by definition.
  - "F" : require **F**ull-station (three-station) big-wheel coincidence for endcap
  - "C" : require inner-**C**oincidence for endcap (additional coincidence between Big Wheel TGC and one of the inner muon detectors — TGC-EI, TileCal, NSW, or RPC-BIS78* if available; *RPC-BIS78 is currently under integration and not yet used for coincidence)
  - "H" : **H**ot-RoI mask (taken only events satisfied the good magnetic field flag) for endcap
  - "R": **R**estricted region. available to exclude the RPC feet.
  - "BO": central (**B**arrel **O**nly) muons (only candidates from RPC, not from BIS78)
  - "EO": **E**ndcap **O**nly muons (everything from EC Sector Logic, so BIS78, TGC EC and FWD)
  - "M": **M**ultiple muon candidates by a flag which indicates two or more candidates in a RPC pad. (only available in barrel to mitigate inefficiencies of close-by muons, i.e. set with B)

Baseline L1 muon menu proposal:

Run2	Run3
MU4	MU3V
MU6	MU5VF
MU10	MU8F
MU11	MU8VF
MU20	MU14FCH
MU21	MU14FCHR

Muon trigger signatures

Muon

Hide

Field	Key description	Default	Allowed values	Value description
etaRange	Pseudorapidity cuts	0eta250	0eta105	barrel region only, 0 < fabs(eta) < 1.05
extra		""	noL1	full scan (only runs precision algos, no seed)
			lateMu	aka mgonly in Run-2. Runs late muon reconstruction
			muoncalib	muon calibration
			noL2Comb	aka nomucomb in Run-2
l2AlgInfo		""	l2io	L2MuonSA inside-out
			l2mt	L2MuonSA Multi-Track
isoInfo	isolation cut	""	ivarloose	ptvarcone30/pt < 0.16
			ivarmedium	ptvarcone30/pt < 0.07
			ivarperf	runs isolation, but no cut on output
			iloosems	isolation for MSonly legs ptcone30 &lt 3 GeV
lrtInfo	Muons with large d0	[]	d0loose	d0>2 mm
			d0medium	d0>3 mm
			d0tight	d0>5 mm
invMassInfo	Invariant mass range	""	10invm70	10<M(mumu)< 70 GeV
		""	invmJPsiOS	2.5<M(mumu)< 4.3 GeV with opposite charge cut
		""	invmDimu	1.5<M(mumu)< 14 GeV
msonlyInfo	MS only, not running combination between ID and MS tracks	[]	msonly	
addInfo		[]	idperf	fast and precision combined muon steps in passthrough
			LRT	Large radius tracking
			3layersEC	3 layer hits in MS EC
			cosmic	naming for cosmic triggers, no actual difference in configuration
			muonqual	muon passes: chi2 < 8.0 && ! isBadMuon && qOverPsignif<7.0 && MuidCo
			nscan	muons with dR of 0.5

BLS trigger signatures

BLS

As BphysicsChainConfiguration inherits from MuonChainConfiguration, the fields defined in the Muon slice are still relevant for BLS chain configuration. B-physics part adds `topo` values responsible for configuration of multi-muon/track handling described below:

