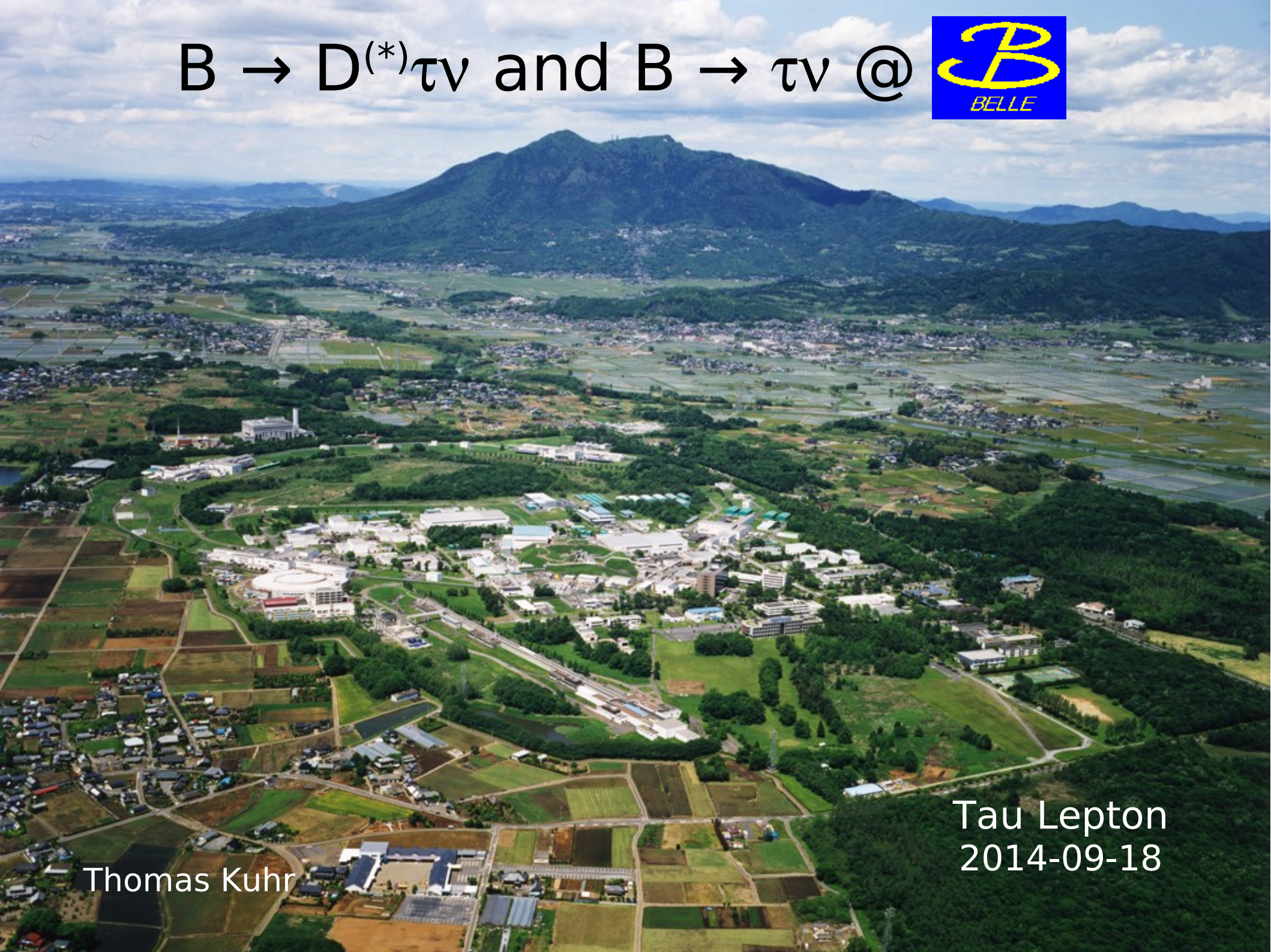
$B \to D^{(*)}\tau\nu$ and $B \to \tau\nu$ @

