


Leptonic, semileptonic and Missing Energy AWG

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Belle II – Physics WG

- Belle II physics activities recently distributed over 7 WG

https://belle2.cc.kek.jp/~twiki/bin/view/Physics/PhysicsGroups

Physics scope of Leptonic, SL and Missing E. WG

Inclusive and Exclusive Semileptonic b → c, b→u transitions: Vub, Vcb, New physics.
Semileptonic b → c and b → u transitions with τ leptons
Charged leptonic decays, B → e/μ/τ ν
Neutral leptonic decays, B^0 → τ τ $B_{(s)}0$→ τ τ
EWP with neutrinos, B → $K^{(*)}$ ν ν, B → ν ν
Lepton flavour and number violating decays, B → l τ

Conveners:
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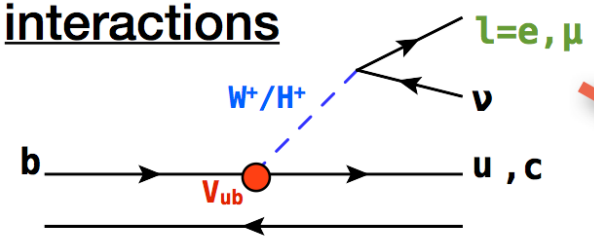
Belle II Physics WGs

1. Semileptonic and Missing Energy Decay
2. Electroweak Penguin
3. Time Dependent CP Violation
4. Hadronic B Decay (time integrated methods)
5. Y(nS)
6. Charm and Charmonium
7. τ and Two-Photon

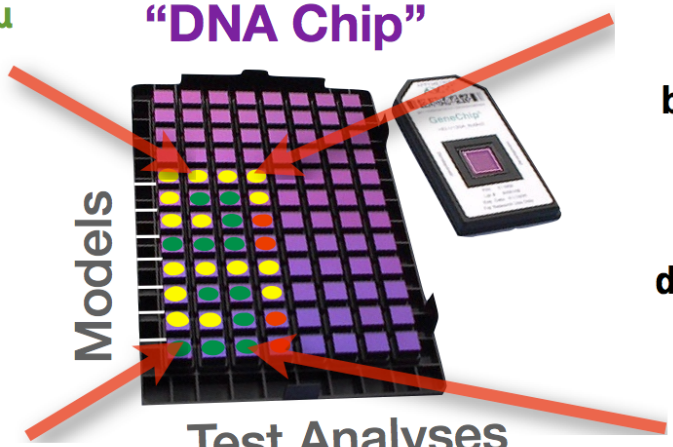
Identify signal of New Physics

From Phys. Coordinator at 2014 BPAC

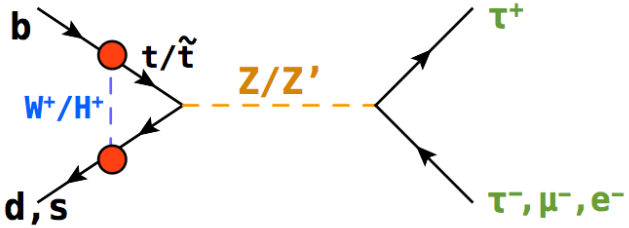
Precision tests of quark interactions



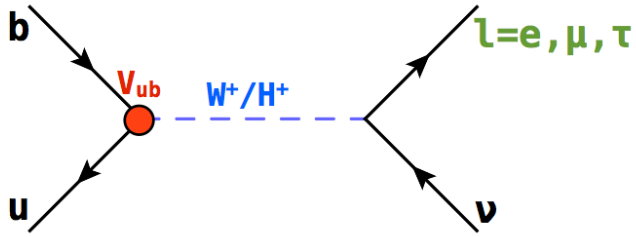
New Physics "DNA Chip"



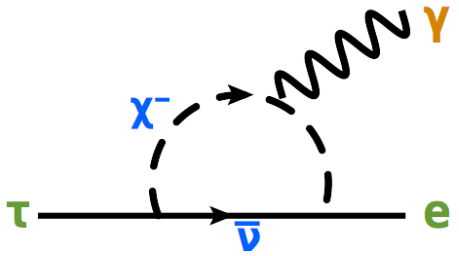
FCNC & mixing



New Phenomena in rare decay processes



Search for lepton flavour violation (neutrino mass...)



