Tau Physics at Belle II.

Current Status and Prospects

Michel Hernández Villanueva
DESY

On behalf of the Belle II collaboration.

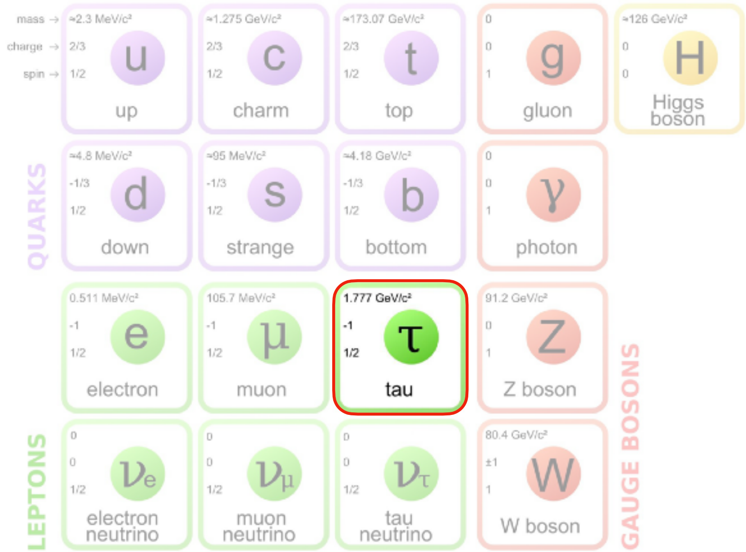
KMI International Symposium
Feb 20, 2023

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Tau lepton physics

Why is it interesting?

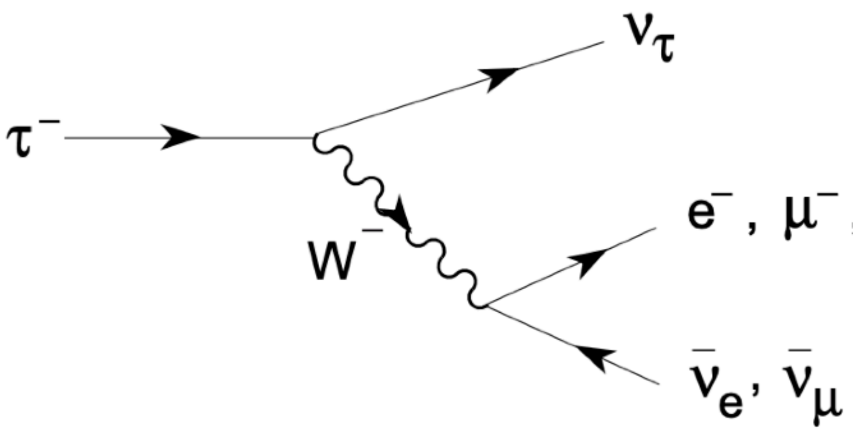
- The τ is the charged lepton of the third generation.

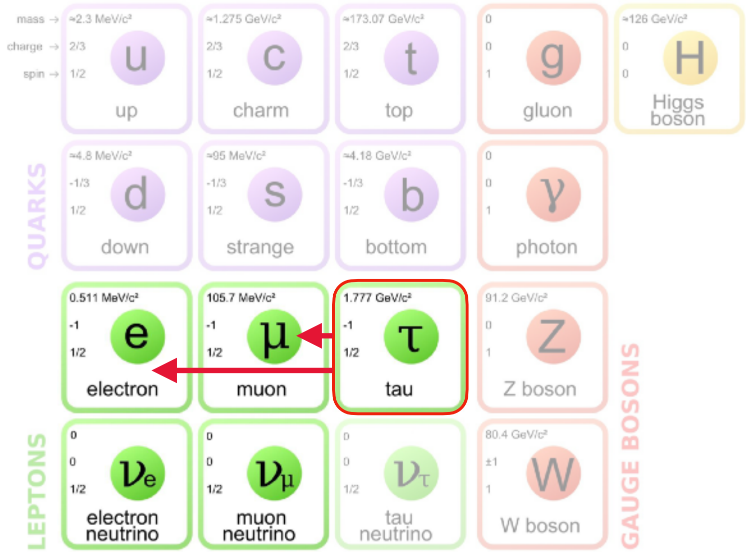


Tau lepton physics

Why is it interesting?

- The τ is the charged lepton of the third generation.

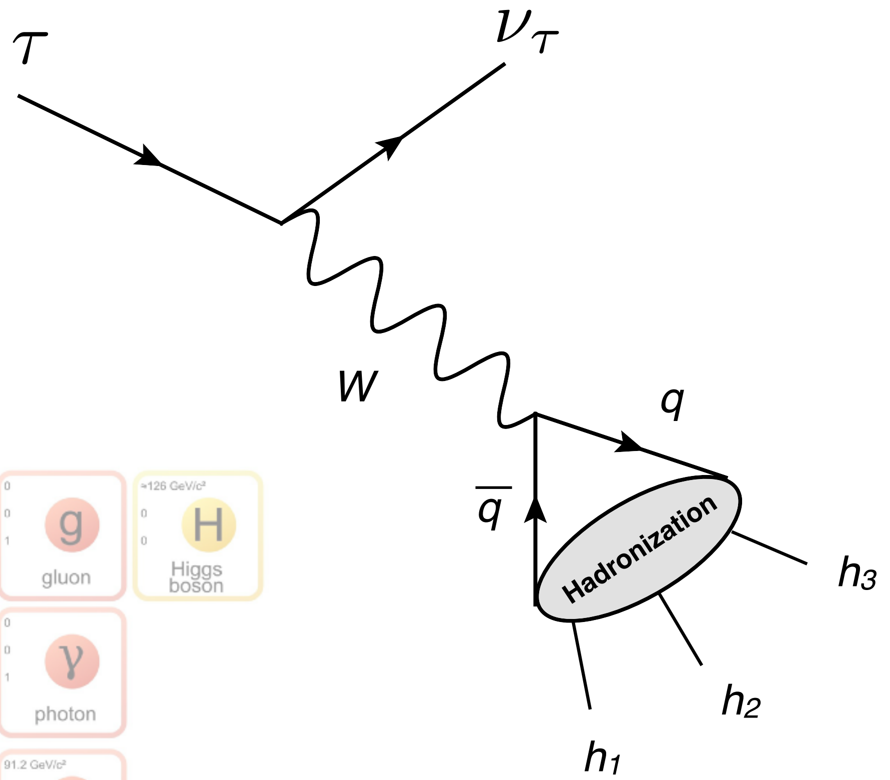


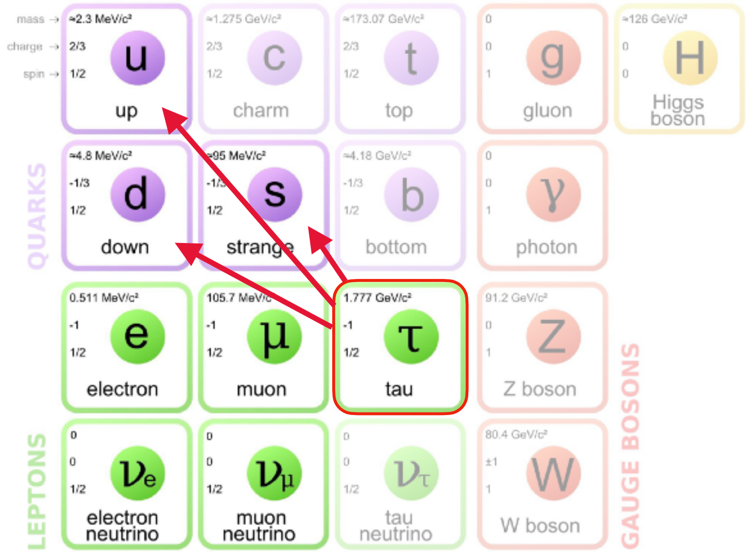


Tau lepton physics

Why is it interesting?

- The τ is the charged lepton of the third generation.
- It is the only lepton massive enough to decay into hadrons.

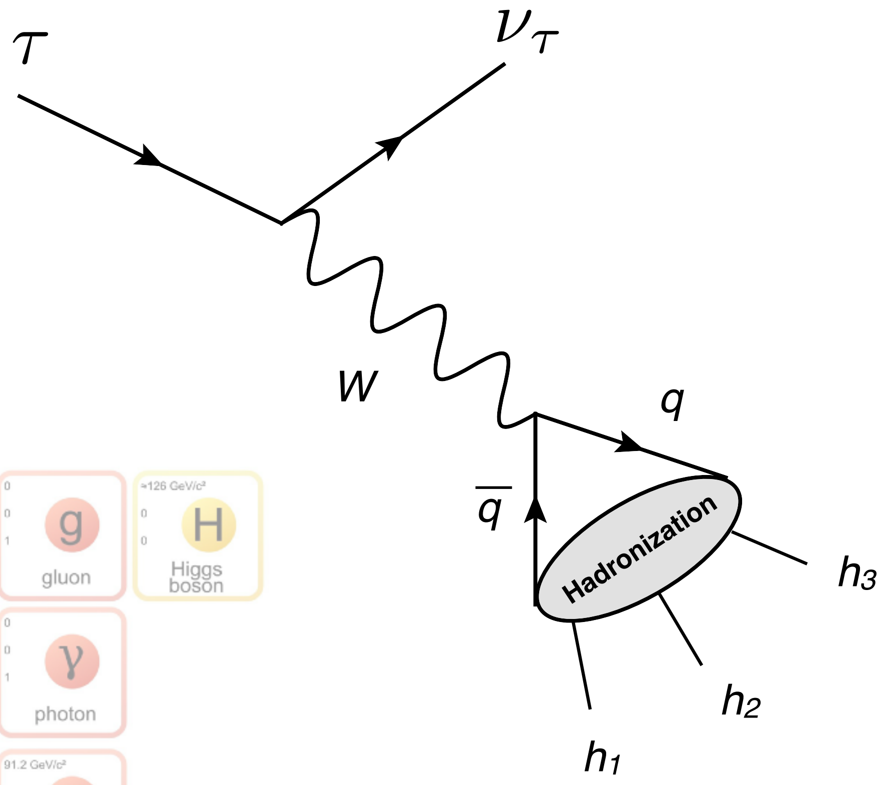


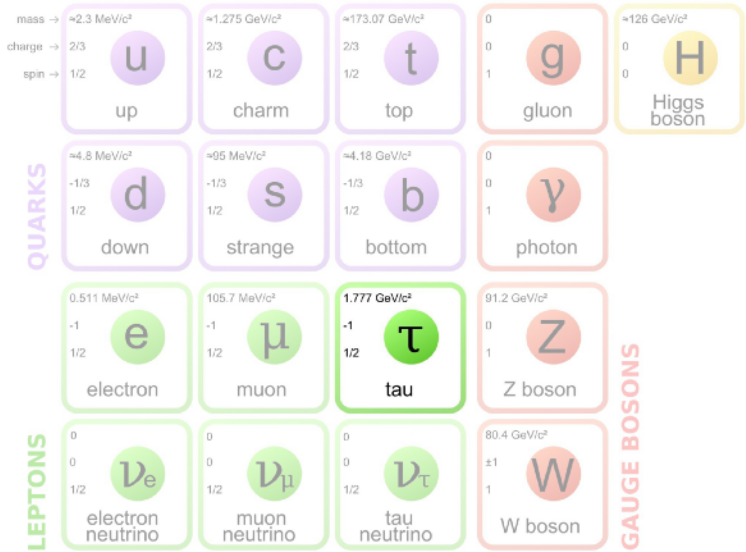


Tau lepton physics

Why is it interesting?