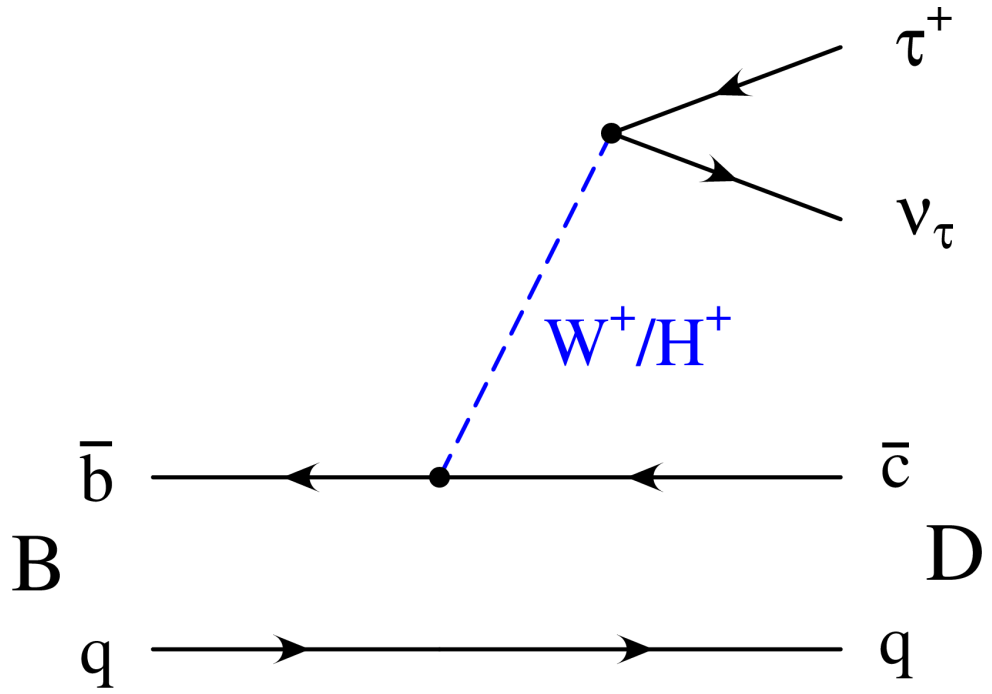


Thomas Kuhr

Tau Lepton
2014-09-18

$B \to D^{(*)}\tau\nu$

- Process with third generation quarks and leptons

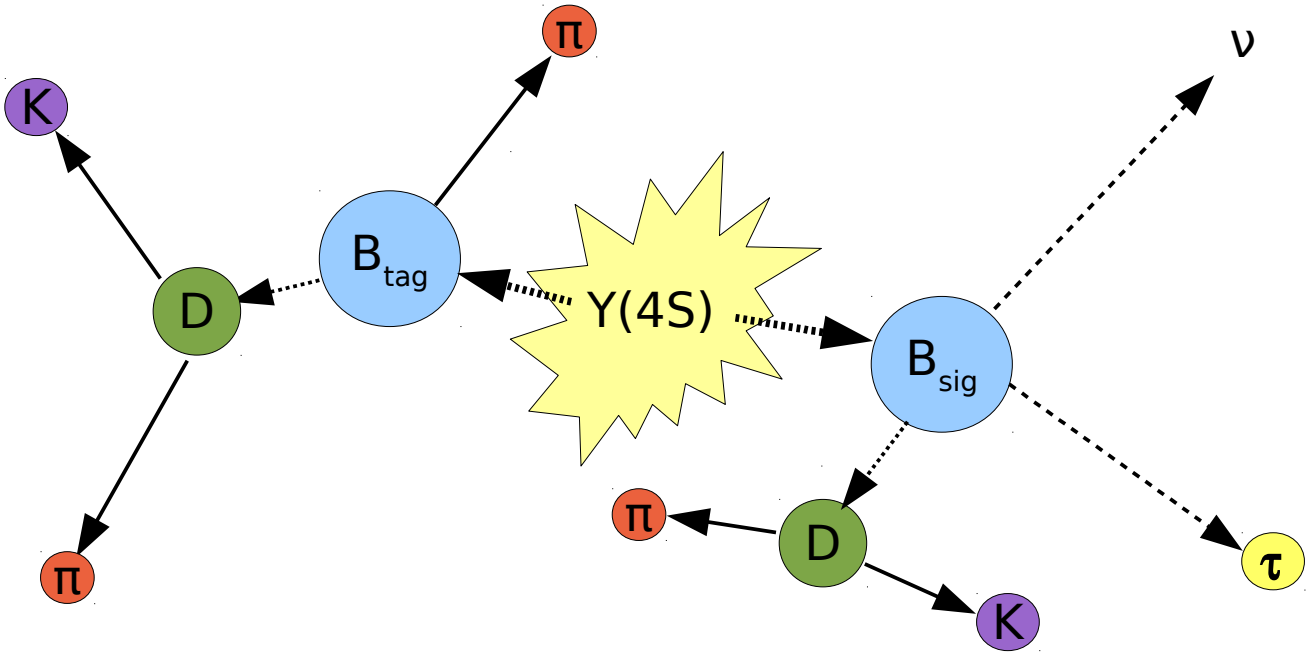


- New Physics (NP) could change:
  - Branching fraction
  - Tau polarization
- → Effect could be different for D and D^*
- *3.4σ deviation from SM observed by BaBar, 2HDM type II excluded*

→ Experimental challenge:
2 (hadronic tau decay) or 3 (leptonic tau decay) undetected neutrinos

Tagging

- Exploit fact that a $B\bar{B}$ pair and nothing else is produced in $e^+e^- \rightarrow \Upsilon(4S)$ events at B factories

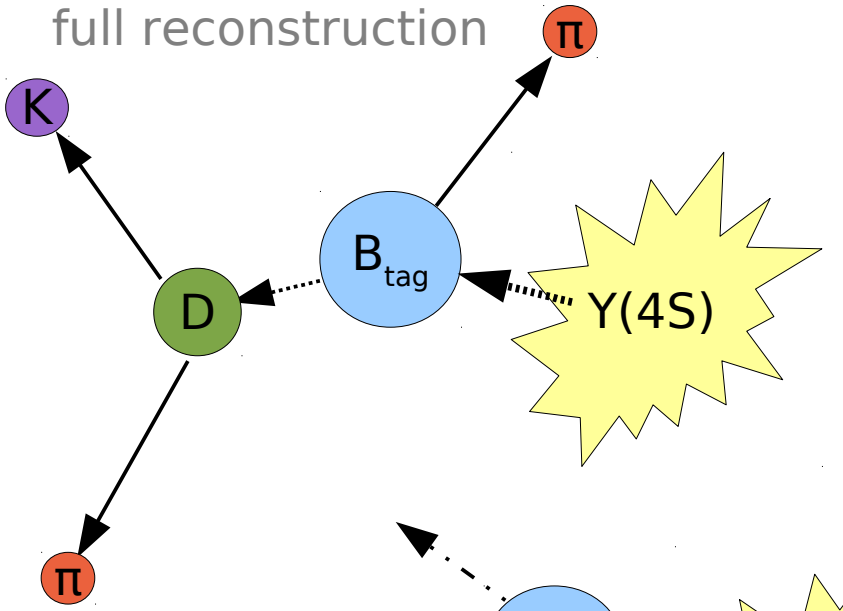


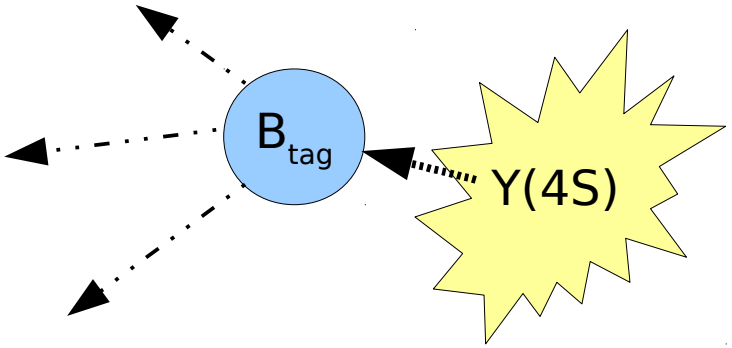
- ✔ Tag B determines charge and momentum of signal B
- ✔ All remaining particles must come from signal B
- Not possible at hadron colliders