2014 BPAC

Phillip URQUIJO

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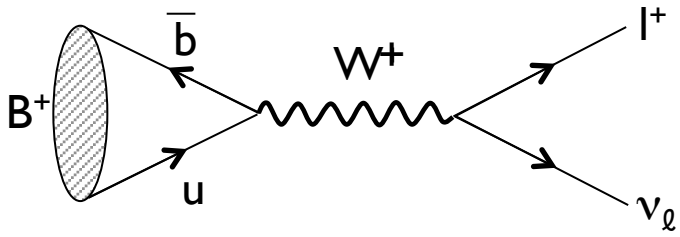
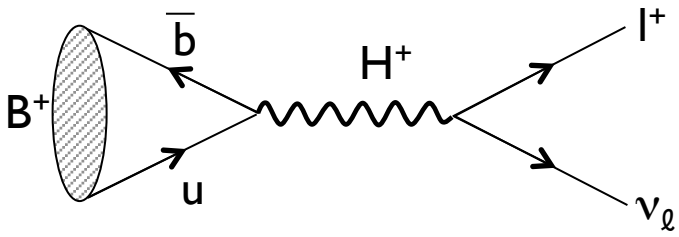
Leptonic B decays





- Very clean theoretically, hard experimentally (weak signature)
- SM contribution suppressed by helicity
- Sensitive to NP contribution (charged Higgs)

$$\mathcal{B}(B \to l\nu) = \frac{G_F^2 m_B}{8\pi} m_l^2 (1 - \frac{m_l^2}{m_B^2})^2 f_B^2 |V_{ub}|^2 \tau_B$$

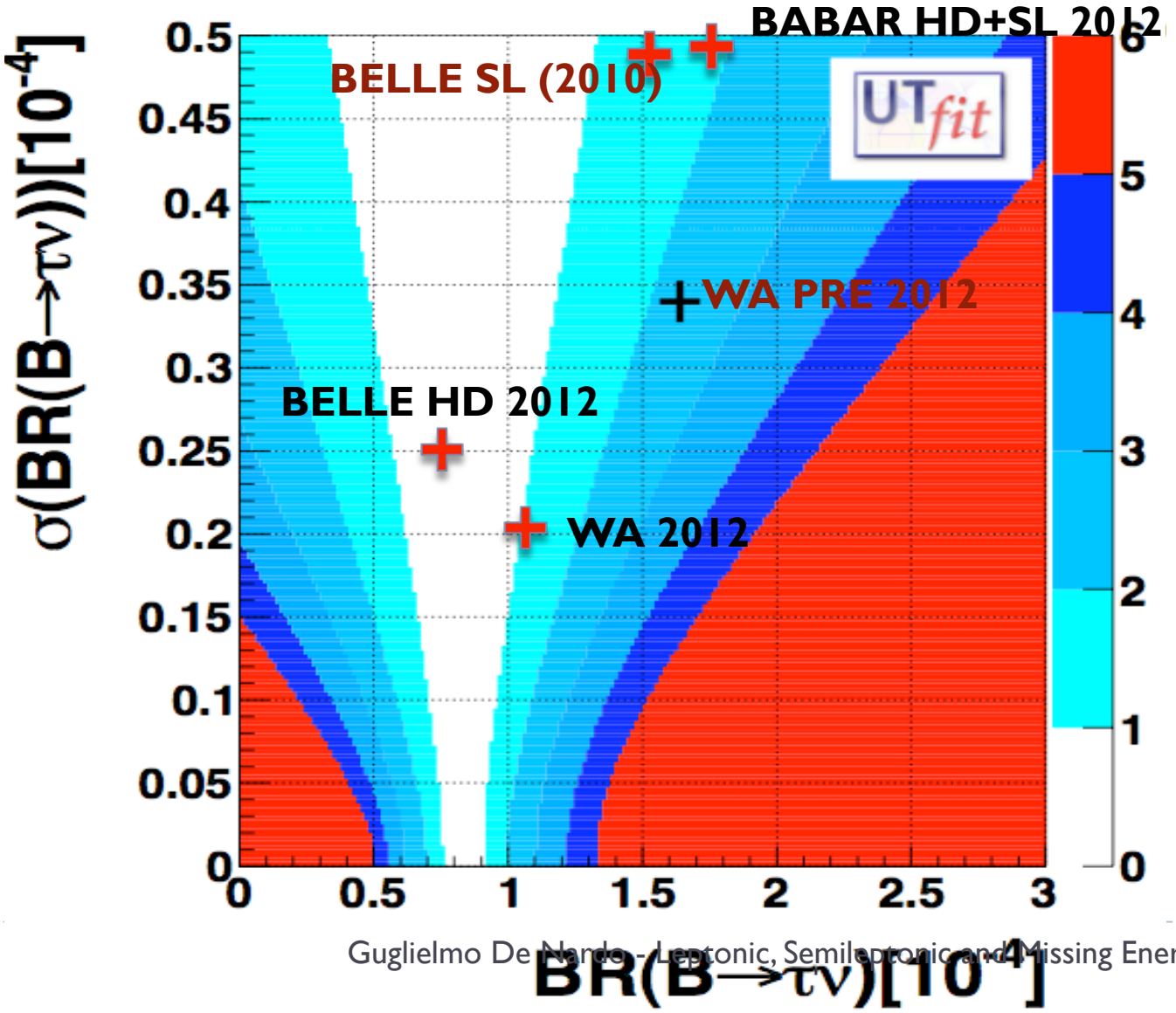
$$\mathcal{B}(B \to l\nu)_{2HDM} = \mathcal{B}(B \to l\nu)_{SM} \times (1 - tan^2\beta \frac{m_B^2}{m_H^2})^2$$