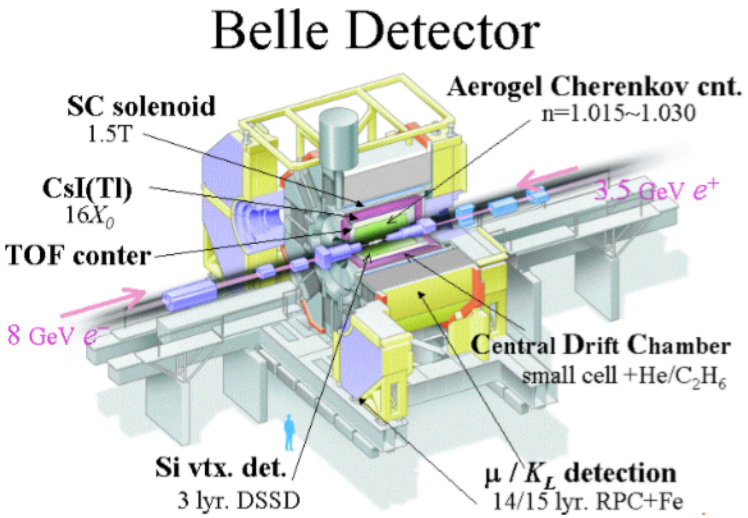
- The τ is the charged lepton of the third generation.
- It is the only lepton massive enough to decay into hadrons.
- Allow a clean determination of SM parameters and searches of new physics.

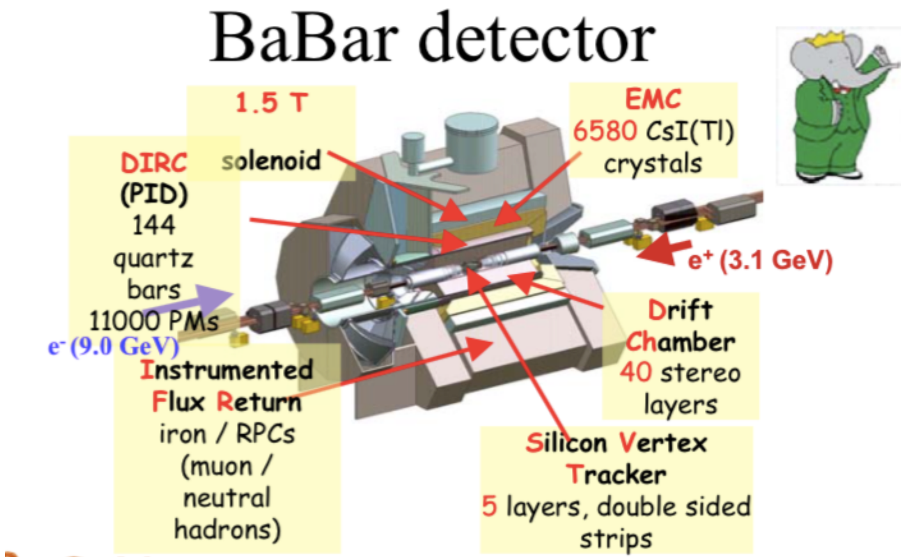




B-Factories

As experiments for precision tau physics

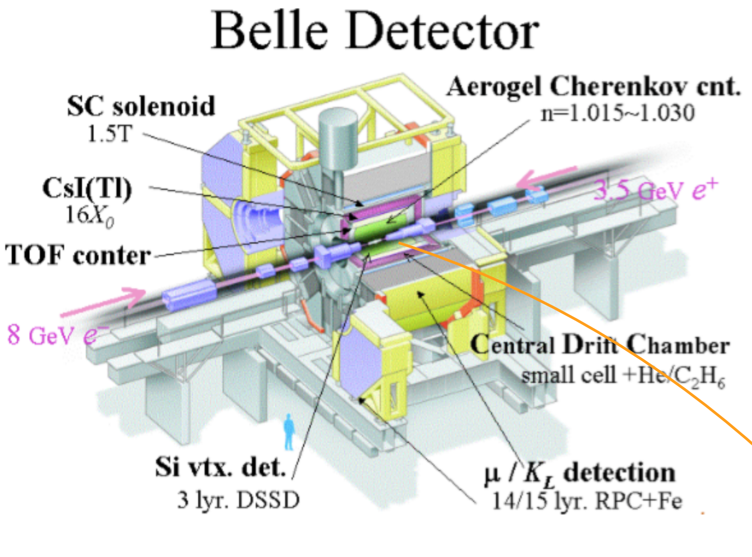


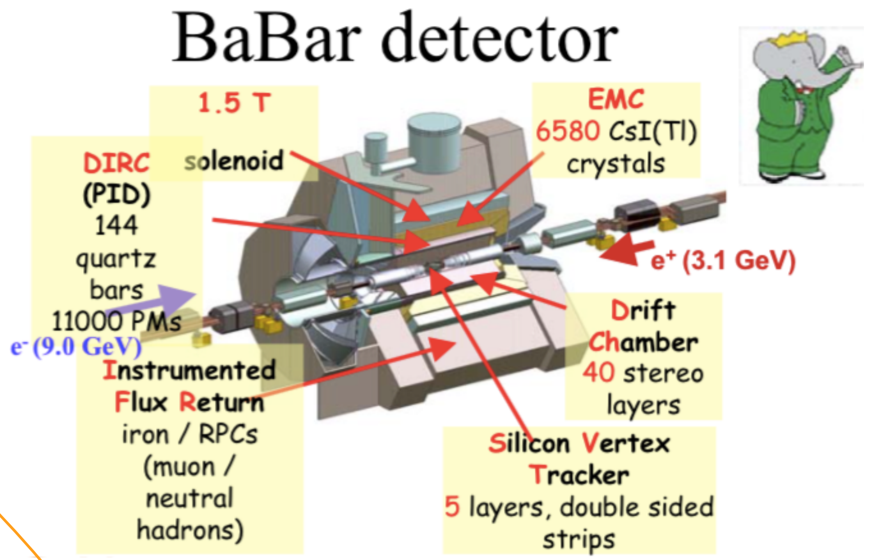


- **Features of a B-Factory:**
  - High luminosity.
  - Well-defined initial state.
  - High vertex resolution.
  - Excellent calorimetry.
  - Sophisticated particle ID.

B-Factories

As experiments for precision tau physics





- **Features of a B-Factory:**
  - High luminosity.
  - Well-defined initial state.
  - High vertex resolution.
  - Excellent calorimetry.
  - Sophisticated particle ID.

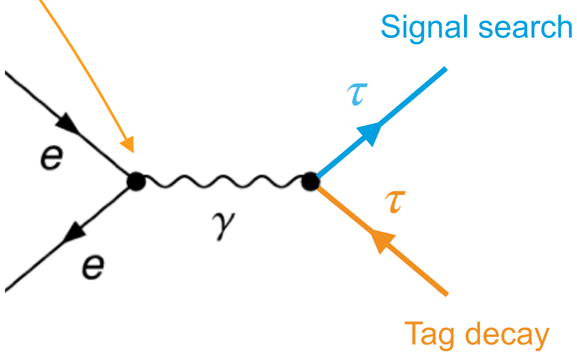
- At Y(4S):

  $\sigma(e^+e^- \to BB) = 1.05$ nb

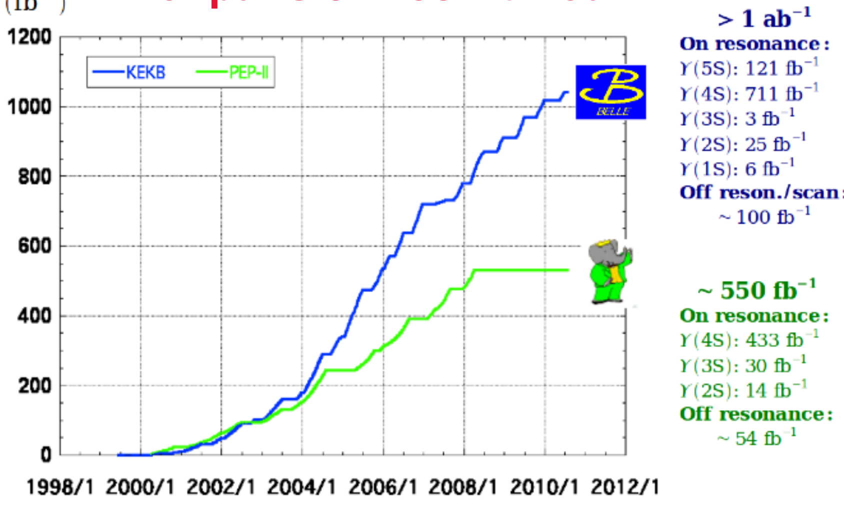
  $\sigma(e^+e^- \to \tau^+\tau^-) = \mathbf{0.92\ nb}$

- **B-Factories are also τ-factories**

- Providing a suitable environment for the study of tau lepton decays.



~ 10^9 pairs of τ combined

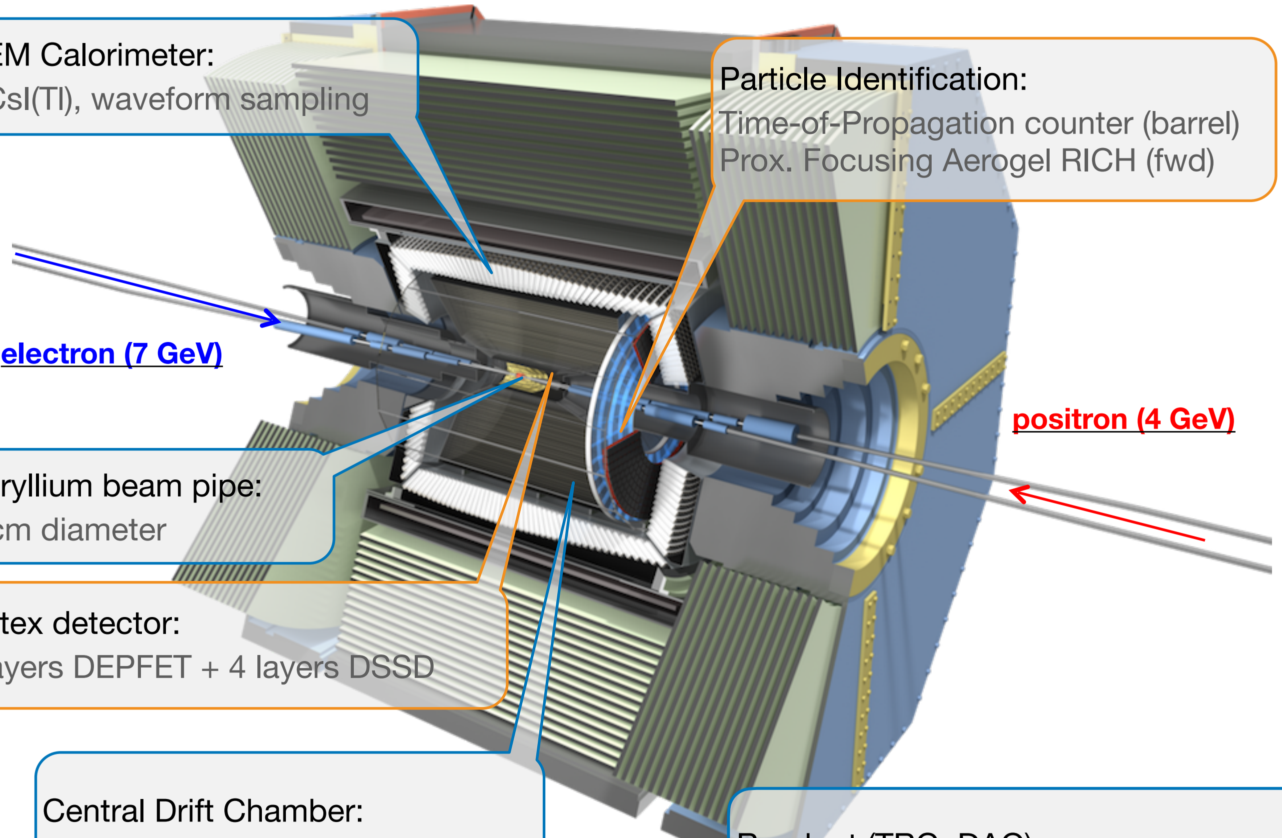


The Belle II Experiment

In a nutshell

EM Calorimeter:
CsI(Tl), waveform sampling

Particle Identification:
Time-of-Propagation counter (barrel)
Prox. Focusing Aerogel RICH (fwd)



electron (7 GeV)

positron (4 GeV)