Tagging Methods

Hadronic tag

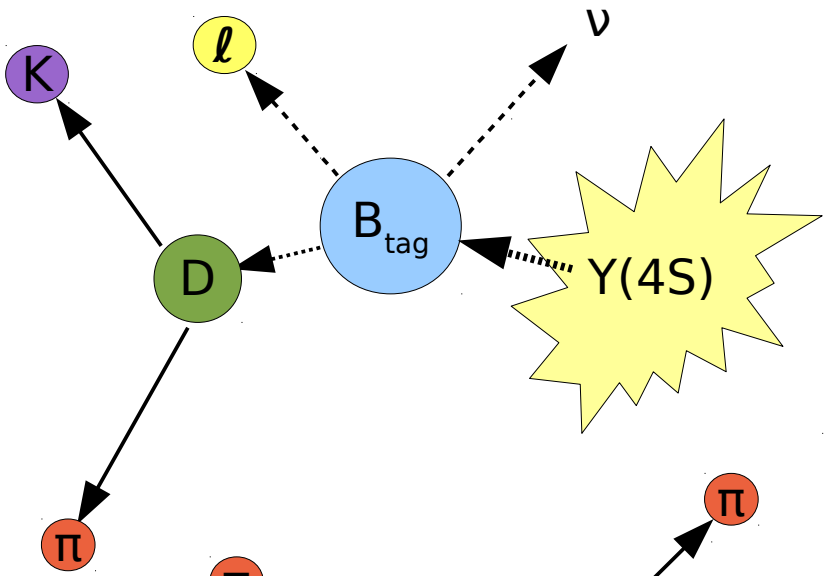
full reconstruction

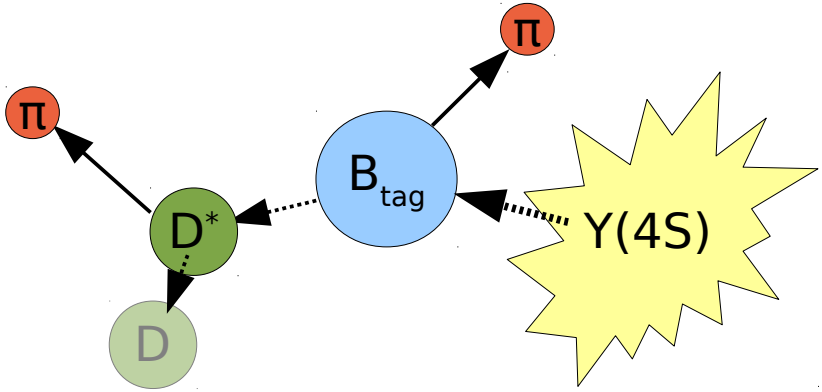




Inclusive tag

Semileptonic tag

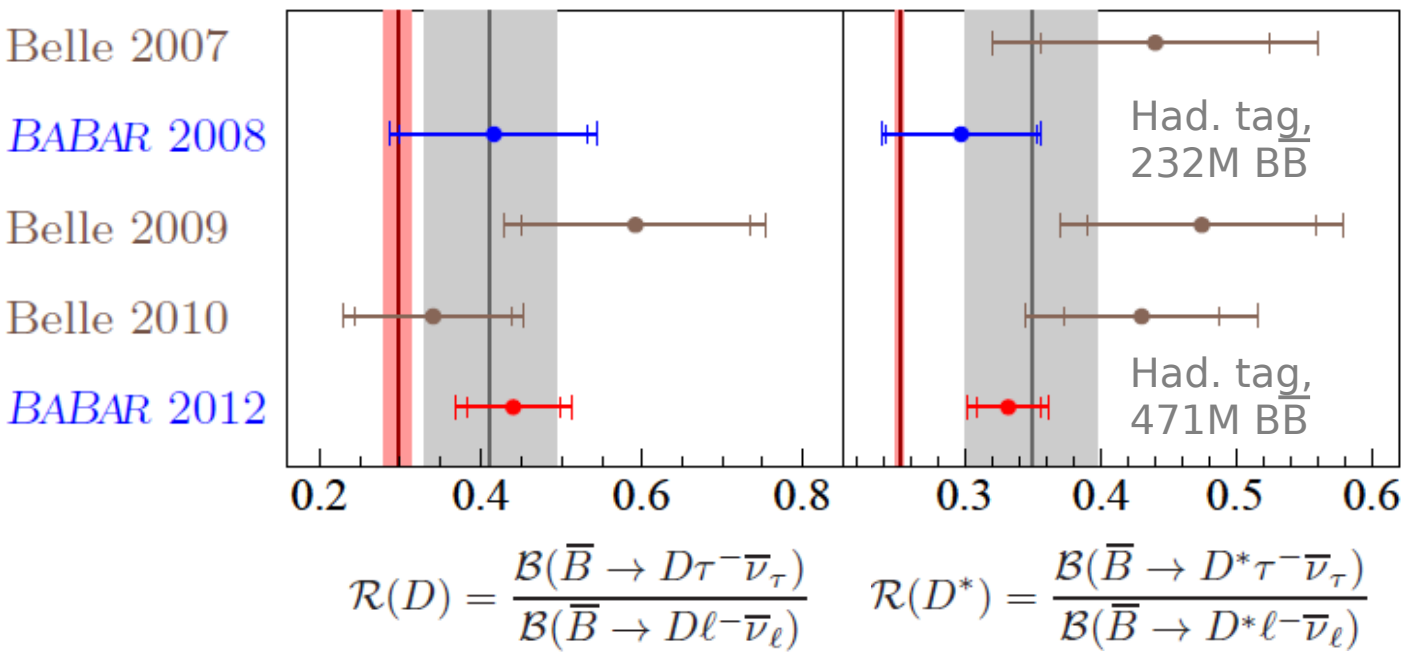




Semi-inclusive tag

$B \to D^{(*)}\tau\nu$ Status

PRD 88 072012



B^0, 535M $B\overline{B}$, Inclusive tag

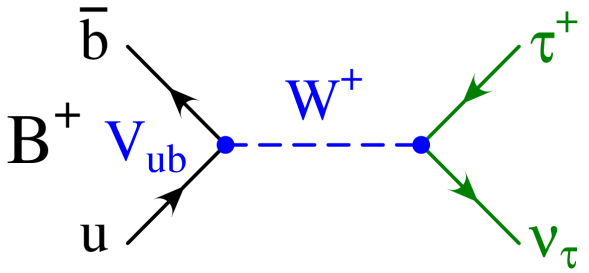
B^+, 657M $B\overline{B}$, Inclusive tag