$$R^{\tau e} = \frac{\Gamma(B \to e\nu)}{\Gamma(B \to \tau\nu)}$$

Belle II can also test lepton flavour universality

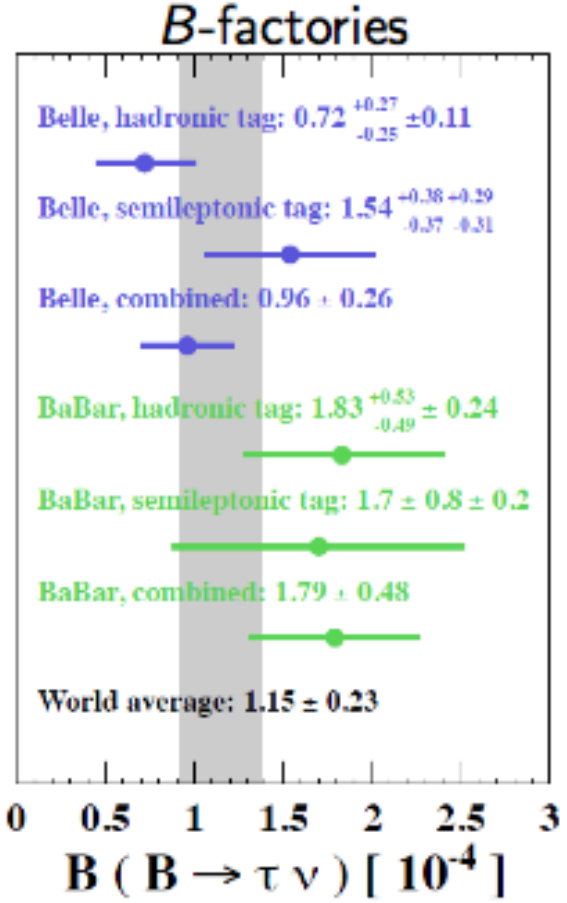
$$R^{\tau\mu} = \frac{\Gamma(B \to \mu\nu)}{\Gamma(B \to \tau\nu)}$$