Beryllium beam pipe:
2 cm diameter

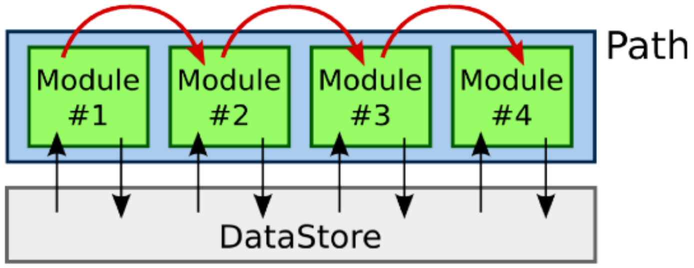
Vertex detector:
2 layers DEPFET + 4 layers DSSD

Central Drift Chamber:
He(50%):C_2H_6(50%), Small cells,
long lever arm, fast electronics

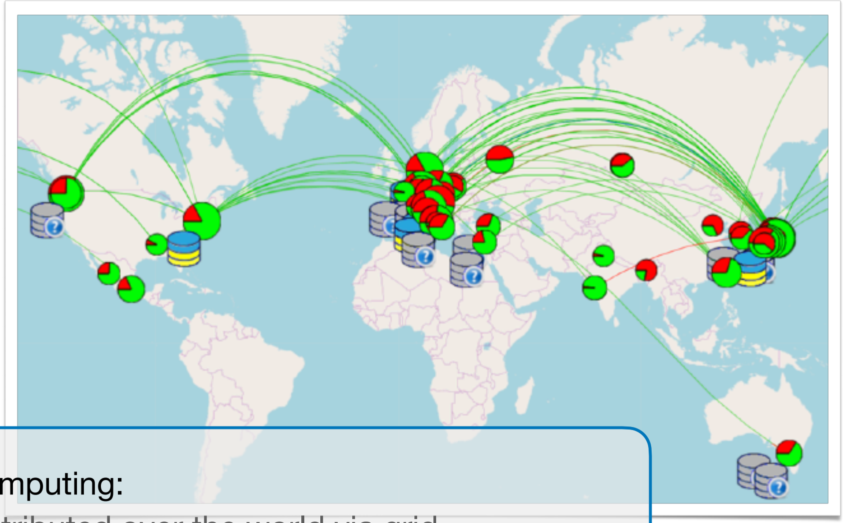
Readout (TRG, DAQ):
Max. 30kHz L1 trigger
~100% efficient for hadronic events.
1MB (PXD) + 100kB (others) per event
- over 30GB/sec to record

arXiv:1011.0352 [physics.ins-det]

Software:
Open-source sophisticated algorithms for simulation, reconstruction, visualization, and analysis.



Comput. Softw. Big Sci. 3 1 (2019)



Computing:
Distributed over the world via grid.

EPJ Web Conf., 245 (2020) 11007

How do we reconstruct τ's at Belle II

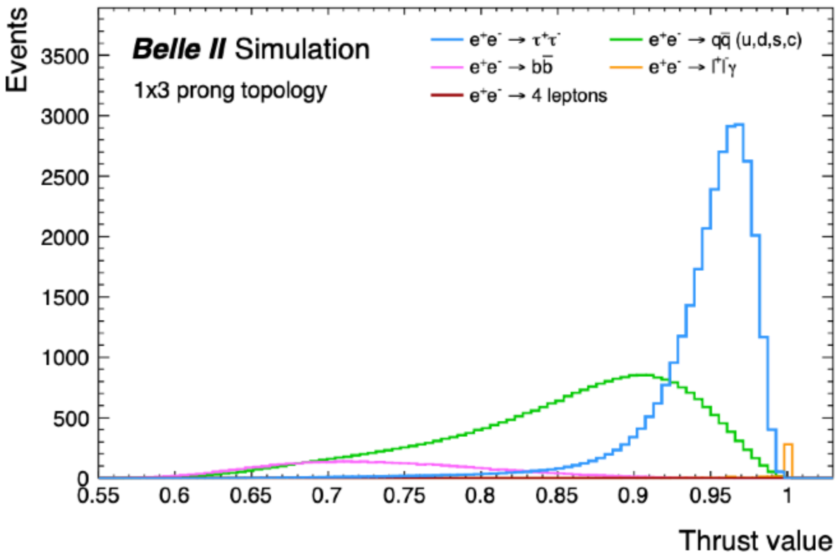
Tag and signal

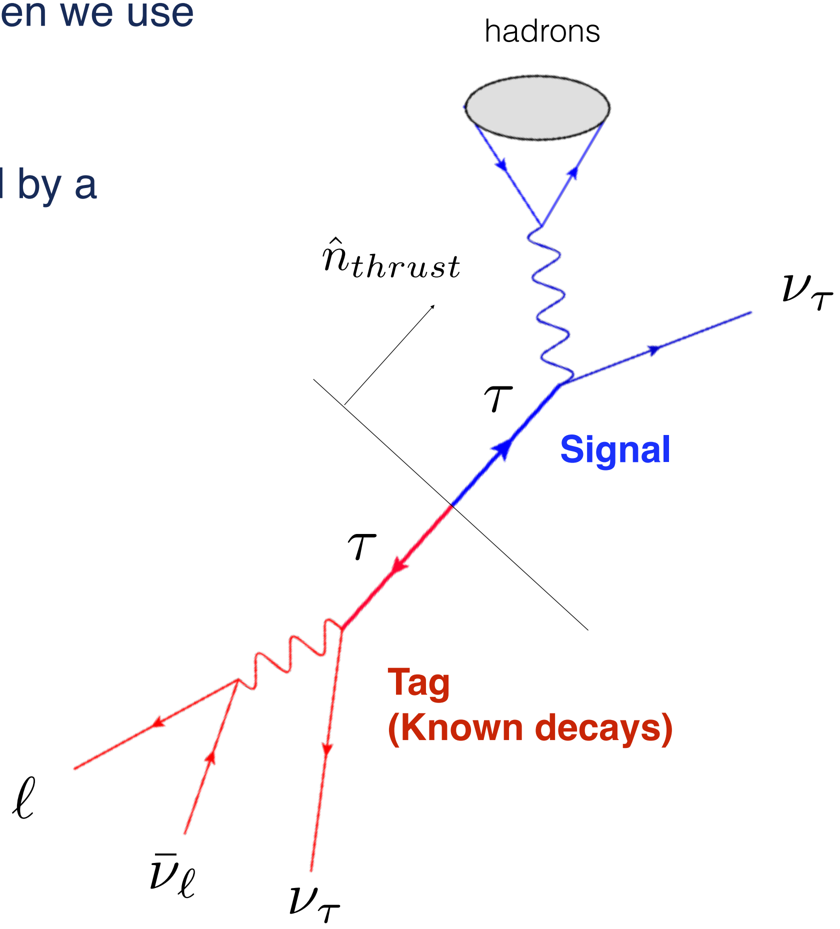
- A τ event is never reconstructed completely (we lose neutrinos), then we use features of the event to identify τ-pair candidates.

- Event is divided in two sides (signal and tag) using a plane defined by a **thrust axis**, build with all the final state particles:

- $$V_{thrust} = \frac{\sum_i |\vec{p}_i^{\,cm} \cdot \hat{n}_{thrust}|}{\sum_i |\vec{p}_i^{\,cm}|}$$

- Thrust axis: $\hat{n}_{thrust}$ such that V_{thrust} is maximum.