Hide

topo[0]	topo[-1]	trigger type	mass selection	chi2 selection	notes
bJpsimumu		di-muon	2.5 < m(mu+mu-) < 4.3 GeV	< 20	
bJpsi		di-muon	2.5 < m(mu+mu-) < 4.3 GeV	< 20	
bUpsimumu		di-muon	8 < m(mu+mu-) < 12 GeV	< 20	
bUpsi		di-muon	8 < m(mu+mu-) < 12 GeV	< 20	
bBmumu		di-muon	4 < m(mu+mu-) < 8.5 GeV	< 20	
bDimu		di-muon	1.5 < m(mu+mu-) < 14 GeV	< 20	
bDimu2700		di-muon	0.1 < m(mu+mu-) < 2.7 GeV	< 20	
bDimu6000		di-muon	0.1 < m(mu+mu-) < 6 GeV	< 20	
bPhi		di-muon	940 < m(mu+mu-) < 1100 MeV	< 10	
bTau		di-muon	0 < m(mu+mu-) < 2.7 GeV	< 50	
bBeeM6000		di-electron	0.1 < m(e+e-) < 6 GeV	< 20	
bJpsimutrk		muon+track	2.5 < m(mu+mu-) < 4.3 GeV	< 20	to use with PEB
bBmumux		dimuon+[1,2,3] tracks		< 20	general cut on dimuon vertex
bBmumux	BpmumuKp	dimuon+1 track	0.1 < m(mu+mu-) < 5.5 GeV, 4.5 < m(mu+mu-K+) < 5.9 GeV	< 50	B+ → μμ K+
bBmumux	BcmumuPi	dimuon+1 track	2.5 < m(mu+mu-) < 4.3 GeV, 5.5 < m(mu+mu-pi+) < 7.3 GeV	< 50	B_c+ → J/ψ π+
bBmumux	BsmumuPhi	dimuon+2 tracks	0.1 < m(mu+mu-) < 5.5 GeV, 940 < m(K+K-) < 1100 MeV, 4.8 < m(mu+mu-K+K-) < 5.8 GeV	< 60	B0_s → J/ψφ
bBmumux	BdmumuKst	dimuon+2 tracks	0.1 < m(mu+mu-) < 5.5 GeV, 700 < m(K+pi-) < 1100 MeV, 4.6 < m(mu+mu-K+pi-) < 5.9 GeV	< 60	B0_d → μμ K*0
bBmumux	LbPqKm	dimuon+2 tracks	2.5 < m(mu+mu-) < 4.3 GeV, 4.8 < m(mu+mu-p+pi-) < 6.4 GeV	< 60	Λ0_b → J/ψ p K- (pentaquark studies)
bBmumux	BcmumuDsloose	dimuon+3 tracks	2.5 < m(mu+mu-) < 4.3 GeV, 940 < m(K+K-) < 1100 MeV, 1750 < m(K+K-pi+) < 2100 MeV, 5.5 < m(mu+mu-K+K-pi-) < 7.3 GeV	< 60	B_c+ → J/ψ D_s+(→φ(K+K-)π+), chi2 cut is on the D_s+ vertex with a requirement to point to the dimuon vertex
bBmumux	BcmumuDploose	dimuon+3 tracks	2.5 < m(mu+mu-) < 4.3 GeV, 1750 < m(K+pi-pi+) < 2000 MeV, 5.5 < m(mu+mu-K-pi+pi+) < 7.3 GeV	< 60	B_c+ → J/ψ D+(K-π+π+), chi2 cut is on the D+ vertex with a requirement to point to the dimuon vertex
bBmumux	BcmumuD0Xloose	dimuon+2 tracks	2.5 < m(mu+mu-) < 4.3 GeV, 1750 < m(K-π+) < 2000 MeV, 5.5 < m(mu+mu-K+pi-) < 7.3 GeV	< 60	B_c+ → J/ψ D0(K-π+) X, chi2 cut is on the D0 vertex with a requirement to point to the dimuon vertex
bBmumux	BcmumuDstarloose	dimuon+3 tracks	2.5 < m(mu+mu-) < 4.3 GeV, 1750 < m(K+pi-) < 2000 MeV, m(K+pi-pi+s) < 2110 MeV, 5.5 < m(mu+mu-K+pi-) < 7.3 GeV	< 60	B_c+ → J/ψ D*+(D0(K-π+)π+s), chi2 cut is on the D0 vertex with a requirement to point to mumupi+ vertex, and the same on the mumupi+ vertex itself
bBmux		muon+[2,3] tracks with cascade fit		< 50	chi2 cut for the entire cascade (common for all branches)
bBmux	BsmuDsX	muon+3 tracks with cascade fit	940 < $m(K^+K^-)$ < 1100 MeV, 1750 < $m(K^+K^-\pi^-)$ < 2100 MeV, $m(\mu^+K^+K^-\pi^-)$ < 10 GeV	<27	$B_s^0 \to \mu^+ D_s^-(\to \phi(\to K^+K^-)\pi^-)X$, chi2 cut is on the D_s^- vertex, $L_{xy}(B_s^0)$ > 0.1mm, $L_{xy}(D_s^-)$ > 0.02mm
bBmux	BdmuDpX	muon+3 tracks with cascade fit	1750 < $m(K^+\pi^-\pi^-)$ < 2000 MeV, $m(\mu^+K^+\pi^-\pi^-)$ < 10 GeV	<27	$B^0 \to \mu^+ D^-(\to K^+\pi^-\pi^-)X$, chi2 cut is on the D^- vertex, $L_{xy}(B^0)$ > 0.1mm, $L_{xy}(D^-)$ > 0.05mm
bBmux	BpmuD0X	muon+2 tracks with cascade fit	1750 < $m(K^+\pi^-)$ < 2000 MeV, $m(\mu^+K^+\pi^-)$ < 10 GeV	<20	$B^+ \to \mu^+ \bar{D}^0(\to K^+\pi^-)X$ (also selects $B^0 \to \mu^+ D^{*-}(\to \bar{D}^-(\to K^+\pi^-)\pi_s^-)X$), chi2 cut is on the D^0 vertex, $L_{xy}(B^+)$ > 0.1mm, $L_{xy}(\bar{D}^0)$ > 0
bBmux	BdmuDstarX	muon+3 tracks with cascade fit	1750 < $m(K^+\pi^-)$ < 2000 MeV, $m(K^+\pi^-\pi_s^+)$ < 2110 MeV, $m(\mu^+K^+\pi^-)$ < 10 GeV	<20	$B^0 \to \mu^+ D^{*-}(\to \bar{D}^-(\to K^+\pi^-)\pi_s^-)X$, chi2 cut is on the D^0 vertex, $L_{xy}(B^0)$ > 0.05mm, $L_{xy}(D^0)$ > 0
bBmux	LbmuLcX	muon+3 tracks with cascade fit	2190 < $m(\bar{p}K^+\pi^-)$ < 2390 MeV, $m(\mu^+\bar{p}K^+\pi^-)$ < 10 GeV	<27	$\Lambda_b^0 \to \mu^+ \bar{\Lambda}_c^-(\to \bar{p}K^+\pi^-)X$, chi2 cut is on the $\bar{\Lambda}_c^-$ vertex, $L_{xy}(\Lambda_b^0)$ > 0.1mm, $L_{xy}(\bar{\Lambda}_c^-)$ > 0.02mm