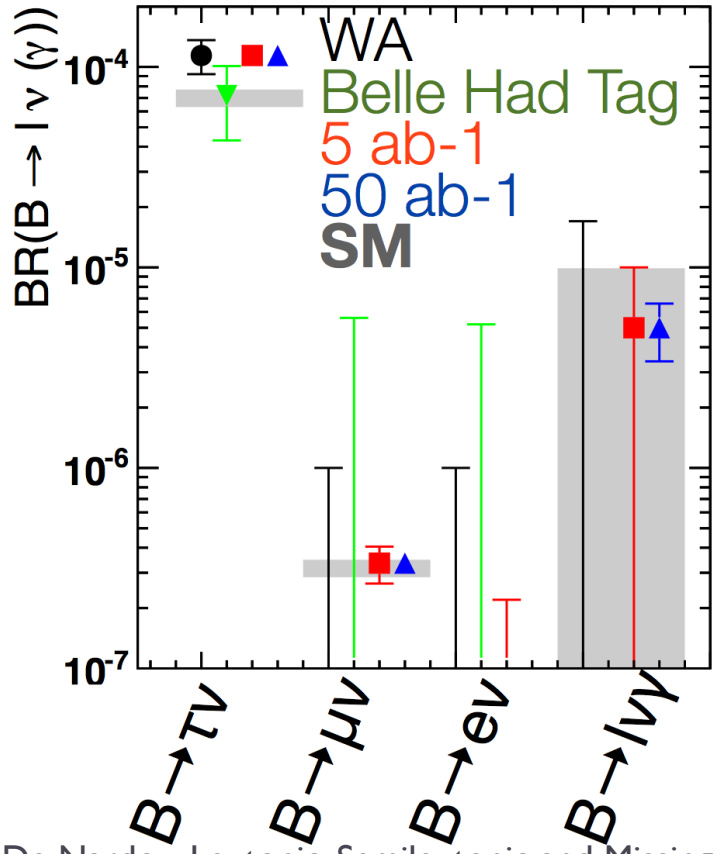
B → τ ν measurements landscape



Sensitivity outlook

- Expected uncertainty for B → τν 3% - systematic dominated
  - How much of the syst. uncertainty is actually irreducible ?



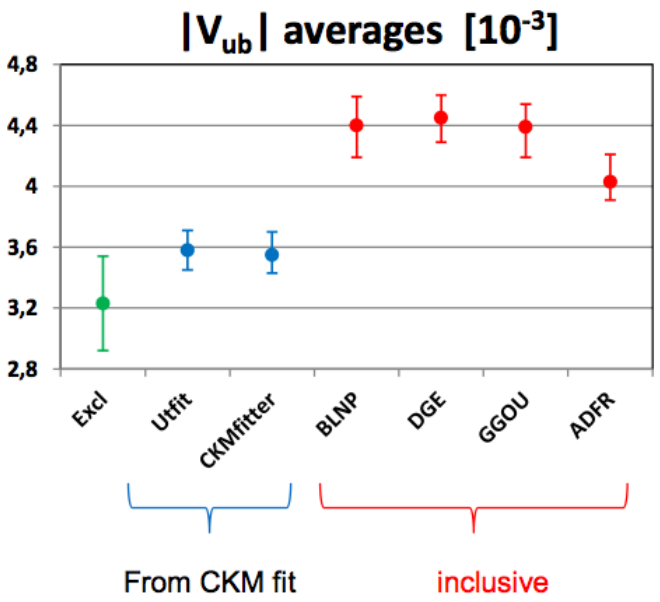


Leptonic SM level
For muonic mode reachable

We will observe
Also radiative modes

Vub measurement

- To observe NP, we must precisely know SM contribution.
  - For b → u transition accurate measurement of |Vub| is needed
  - inclusive and exclusive measurements in "tension"
    - Theoretical or experimental problem? Or just statistics?
  - Belle II will settle the argument