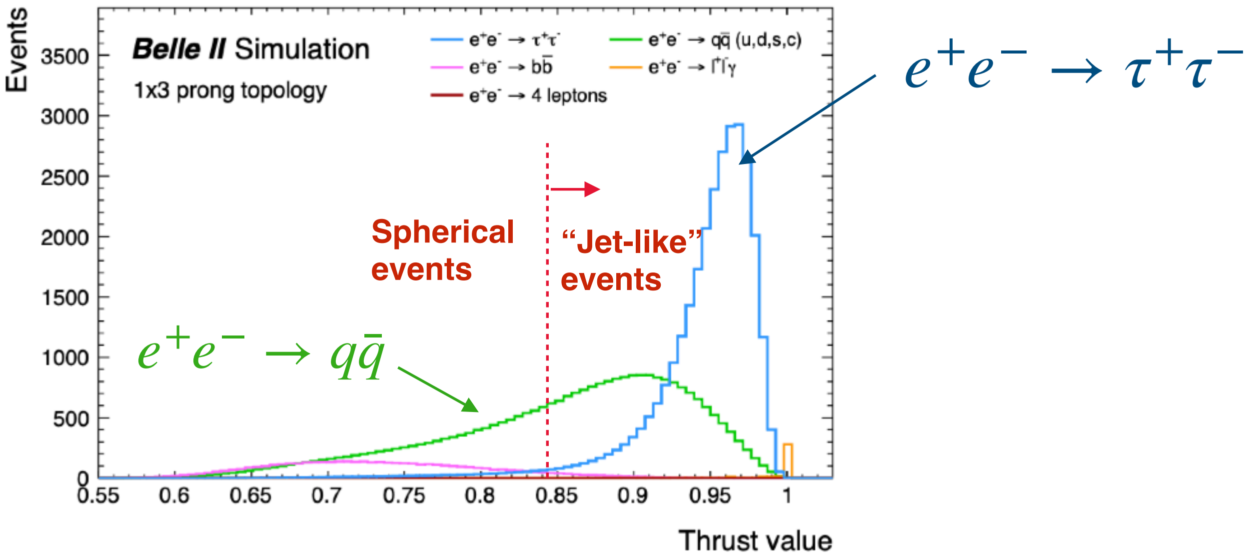


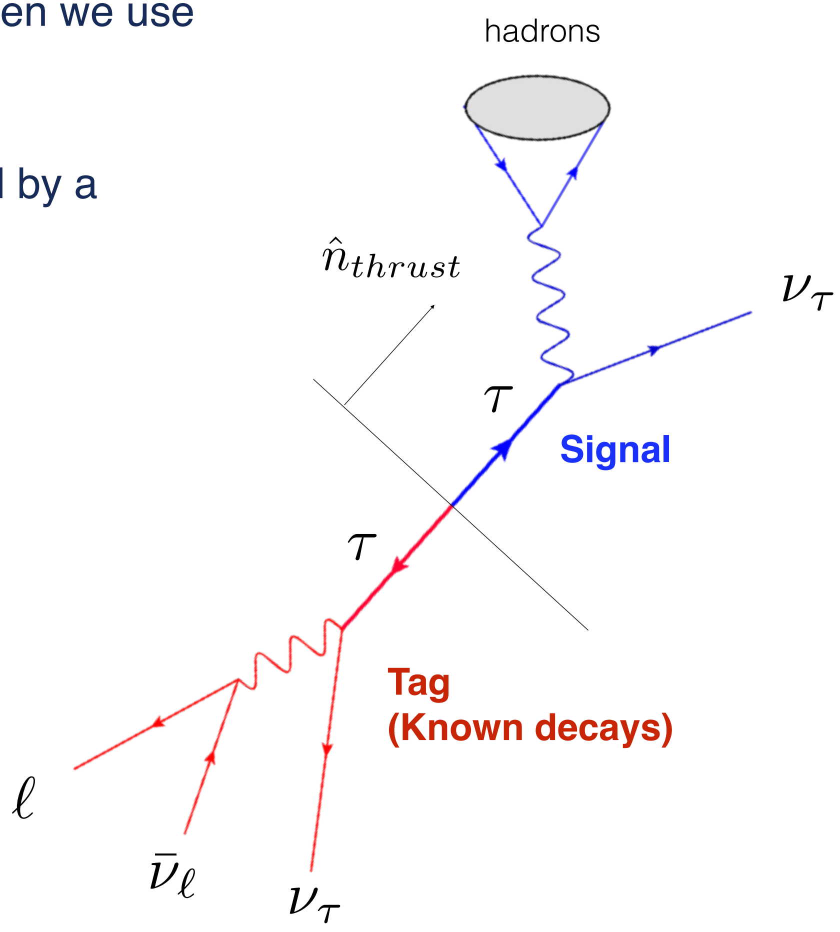


How do we reconstruct τ's at Belle II

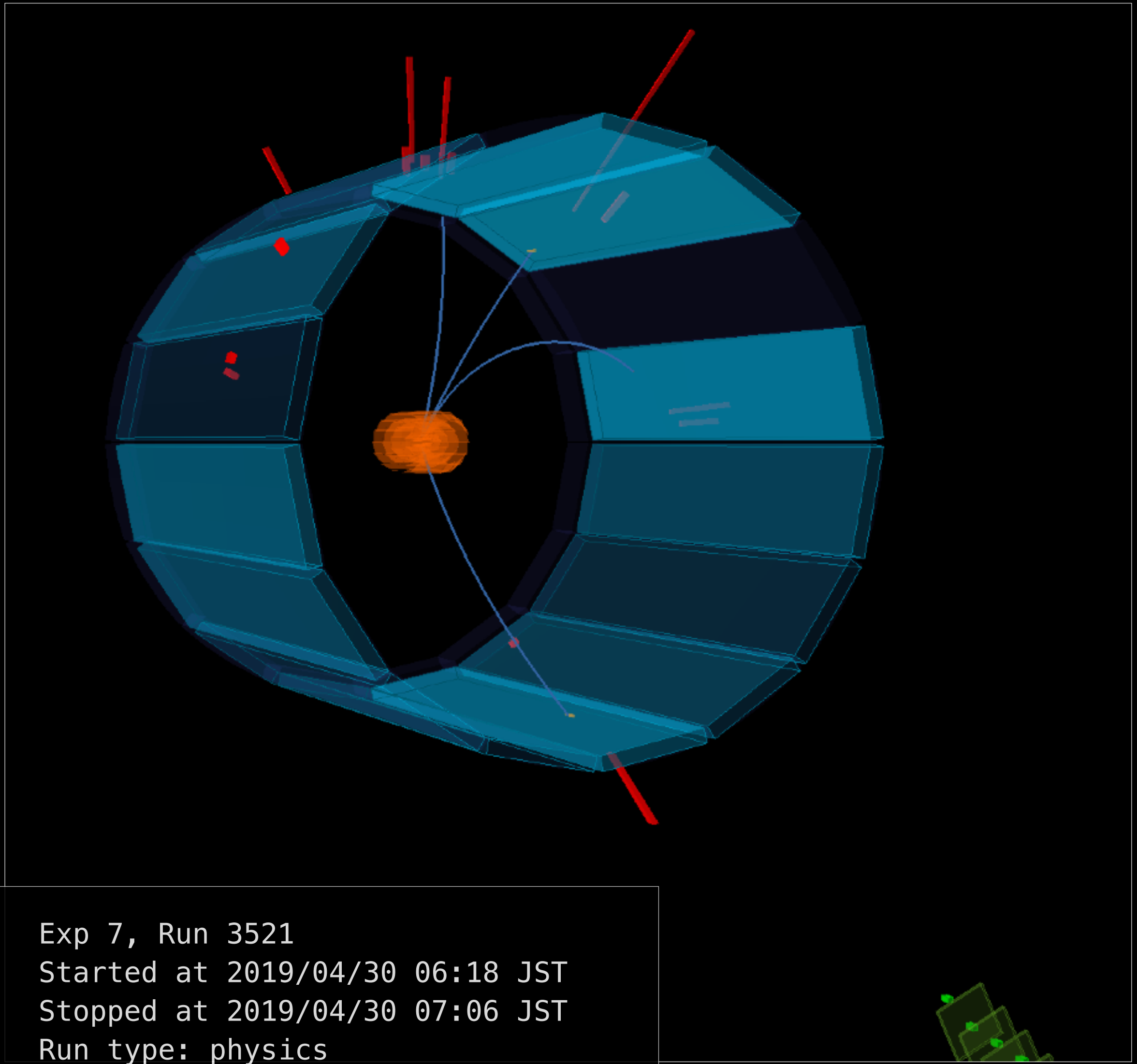
Tag and signal

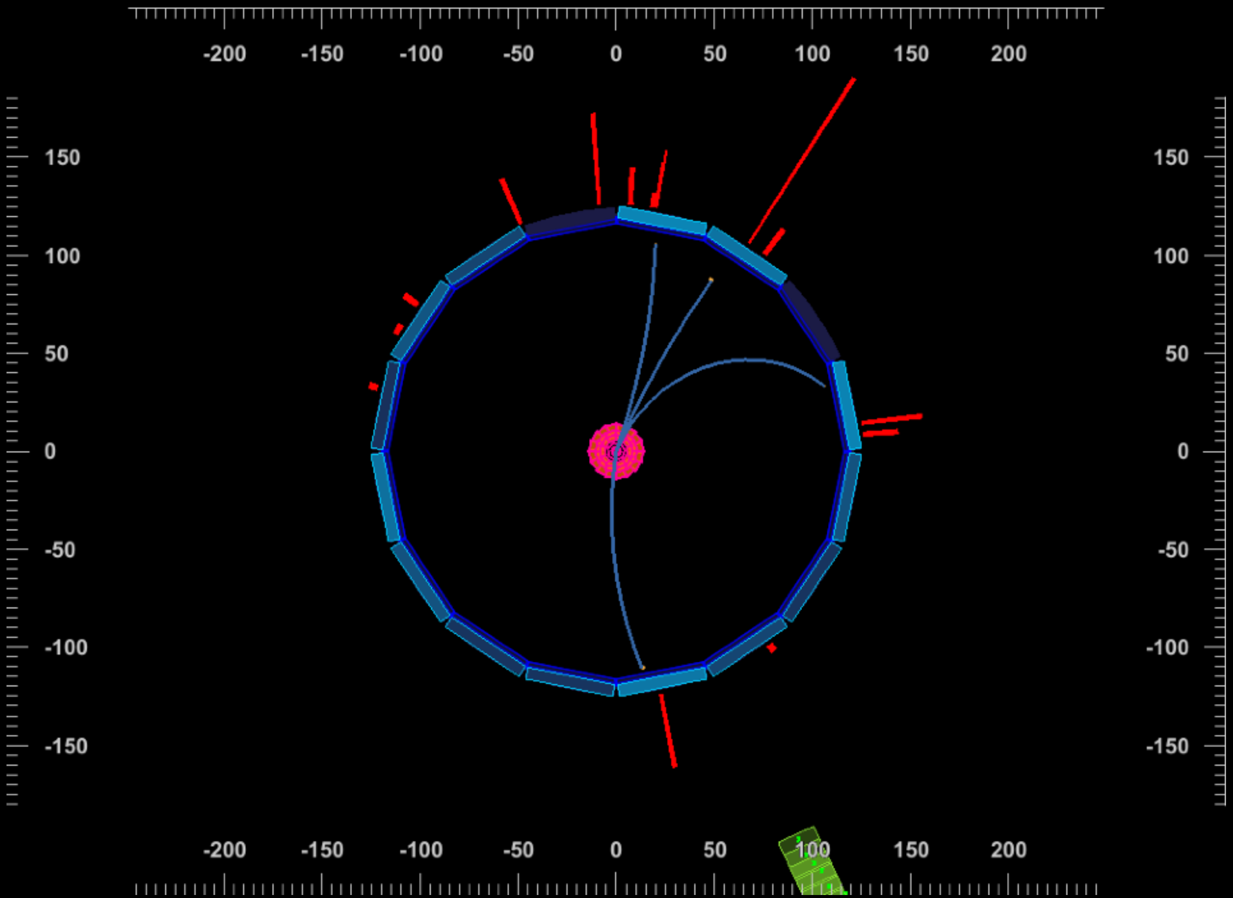
- A τ event is never reconstructed completely (we lose neutrinos), then we use features of the event to identify τ-pair candidates.
- Event is divided in two sides (signal and tag) using a plane defined by a **thrust axis**, build with all the final state particles:
- $$V_{thrust} = \frac{\sum_i |\vec{p_i}^{\,cm} \cdot \hat{n}_{thrust}|}{\sum_i |\vec{p_i}^{\,cm}|}$$
- Thrust axis: $\hat{n}_{thrust}$ such that V_{thrust} is maximum.