$B^{+/0}$, 657M $B\overline{B}$, Hadronic tag

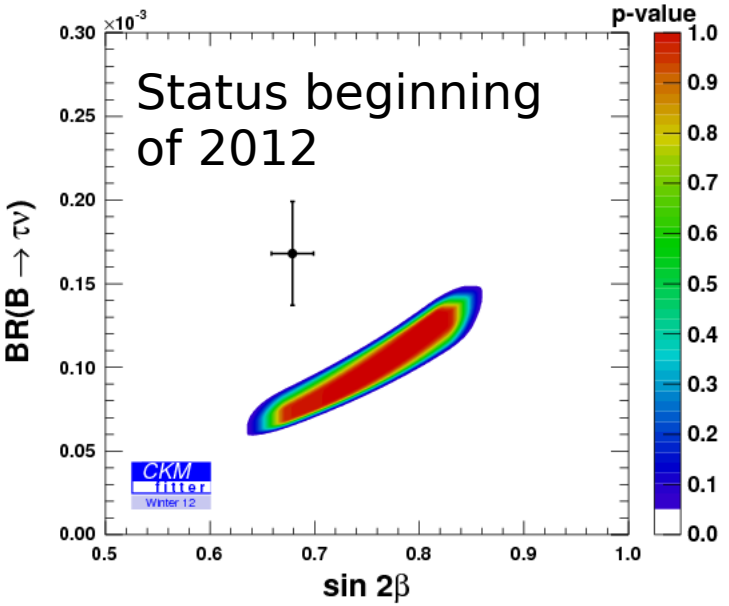
- Analyses of full Belle data sample with different tagging method in progress
- → Result with hadronic tag expected soon

$B \to \tau\nu$

- SM:

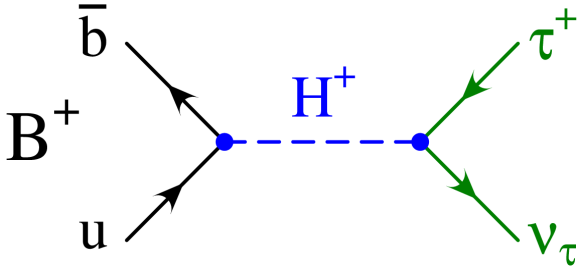


$$\mathcal{B}(B^+ \to \tau^+\nu) = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$



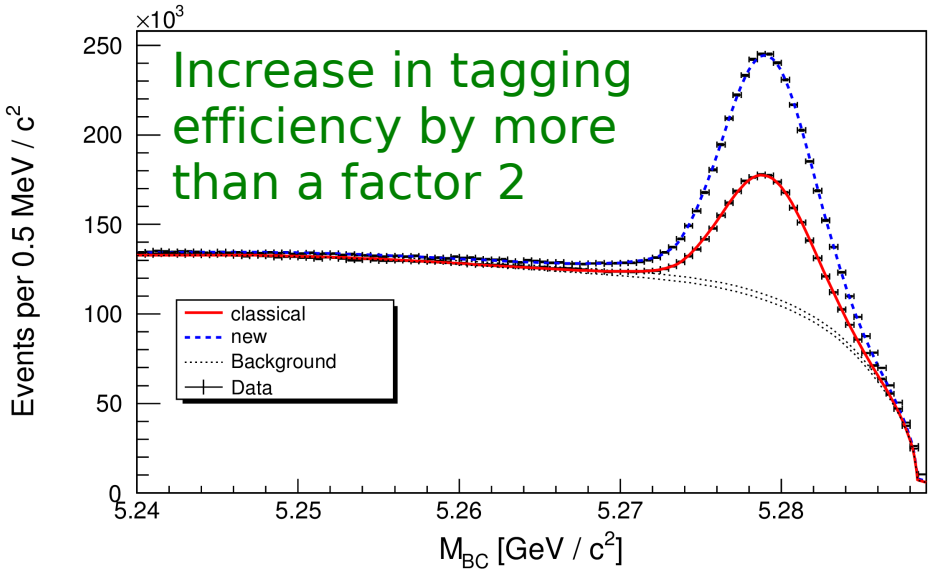
- Two Higgs doublet model:

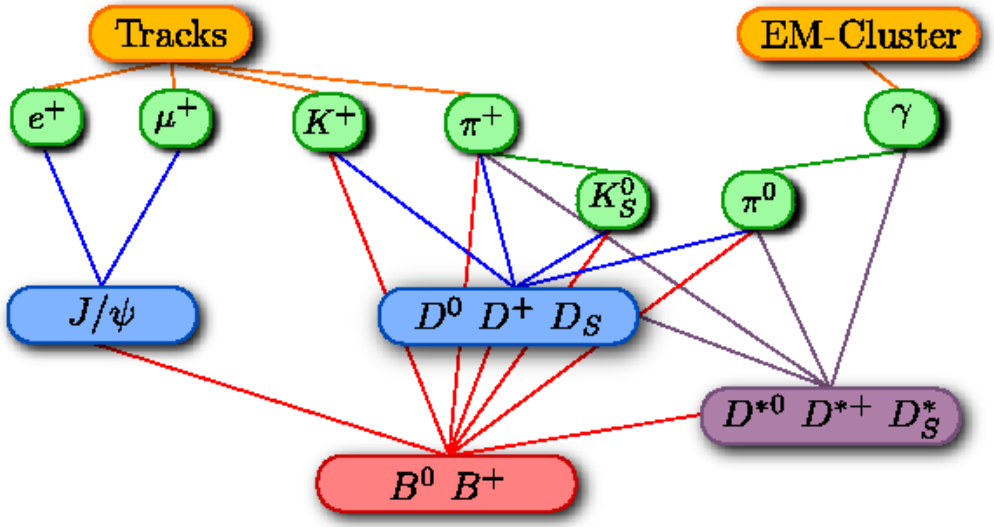
$$\mathcal{B}(B^+ \to \tau^+\nu) = \mathcal{B}(B^+ \to \tau^+\nu)_{SM}\left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

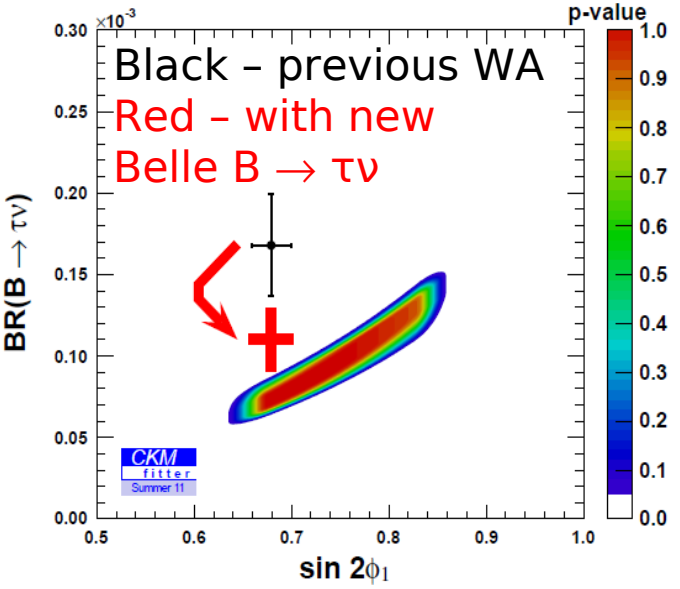


Update of B → τν with Hadronic Tag

- PRL 110, 131801 (2013)
- ✔ Full Belle dataset
- ✔ Reprocessed data
- ✔ 2D fit for signal extraction
- ✔ Improved hadronic tag
  NIMA654, 432 (2011)







Update of B → τν with Semileptonic Tag

NEW

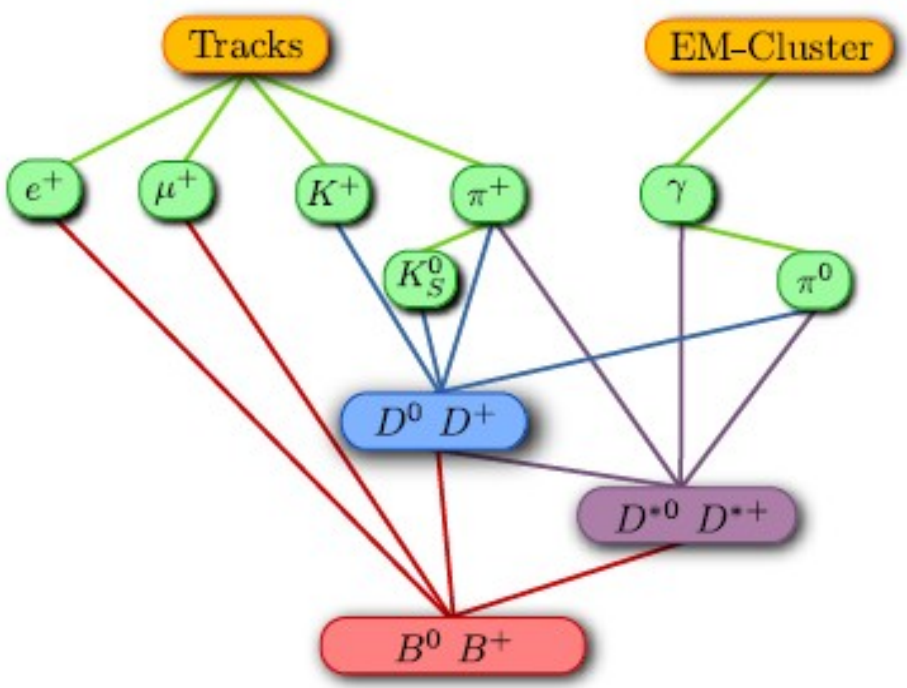
- Improvements compared to previous analysis (PRD 82, 071101 (2010), 657M $B\bar{B}$)
- ✔ Full Belle dataset (772M $B\bar{B}$)
- ✔ Reprocessed data
- ✔ Additional tau decay channel
- ✔ Improved semi-leptonic tag
- ✔ Reoptimized selection
- ✔ Data-driven continuum background estimation
- ✔ 2D fit for signal extraction