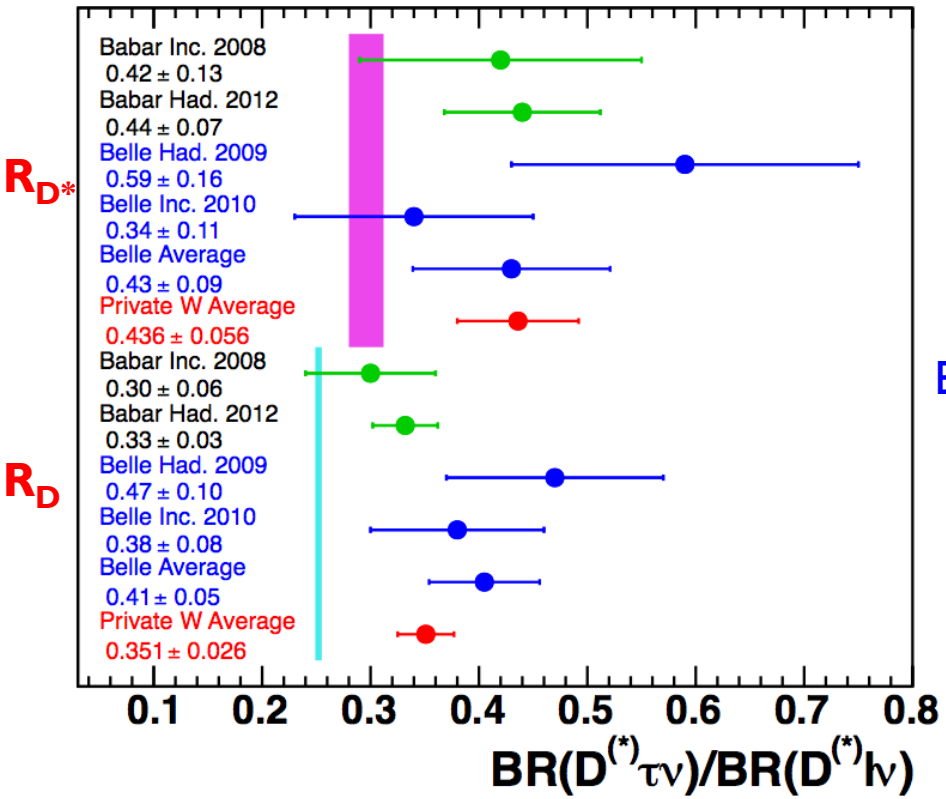


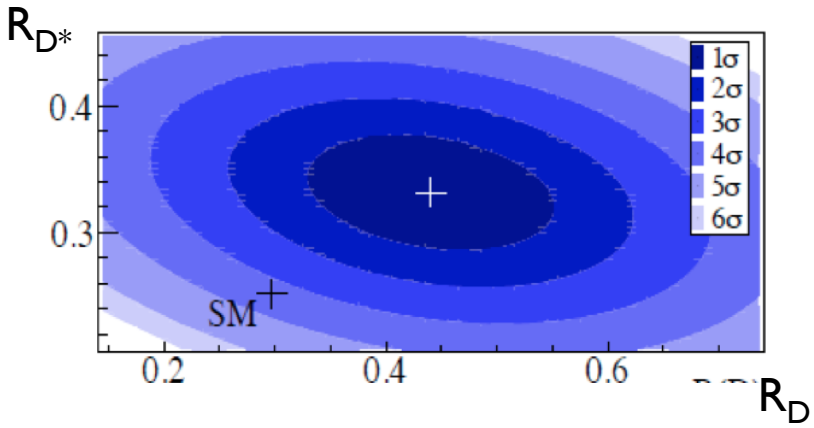
Belle II extrapolations

	Statistical	Systematic (reducible, irreducible)	Total Exp	Theory	Total
$\|V_{ub}\|$ exclusive (had. tagged)					
711 fb^{-1}	5.8	(2.3, 1.0)	6.3	8.7 (2.0)	10.8 (6.6)
5 ab^{-1}	2.2	(0.9, 1.0)	2.6	4.0 (2.0)	4.7 (3.3)
50 ab^{-1}	0.7	(0.3, 1.0)	1.3	2.0	2.4
$\|V_{ub}\|$ exclusive (untagged)					
605 fb^{-1}	2.7	(2.1, 0.8)	3.5	8.7 (2.0)	9.4 (4.0)
5 ab^{-1}	1.0	(0.8, 0.8)	1.5	4.0 (2.0)	4.2 (2.5)
50 ab^{-1}	0.3	(0.3, 0.8)	0.9	2.0	2.2
$\|V_{ub}\|$ inclusive					
605 fb^{-1} (old B tag)	4.5	(3.7, 1.6)	6.0	2.5	6.5
5 ab^{-1}	1.1	(1.3, 1.6)	2.3	2.5	3.4
50 ab^{-1}	0.4	(0.4, 1.6)	1.7	2.5	3.0

Semi-tauonic decays