Tau decay event in early Belle II data

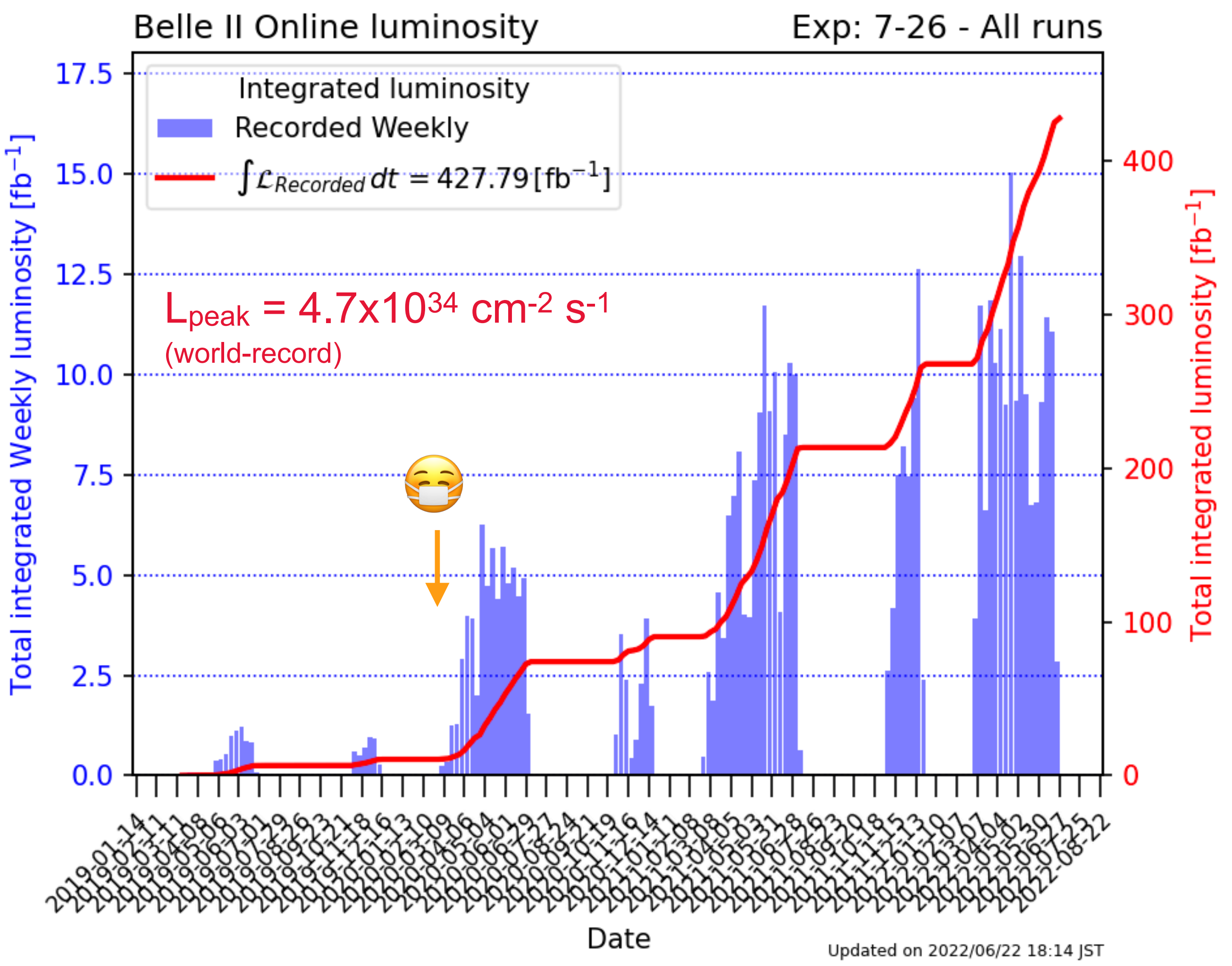




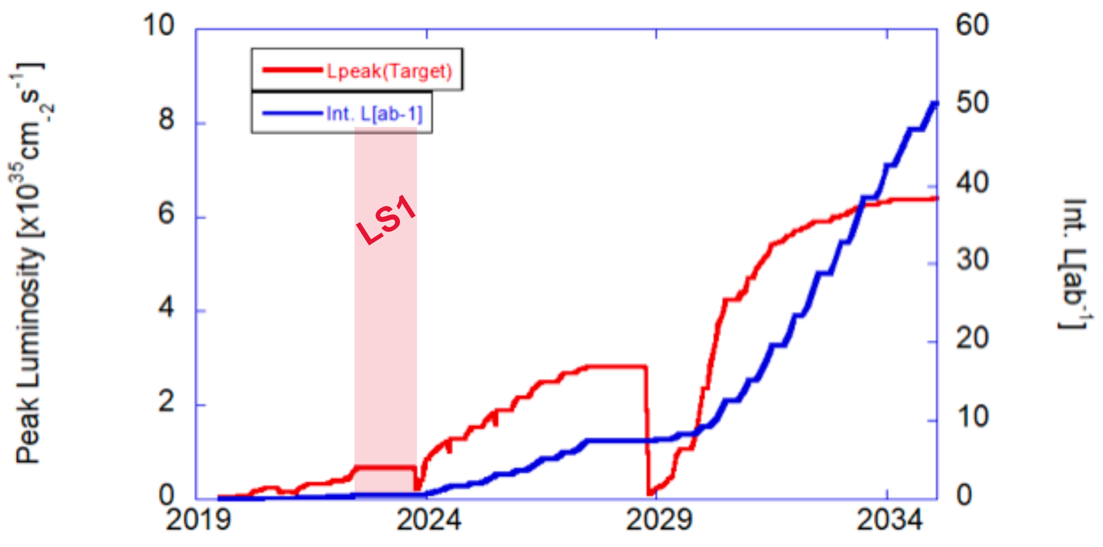
Exp 7, Run 3521
Started at 2019/04/30 06:18 JST
Stopped at 2019/04/30 07:06 JST
Run type: physics

Integrated Luminosity

Today and future



- **Super B-factory performance levels.**
  - **A unique environment for the study of τ physics** with high precision.
  - Ultimate goal: reach **50 ab^{-1}** by operating at the instantaneous luminosity of $6 \times 10^{35}\ cm^{-2}\ s^{-1}$
- Challenges at $L = 6 \times 10^{35}\ cm^{-2}\ s^{-1}$:
  - Higher beam-induced background
  - Higher trigger rates



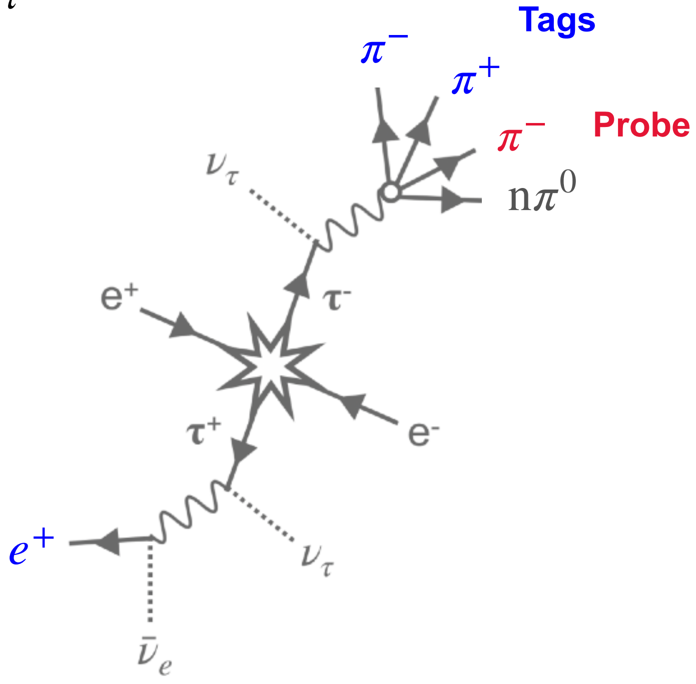
Performance

Towards precision measurements in tau lepton physics

- Tau pairs are not only tools for the comprehension of fundamental physics, but also for the understanding of our detector.

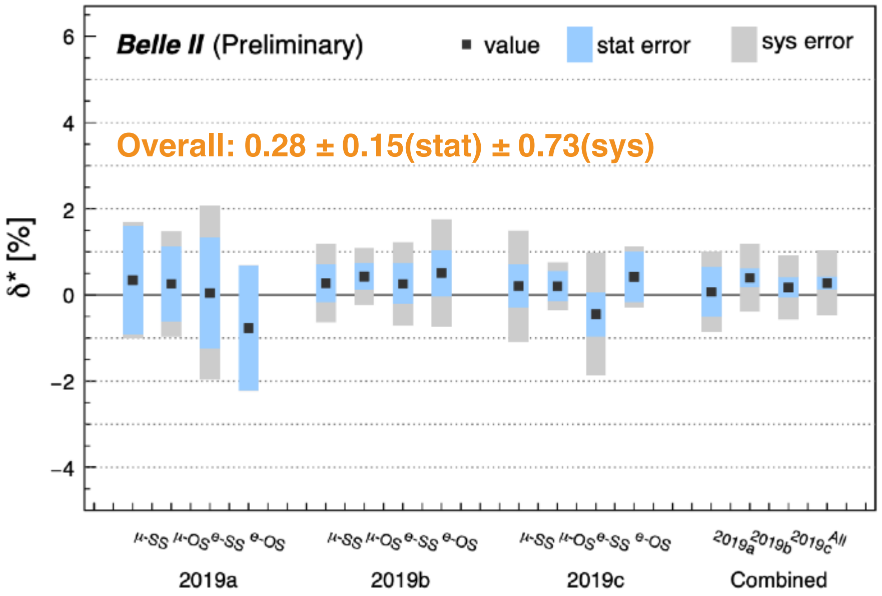
Tracking efficiency

- Tracking efficiency and fake rates have been measured using $\tau\tau$ events, with one of the leptons decaying to $\tau^- \to 3\pi^\pm \nu_\tau + n\pi^0$.



Calibrated discrepancy between data/MC:

$$\delta^* = 1 - \epsilon_{\text{data}}/\epsilon_{\text{MC}}$$



BELLE2-NOTE-PL-2020-014

Performance

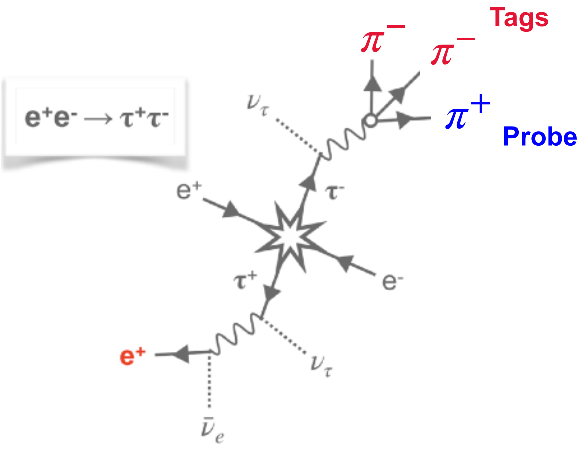
Towards precision measurements in tau lepton physics

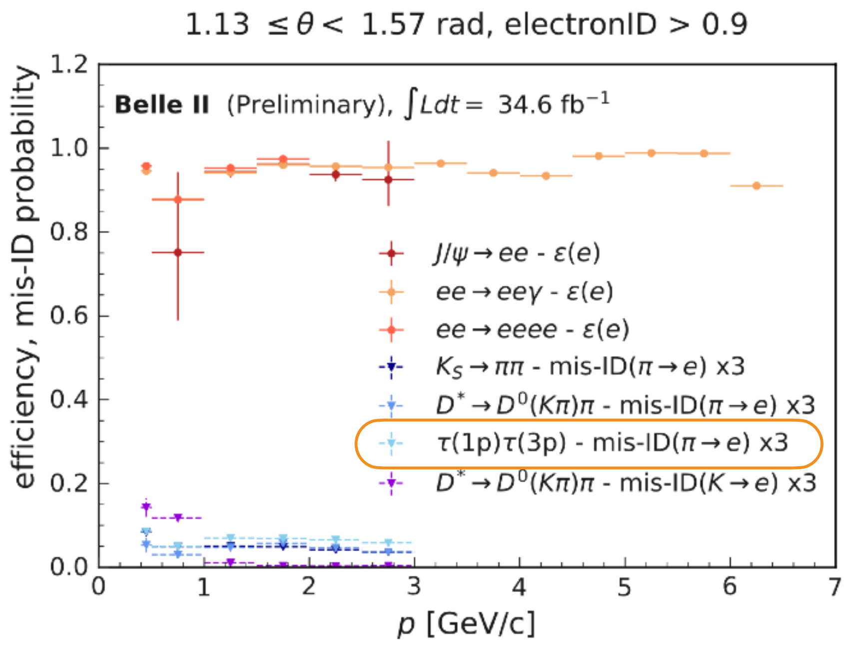
Lepton ID performance

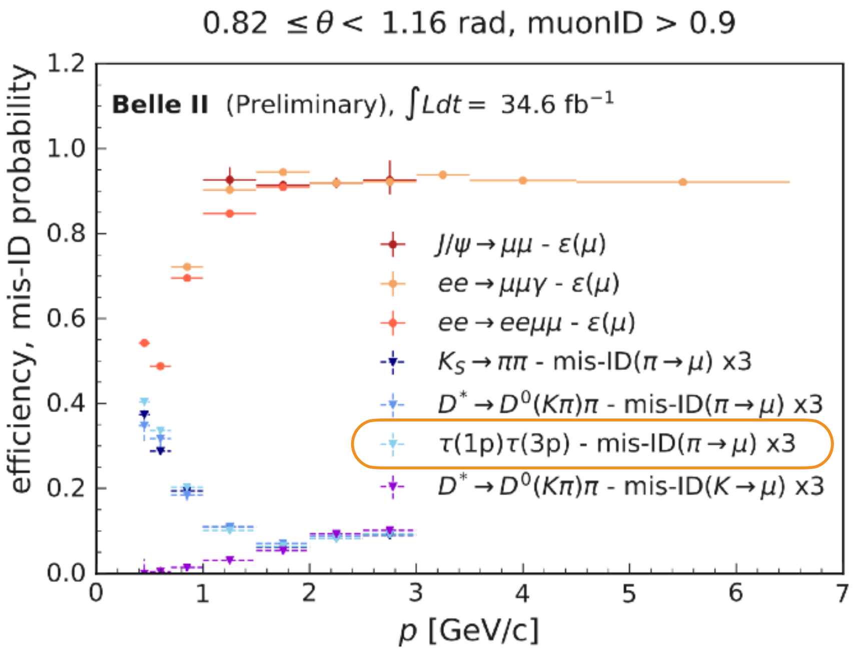
- Particle identification is based on the global likelihood ratio from all sub detectors.