Efficiencies [10^{-4}] of reconstructed $\tau \to X\nu$ decay modes

Final State	e^+	μ^+	π^+	$\pi^+\pi^0$
e^+	6.6 ± 0.1	0.1 ± 0.0	0.2 ± 0.0	0.1 ± 0.0
μ^+	0.1 ± 0.0	4.7 ± 0.1	0.6 ± 0.0	0.2 ± 0.0
π^+	0	0.1 ± 0.0	1.6 ± 0.0	0.5 ± 0.0
$\pi^+\pi^0$	0	0.1 ± 0.0	1.4 ± 0.0	4.9 ± 0.1
$\pi^+\pi^0\pi^0$	0	0	0.2 ± 0.0	1.3 ± 0.0
Other	0	0	0.1 ± 0.0	0.2 ± 0.0
All	6.8 ± 0.1	5.1 ± 0.1	4.0 ± 0.0	7.2 ± 0.1
Total		23.1 ± 0.1		

Improved Semileptonic Tag

- Hierarchical system similar to new hadronic tag
- Multivariate classifiers (NeuroBayes)
- More D^0 decay channels

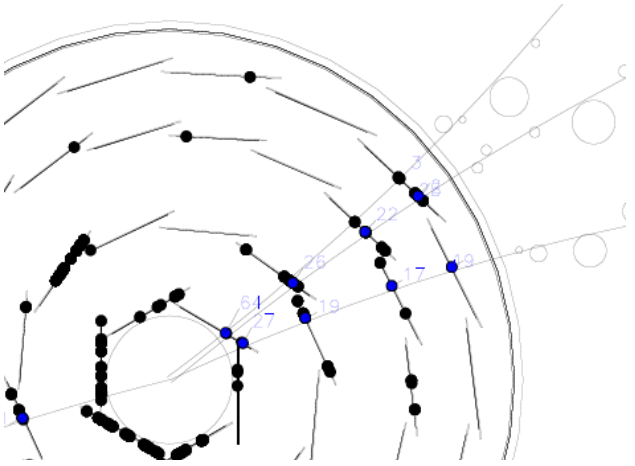


Decay Channel	Branching Fraction (%)
$D^0 \to K^-\pi^+\pi^0$	13.9 ± 0.5
$D^0 \to K^-\pi^+\pi^+\pi^-$	8.1 ± 0.2
$D^0 \to K_S^0\,\pi^+\pi^-\pi^0$	5.2 ± 0.6
$D^0 \to K^-\pi^+$	3.9 ± 0.1
$D^0 \to K_S^0\,\pi^+\pi^-$	2.8 ± 0.2
$D^0 \to \pi^+\pi^-\pi^0$	1.4 ± 0.1
$D^0 \to K_S^0\,\pi^0$	1.2 ± 0.1
$D^0 \to K_S^0\,K^+K^-$	0.5 ± 0.03
$D^0 \to K^+K^-$	0.4 ± 0.01
$D^0 \to \pi^+\pi^-$	0.1 ± 0.003
Sum	37.5 ± 0.85

Reoptimized Selection

$$\cos\theta_{B,D^{(*)}\ell} = \frac{2E_{\mathrm{beam}}E_{D^{(*)}\ell} - m_B^2 - m_{D^{(*)}\ell}^2}{2p_B^* p_{D^{(*)}\ell}^*}$$

- Selection on momenta, impact parameters, tag quality, K/π PID, ρ mass, and $\cos\theta_{B,D(*)\ell}$ chosen to maximize signal significance
- Events with additional tracks or π^0 not from $B_{sig/tag}$ rejected
  - ➔ Selection of tracks for veto optimized
- Large continuum background for hadronic tau decays
  - ➔ Multivariate continuum suppression algorithm using 27 event shape variables
- Background from conversions in electron channel
  - ➔ Rejection of candidates with low track pair mass