$B \rightarrow D^* \tau \nu$ / $B \rightarrow D^* l \nu$ >3 σ above the SM prediction





BaBar results extrapolated to Belle II

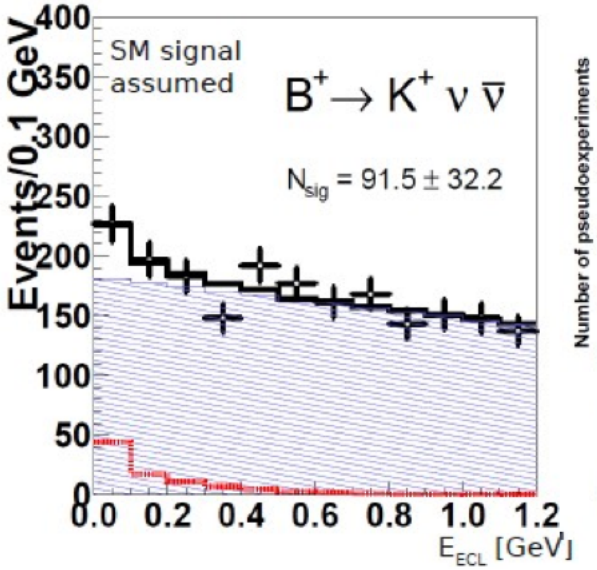
	fb-1	Statistical	Systematic	Total
R(D)	423	13.0	(9.6, 1.3)	16.5
	5000	3.8	(2.8, 1.3)	5.2
	50000	1.2	(0.9, 1.3)	**2.5**
R(D*)	423	7.0	(5.5, 1.3)	9.0
	5000	2.1	(1.6, 1.3)	2.9
	50000	0.7	(0.5, 1.3)	**1.6**

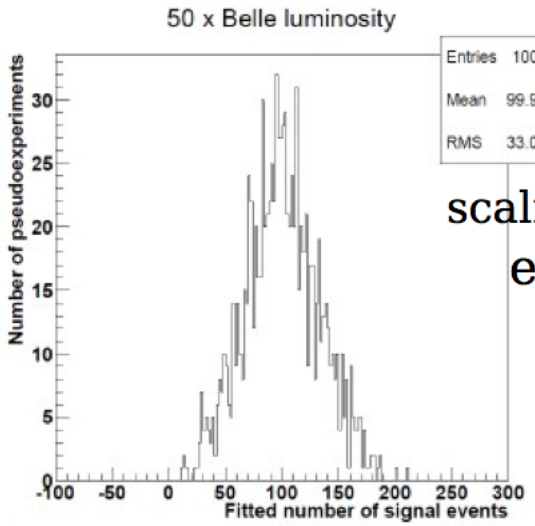
From 16.5% to 2.5%

From 9% to 1.6%

FCNC transition with neutrinos
$B \rightarrow h \nu \nu$

- SM level out of reach for Belle and BaBar. Expected to be at the limit of sensitivity for Belle II.
- Scaling Belle results (just with had. Tagging) 100 signal events and 20% accuracy on BR.