$$\ell\ \mathrm{ID} = \frac{\mathcal{L}_\ell}{\mathcal{L}_e + \mathcal{L}_\mu + \mathcal{L}_\pi + \mathcal{L}_K + \mathcal{L}_p}$$

- With the same tag-and-probe approach, lepton misidentification rates are calculated with pions from the 3-prong decay $\tau^- \to 3\pi^\pm + \nu_\tau$







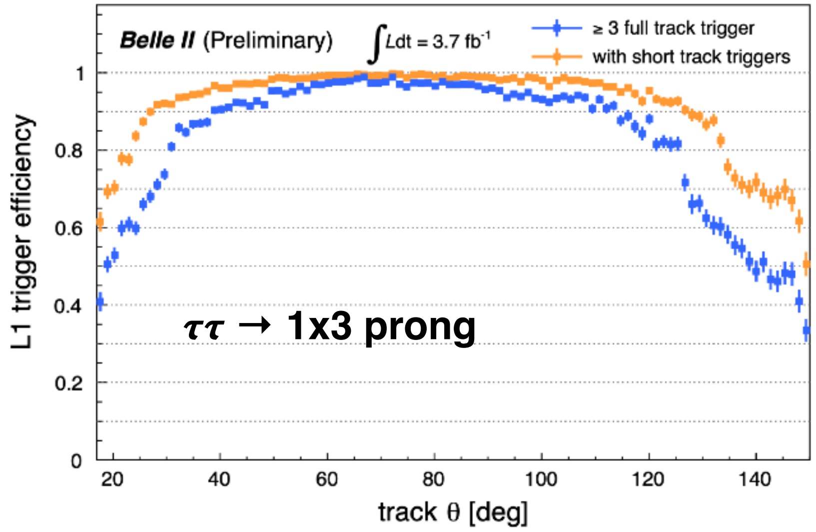
BELLE2-NOTE-PL-2020-027

Performance

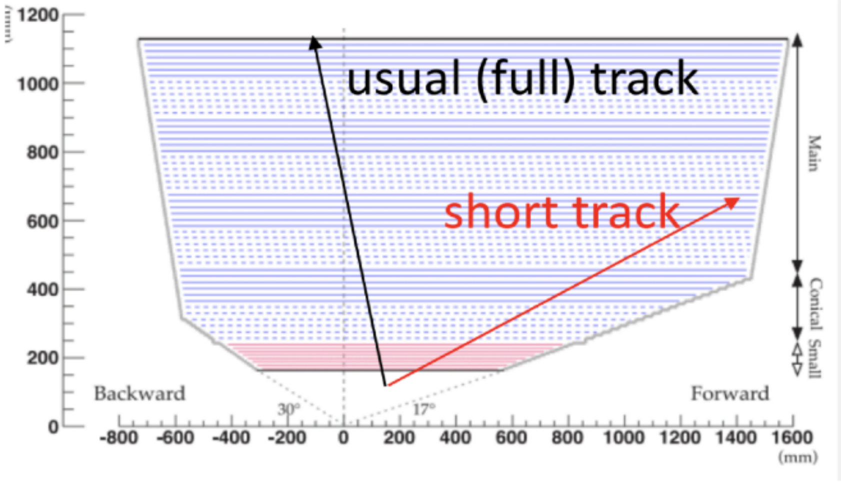
Towards precision measurements in tau lepton physics

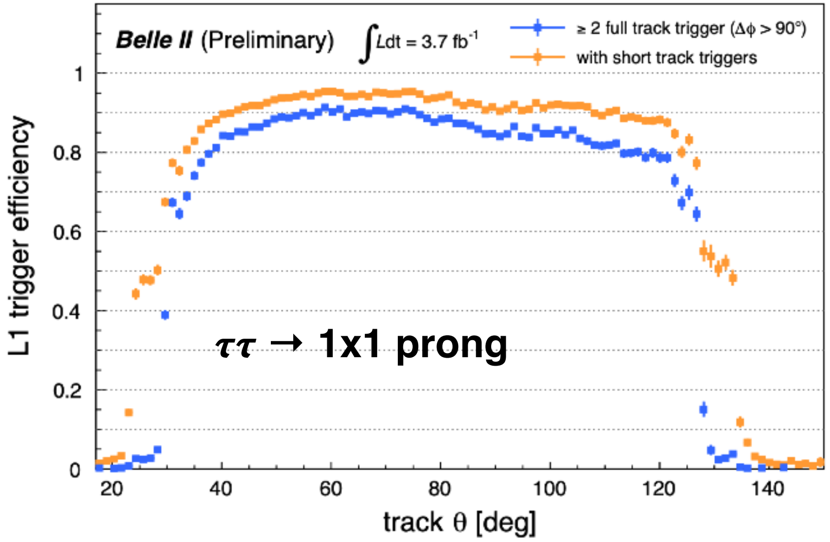
Trigger efficiencies

- The Level 1 trigger efficiency has been studied using $e^+e^- \to \tau^+\tau^-$ events with 1x1 and 3x1 topologies.
- Full track triggers present low efficiency in endcaps.
- To compensate, the CDC trigger also searches for **short tracks,** providing a significant gain in efficiency for endcaps/low p_T.



- Additional advantage wrt Belle and BaBar: several low multiplicity triggers based on number of calorimetric clusters.



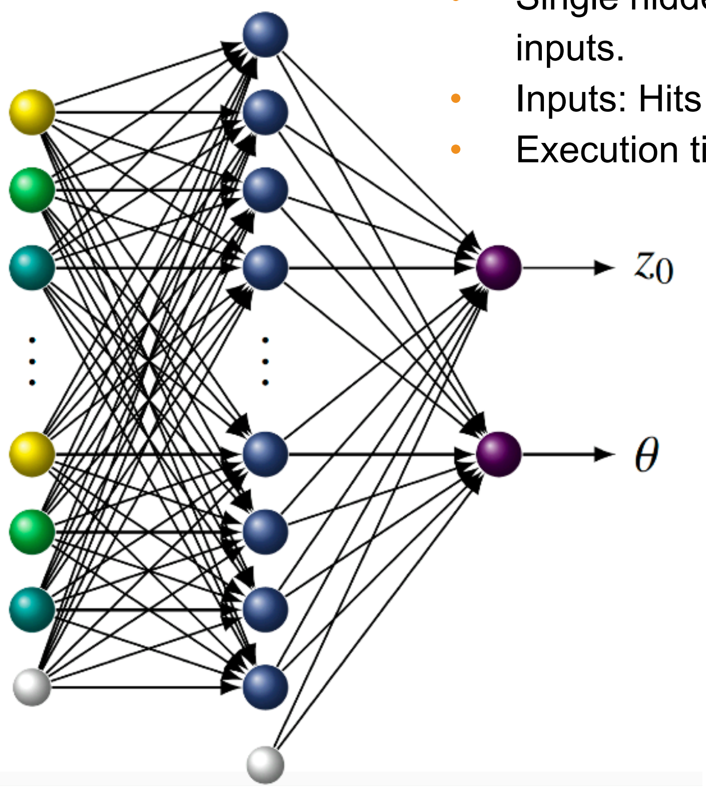


BELLE2-NOTE-PL-2020-015

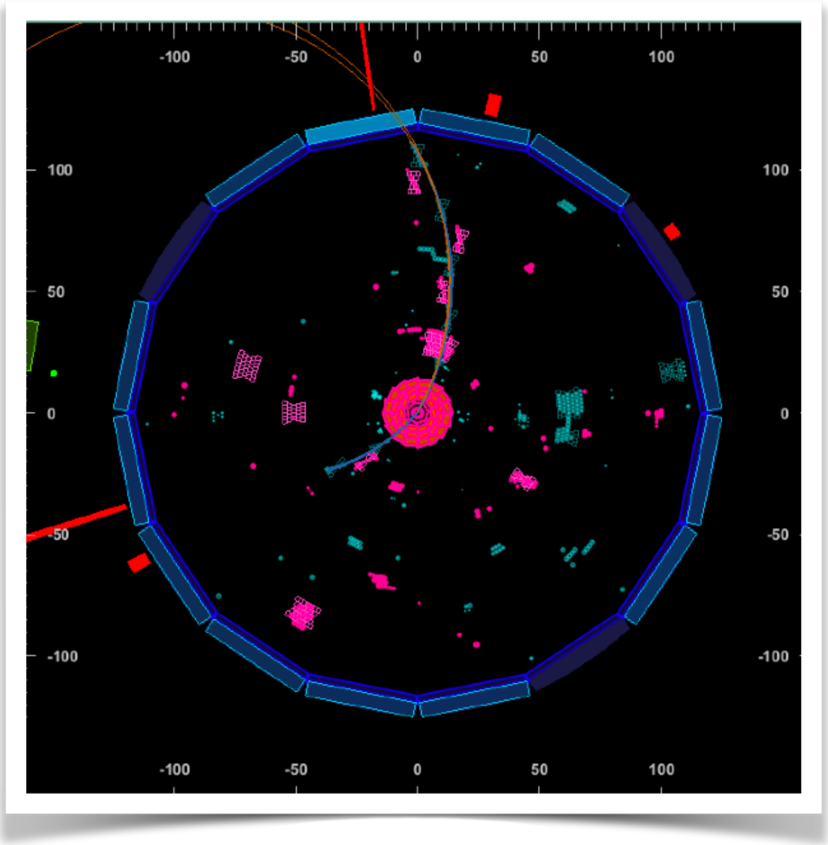
Single Track Trigger

Neural-net based hardware track trigger

- A neural-net based hardware trigger is now operational, showing great performance.
- It fires if it finds a track within 15 cm from the collision vertex and a momentum larger than 700 MeV.