Other options affecting the selection are listed below:

topo[0]	description
nocut	for di-muon chains: no selection, AcceptAll=True
noos	for di-muon chains: no muon opposite-sign requirement
Lxy0	for di-muon chains: require Lxy of dimuon vertex > 0

ATLAS muon system

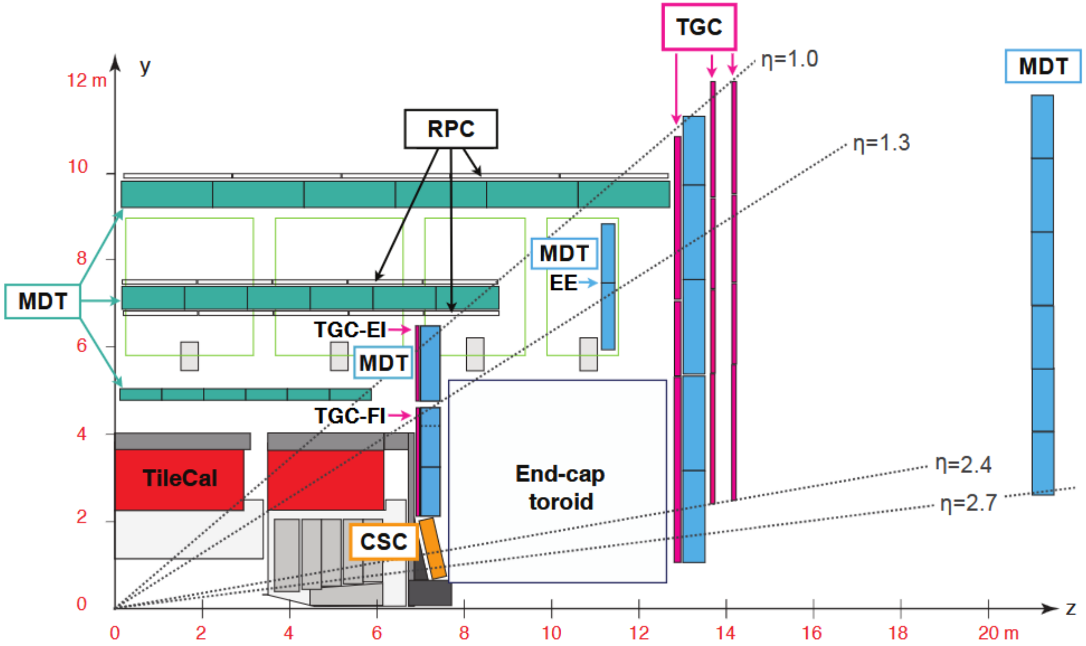


Figure 1: A schematic picture showing a quarter-section of the muon system in a plane containing the beam axis, with monitored drift tube (MDT) and cathode strip (CSC) chambers for momentum determination and resistive plate (RPC) and thin gap (TGC) chambers for triggering. The Forward Inner and Endcap Inner TGC chambers are marked as TGC-FI and TGC-EI, respectively. The Extended Endcap MDT chambers are referred to as EE.