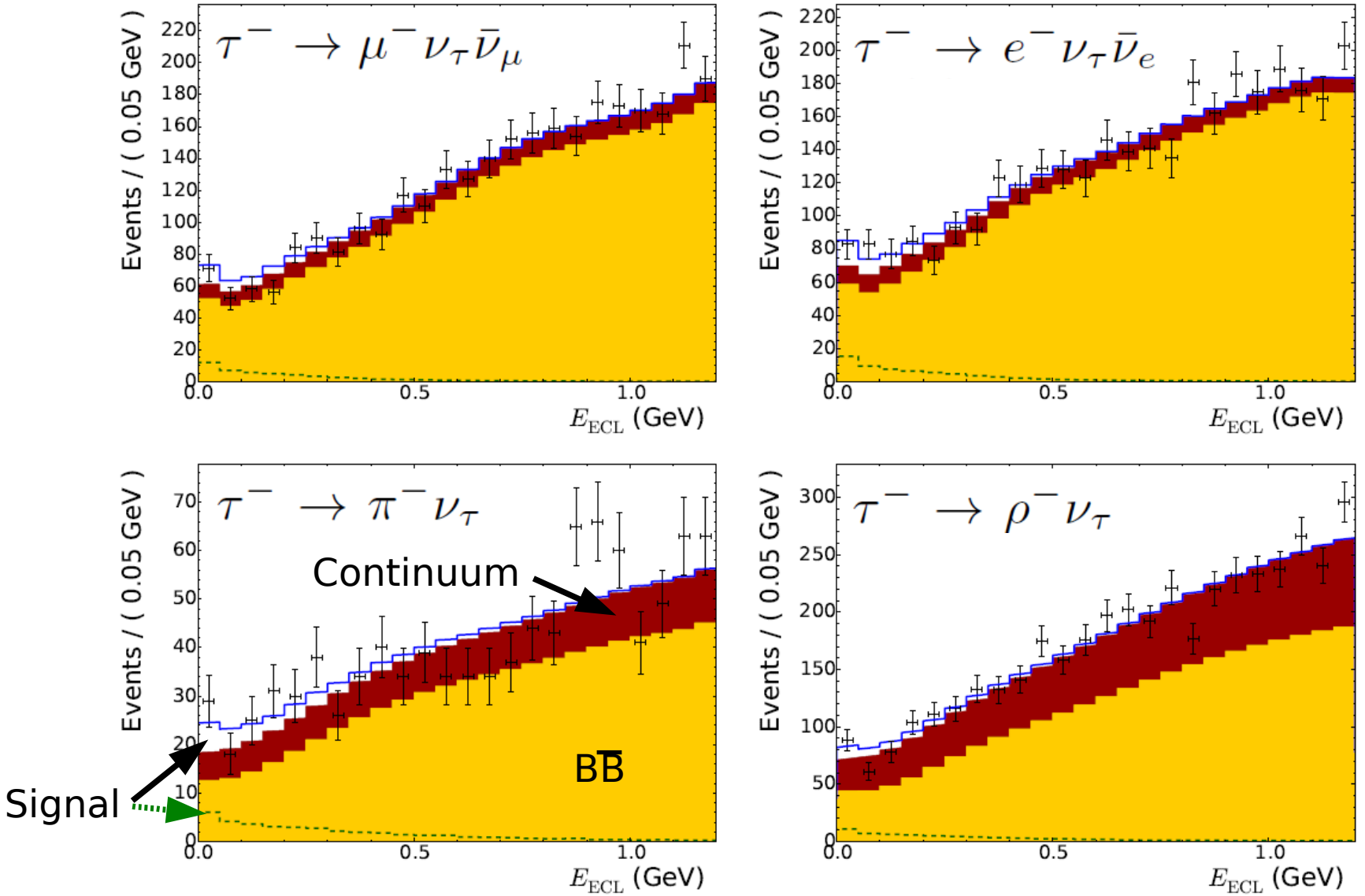
Signal Extraction

- 2D binned maximum likelihood fit of
  - Extra energy not from $B_{sig/tag}$ in calorimeter: E_{ECL}
  - Tau daughter particle momentum in CMS: p^*_{sig}

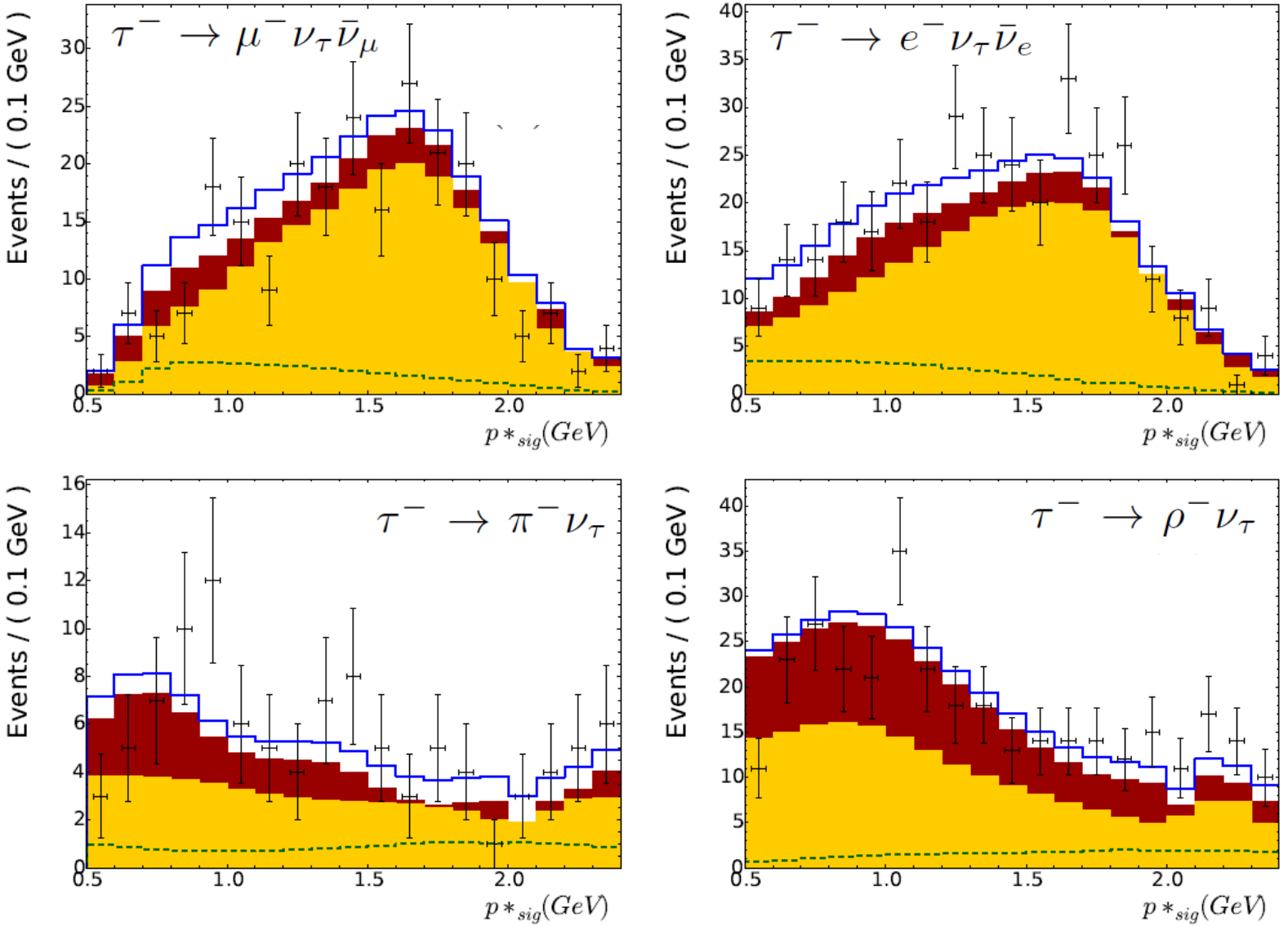
- PDFs: Product of 1D PDFs,
  except for tau signal in hadronic modes (2D histogram)
- Signal and $B\bar{B}$ background shapes from simulation
- Continuum background shape from off-resonance data
- Relative size of continuum and $B\bar{B}$ background fixed