- Single hidden layer with 81 neurons and 27 inputs.
- Inputs: Hits on wires of the CDC.
- Execution time: 300 ns

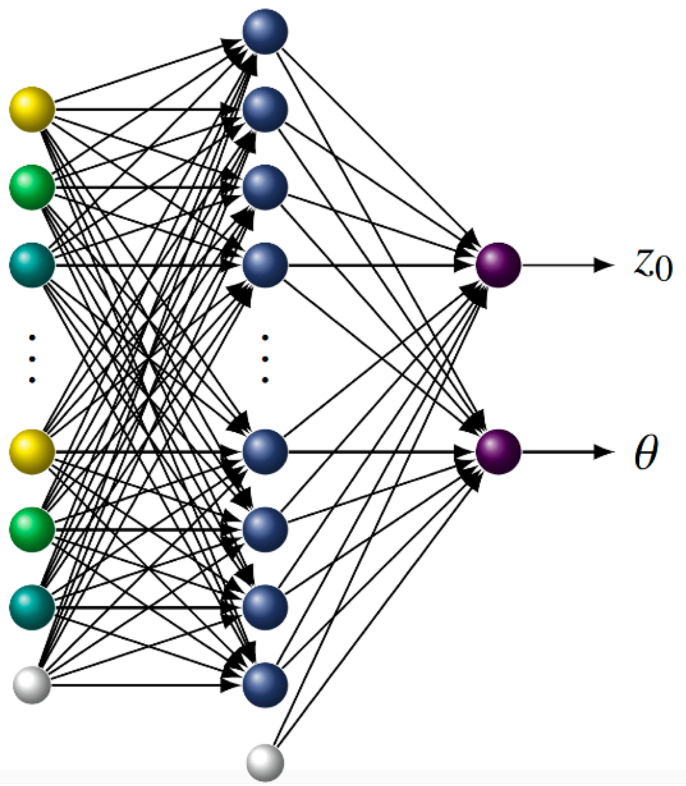


Single Track Trigger

Neural-net based hardware track trigger

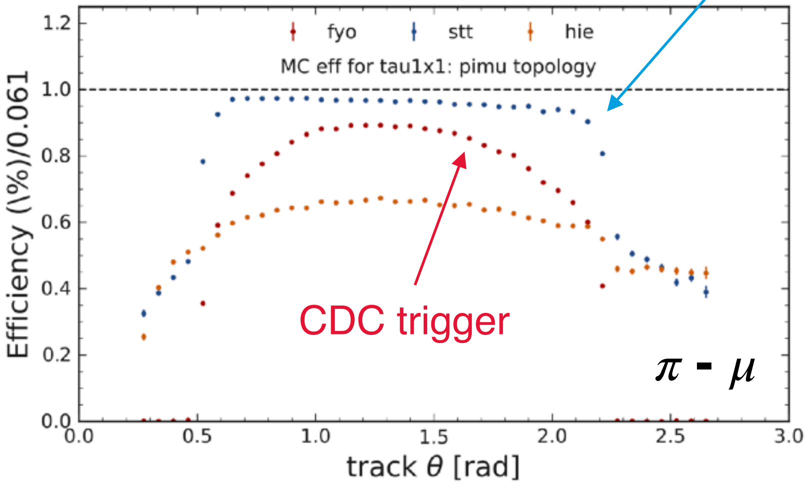
- A neural-net based hardware trigger is now operational, showing great performance.
- It fires if it finds a track within 15 cm from the collision vertex and a momentum larger than 700 MeV.

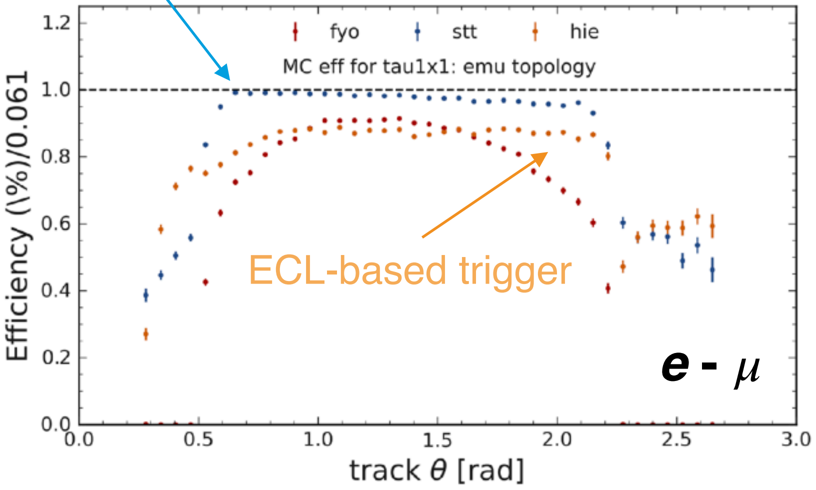
- **1x1 prong events**
  - up to ~20% gains in barrel region.



Single track trigger

$\tau\tau \to$ 1x1 prong





Measurement of tau properties

Mass, lifetime, leptonic decays

- Current flavor anomalies motivate to explore LFU violation in tau decays.
- Inputs:
  - Tau mass (width of the diagonal band).
  - Tau lifetime τ_τ
  - Leptonic BR
- Belle II has the potential of provide precise measurements of these parameters.

Input	Uncertainty	Best Result
BR($\tau \to e\nu\nu$)	0.179 %	ALEPH
τ_τ	0.172 %	Belle
mτ	0.007 %	BESIII

$$B_{\tau\ell} \propto B_{\mu e} \frac{\tau_\tau}{\tau_\mu} \frac{m_\tau^5}{m_\mu^5}$$

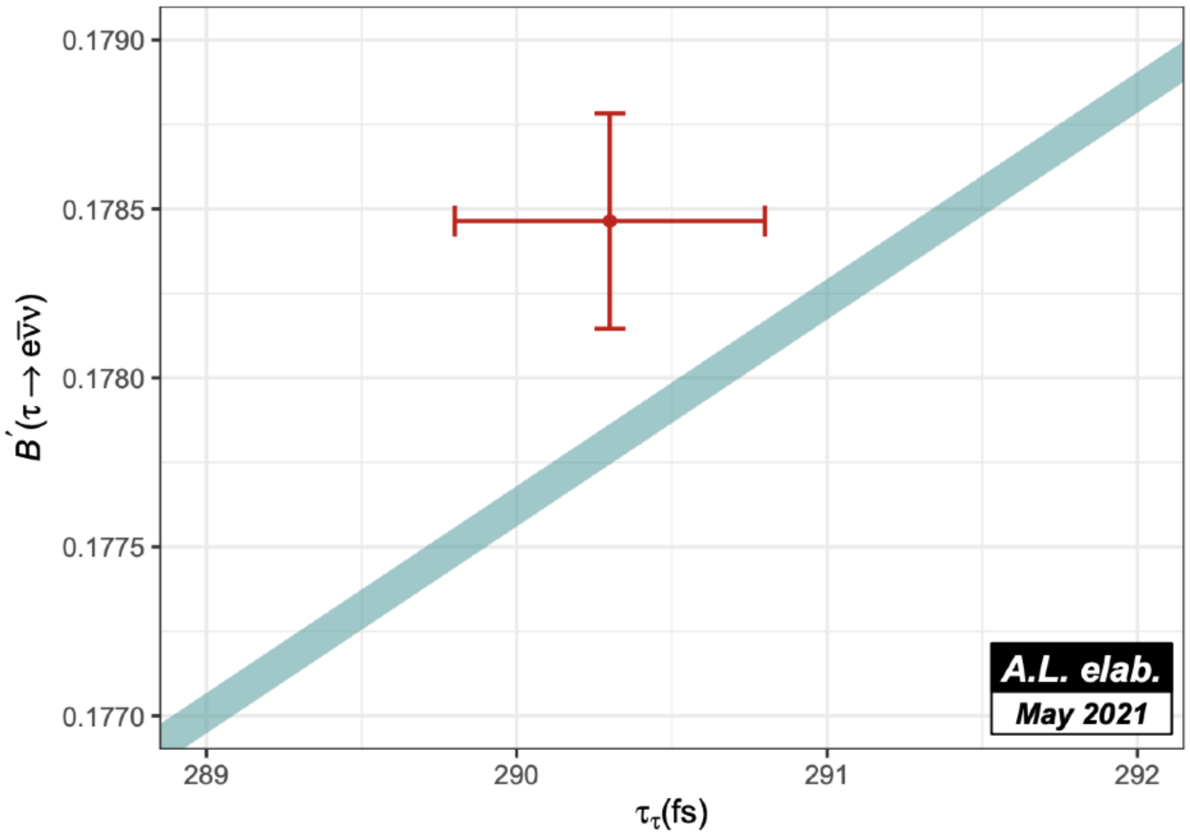


Fig: A. Luisiani, Anomalies and Precision in the Belle II Era - Workshop

Tau Lepton Mass Measurement

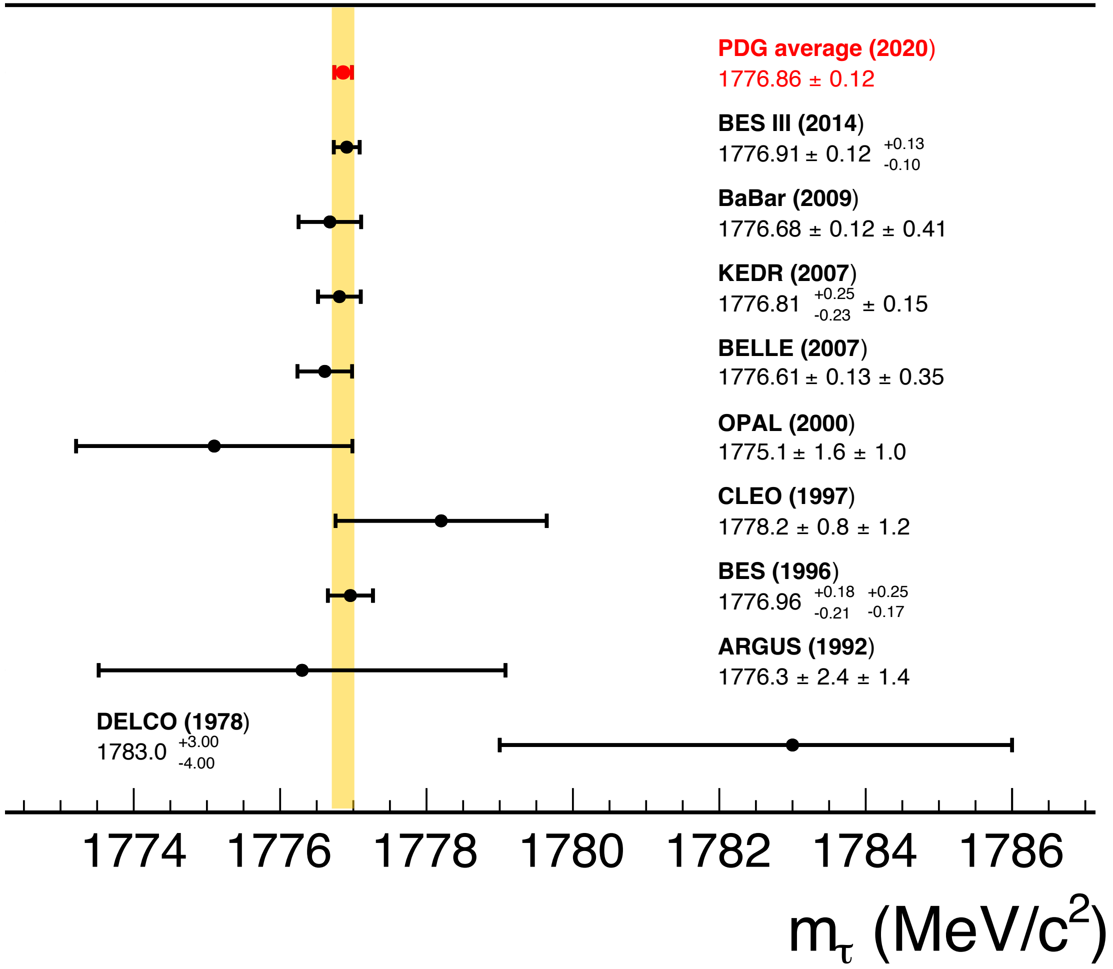
Historical overview

- The lepton masses are fundamental parameters of the SM:

$$m_e = (0.5109989461 \pm 0.0000000031) \text{ MeV},$$
$$m_\mu = (105.6583745 \pm 0.0000024) \text{ MeV},$$
$$m_\tau = (1776.86 \pm 0.12) \text{ MeV}.$$

- Precision of m_τ have consequences in LFU tests:
  - $$\frac{\Gamma(\mu \to e\nu\bar{\nu})}{\Gamma(\tau \to e\nu\bar{\nu})} \sim \left(\frac{g_\mu}{g_\tau}\right)^2 \frac{m_\mu^5}{m_\tau^5}$$

- Two methods for measuring m_τ:
  - Measurement in the production threshold (DELCO, BES, KEDR, BES III).
  - Pseudomass distribution (ARGUS, OPAL, BaBar, Belle, **Belle II**).