$B^+ \rightarrow K^+ \nu \bar{\nu}$

$N_{sig} \sim 100 \pm 30$

scaling from **new** Belle result

evidence with 50 ab^{-1}

(had.tag only)

Working group activities (in preparation for data taking)

- Sensitivity/feasability studies
  - Update the existing extrapolations to Belle II with current Belle II simulation
  - Identify the systematic effects that may become dominant and develop strategies for improvement
  - Check and extend MC generators when new measurement or new physics model become available
- Common tools development and physics validation
  - Feedback to sub-system reconstruction experts studying performances on physics modes
  - Contribute to the development of physics analysis tools
    - Ex: Tag B reconstruction & missing energy tools
    - Definition of Particle ID and tracking criteria
    - Identify data driven methods to calibrate reconstruction tools relevant to the WG physics
    - Identify physics motivated content of mdst.
    - Definition of physics skims (they will be run centrally)

Available tools

- Physics Analysis Software is starting to take shape
  - We just have defined the first version of the mdst.

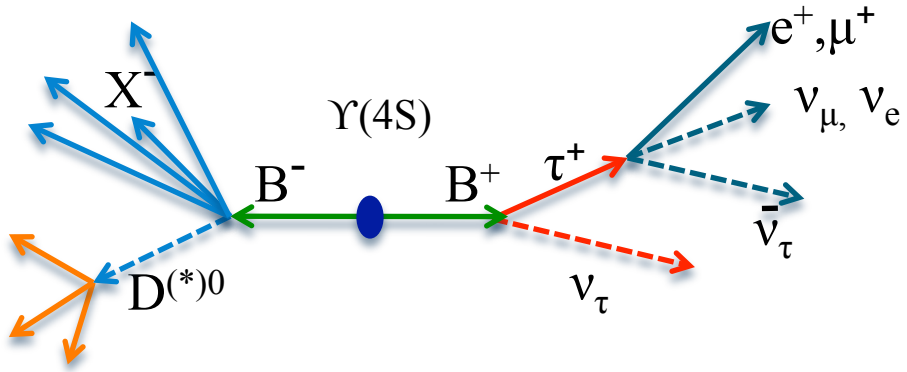
MDST object	Physics object	Comment
Tracks	e, μ, π, K, p	✓
PIDLikelihood	e, μ, π, K, p IDs	✓
ECLCluster	γ, π^0	✓
V0	$K^0_S, \Lambda, \gamma \to e^+e^-$	✗
KLMCluster	K^0_L	✓ (only endcap KLM)

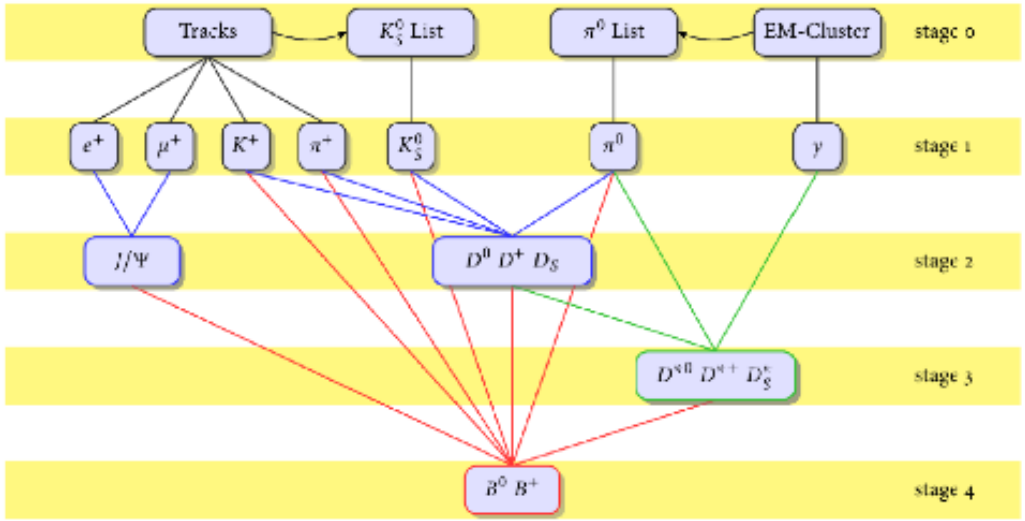
  - and of basic analysis tools

Module	Physics action
ParticleLoader	creates Particle(s) from MDST objects
ParticleSelector	applies cuts on existing Particle(s) (over 50 functions/variables already supported)
ParticleCombiner	performs combinations
ParticleVertexFitter	kinematic fitter
MCMatching	MC truth matching
NtupleMaker	creation/filling of flat ntuples
RestOfEventBuilder	determines remaining tracks/ECL/KLMClusters