- Fit parameters:
  - signal BR
  - background normalization for each tau mode

E_{ECL} Fit Projections



p^*_{sig} Fit Projection in E_{ECL} Signal Region



Cross Checks and Systematics

- Data – MC agreement checked on control samples:
  - E_{ECL} sideband
  - Double tagged
  - B^0 tagged
- Dominant systematics:
  - Tagging efficiency, determined by double tag
  - Continuum background

Source	Relative Uncertainty (%)
Histogram PDF shapes	8.5
Continuum description	14.1
Signal reconstruction efficiency	0.6
Background branching fractions	3.1
Efficiency calibration	12.6
τ decay branching fractions	0.2
Best candidate selection	0.4
Charged track reconstruction	0.4
π^0 reconstruction	1.1
Particle identification	0.5
Charged track veto	1.9
Number of $B\bar{B}$ pairs	1.4
Total	22.0

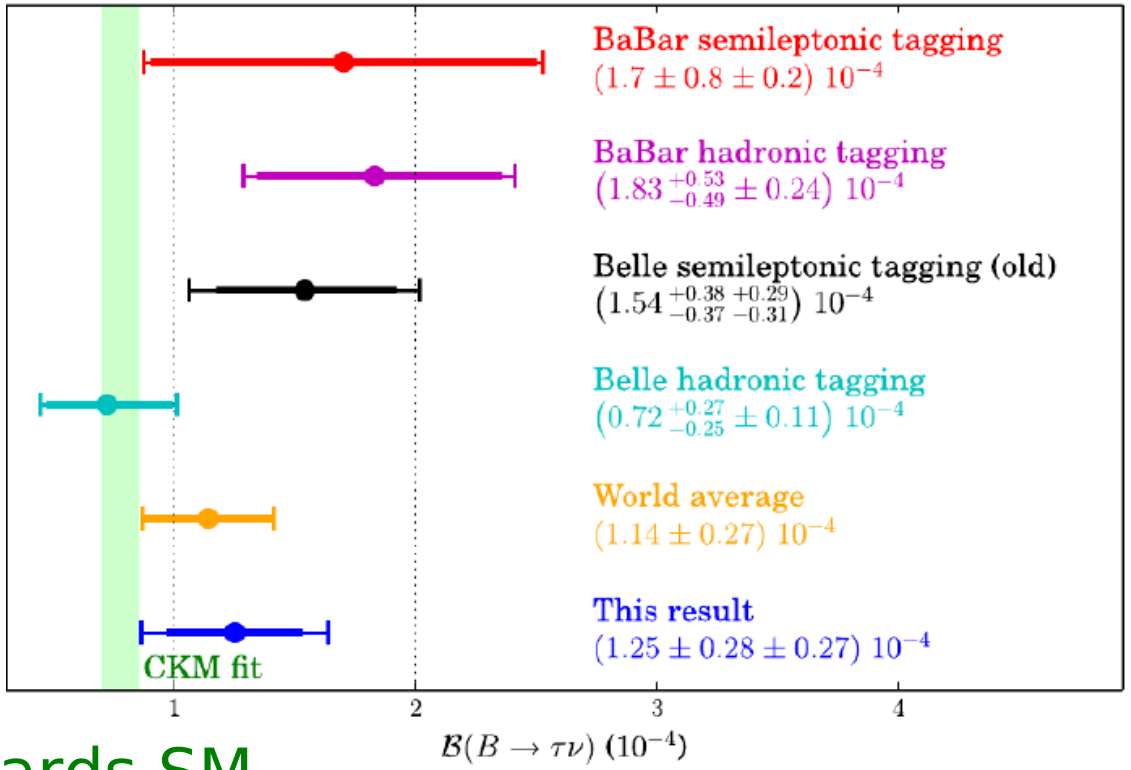
Result

Belle-CONF-1401

- $B(B \to \tau\nu) = [1.25 \pm 0.28\ (stat) \pm 0.27\ (syst)] \times 10^{-4}$
- Signal significance of 3.4σ including systematics

Decay Mode	N_{sig}	$\mathcal{B}(10^{-4})$
$\tau^- \to \mu^- \nu_\tau \bar{\nu}_\mu$	13±21	0.34±0.55
$\tau^- \to e^- \nu_\tau \bar{\nu}_e$	47±25	0.90±0.47
$\tau^- \to \pi^- \nu_\tau$	57±21	1.82±0.68
$\tau^- \to \rho^- \nu_\tau$	119±33	2.16±0.60
Combined	222±50	1.25±0.28

statistical errors only



- Consistent results among tau channels

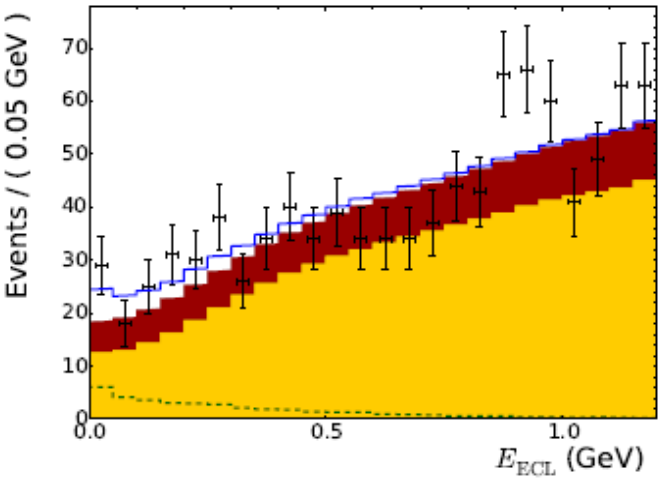
➔ Central value shifted towards SM

- Combination with Belle hadronic tag result in progress

Summary

$B \to D^{(*)}\tau\nu$

- No news (yet)



$B \to \tau\nu$

- New Belle result with semileptonic tag
- Improved precision
- → "Tension" with SM prediction further reduced

- → Have to search for NP with higher precision
  - ✔ Belle II

Backup