B tag reconstruction

- Essential tool for this WG
  - Core code for hadronic tagging developed by KIT group
- Have to produce calibration and validation samples
- Study of the related systematics uncertainties
- Semileptonic tagging missing

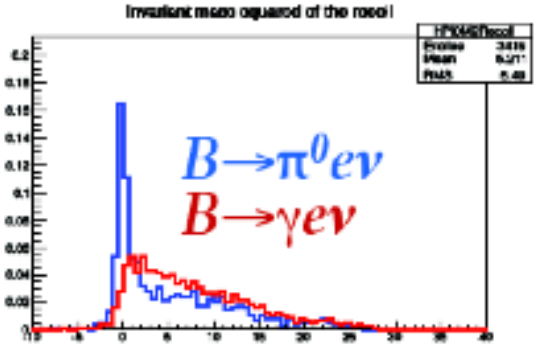


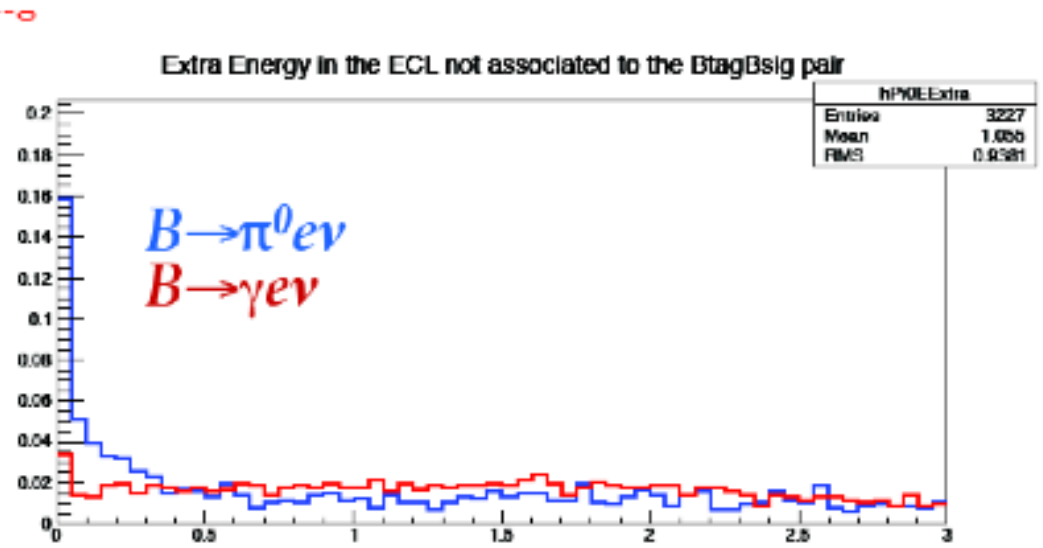


Perform multivariate classification at each stage (and per decay mode).

Recoil Physics

- Basic functionalities available (extra energy, missing mass..)
  - A lot of room for improvement and new features…





Conclusions

- Belle II Physics working group recently established
  - Real work (meeting, tasks) not yet started, though.
- Leptonic, Semileptonic and Missing Energy WG physics scope include many key measurements in Belle II program
- Belle II software reached a status that allows realistic physics studies (no more extrapolations of BaBar/Belle)
  - Utmost importance that further developments in be driven by physics
    - Feedback to detector experts based on impact on physics
    - Requirements on computing/software based on physics needs
  - Data taking is not that far. It's time now to start building up the Belle II physics program
- Many opportunities to contribute from tools development to feasibility studies/physics analysis