Tau Lepton Mass Measurement

Pseudomass distribution

- Measured in the decay mode $\tau \to 3\pi\nu$, using a pseudomass technique developed by the **ARGUS** collaboration.

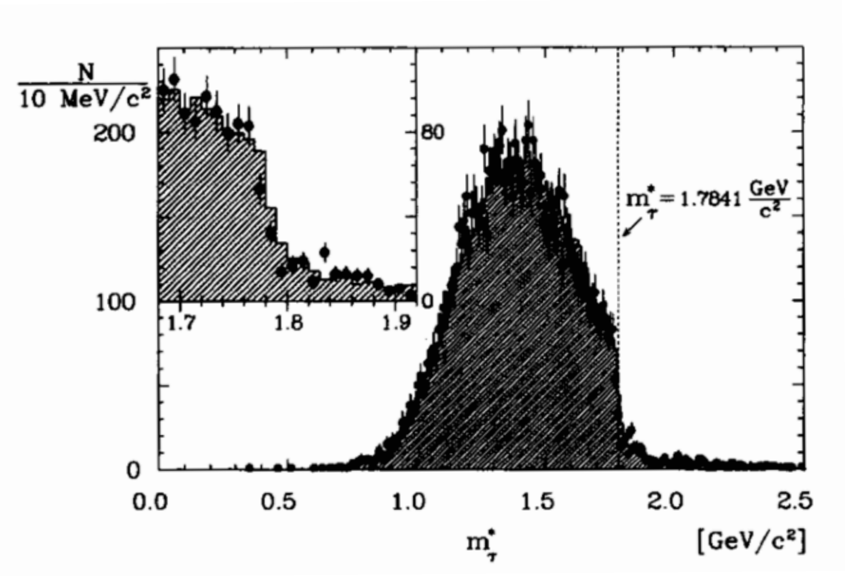
- The tau mass can be calculated as

$$m_\tau^2 = (p_h + p_\nu)^2$$
$$= 2E_h(E_\tau - E_h) + m_h^2 - 2|\vec{p}_h|(E_\tau - E_h)\ \cos(\vec{p}_h, \vec{p}_\nu)$$

- As the direction of the neutrino is not known, the approximation $\cos(\vec{p}_\nu, \vec{p}_h) = 1$ is taken, resulting in

$$M_{\text{min}}^2 = 2E_h(E_\tau - E_h) + m_h^2 - 2|\vec{p}_h|(E_\tau - E_h)\ \ < m_\tau^2$$

- Then, the distribution of the pseudomass is fitted to an empirical edge function, and the position of the cutoff indicates the value of the mass.



Phys. Lett. B 292 (1992) 221-228

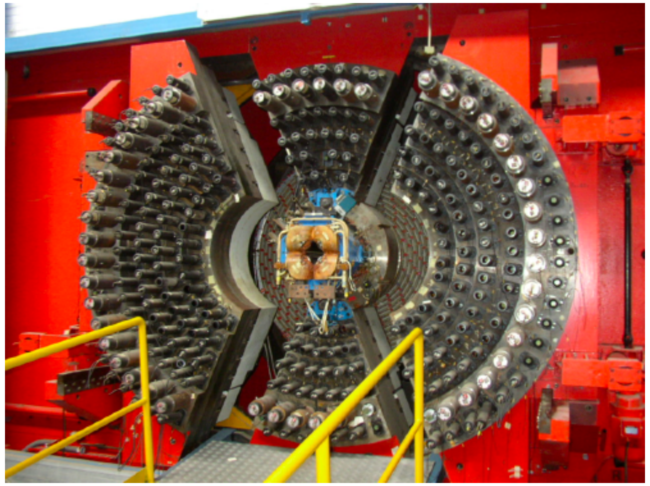


Figure: The ARGUS detector at DESY

Tau Lepton Mass Measurement

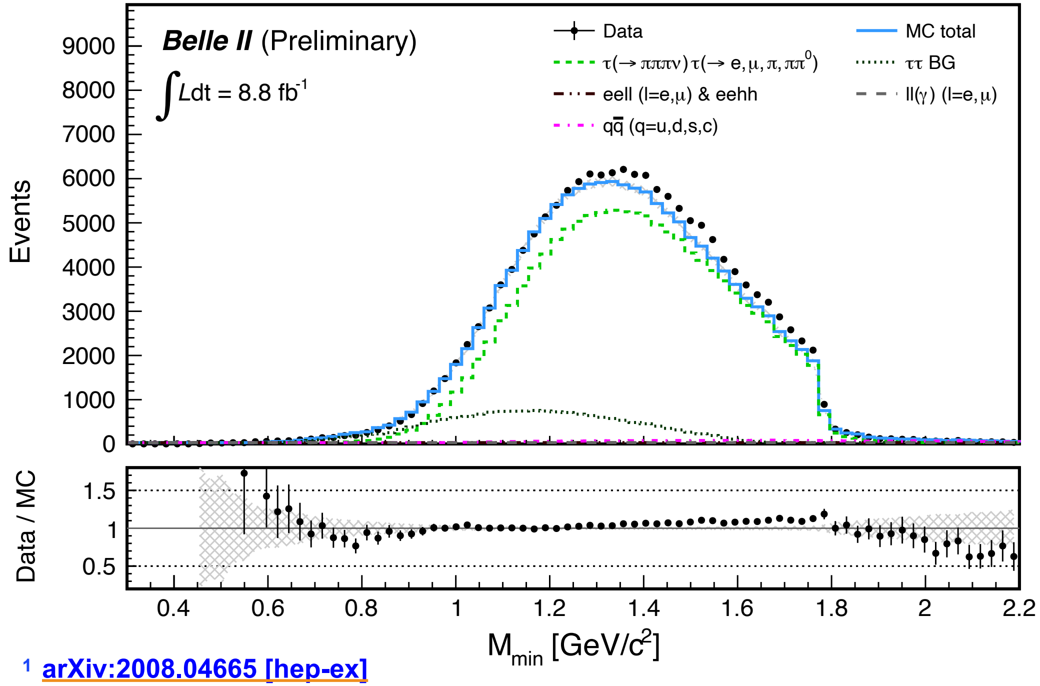
Performance test @ 8.76 fb^{-1}

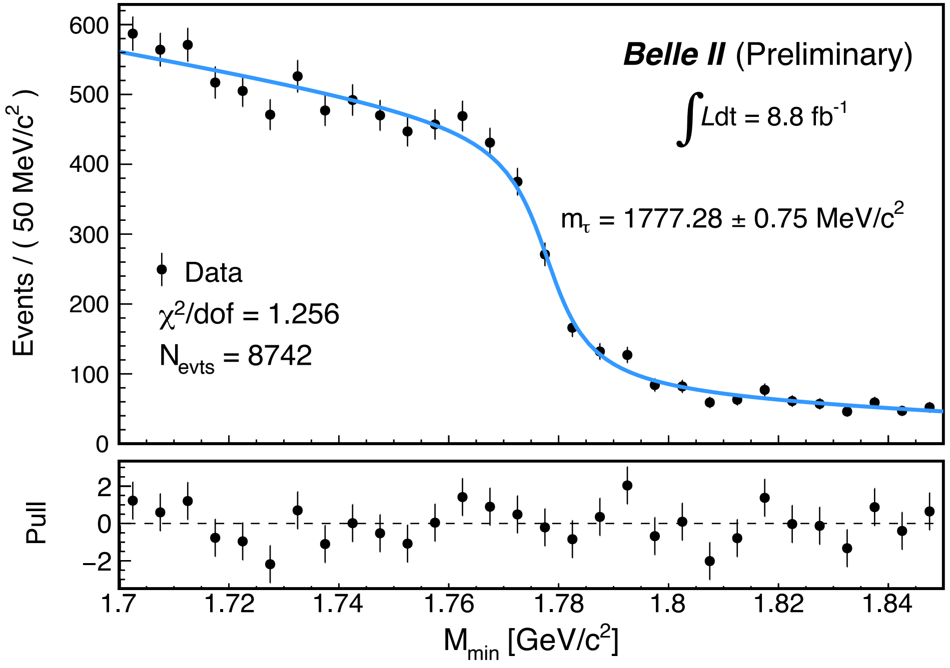
- Our latest result: **1777.28 ± 0.75 ± 0.33 MeV/c^2.**
- Main systematic sources:
  - Momentum shift due to imperfections on the B-Field map: 0.29 MeV/c^2.
  - Bias of the m_τ estimator: 0.12 MeV/c^2.

Fit to edge p.d.f. in the cutoff region

$$F(M_{\min}, \vec{P}) = (P_3 + P_4 M_{\min}) \cdot \tan^{-1}[(M_{\min} - P_1)/P_2] + P_5 M_{\min} + 1$$

Pseudomass distribution, data vs MC





[1] arXiv:2008.04665 [hep-ex]

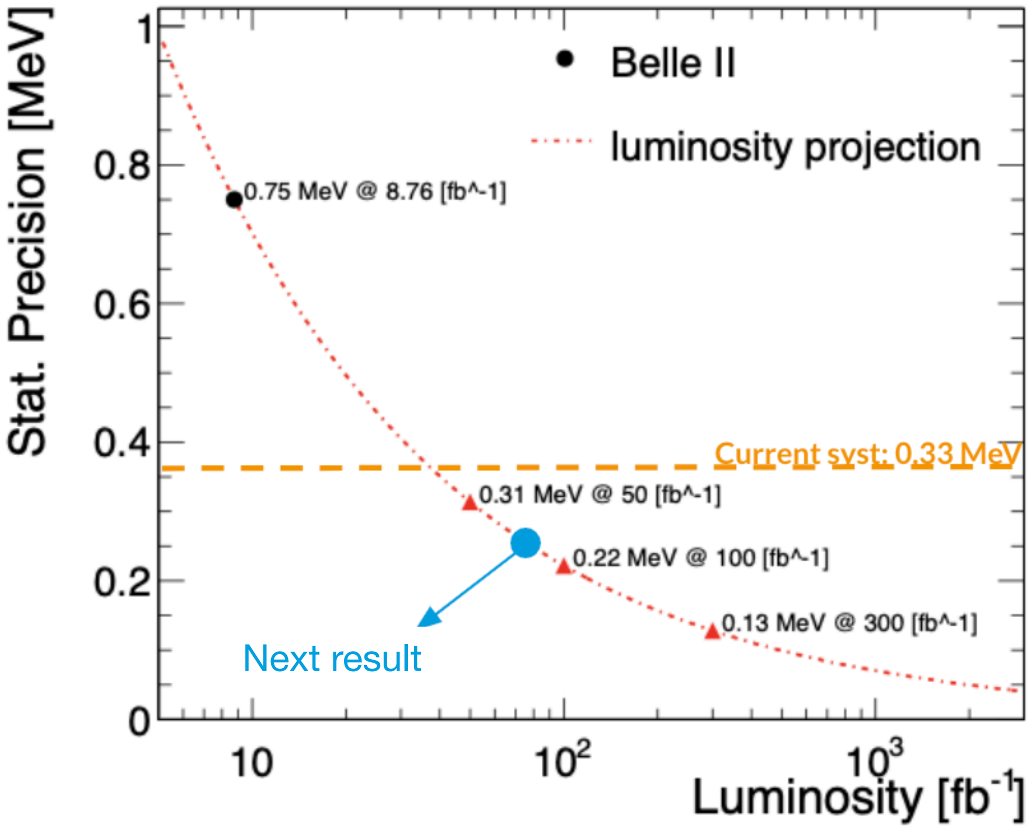
Tau Mass Measurement at Belle II

Projection for early 2023

- Corrections on momentum reconstruction due to mismodeling of the B-field map are on place and are being used for the next m_τ measurement.
- Improved estimator for $m\tau$.
- We expect a significant reduction in the systematics.

Snapshot in the last measurement:

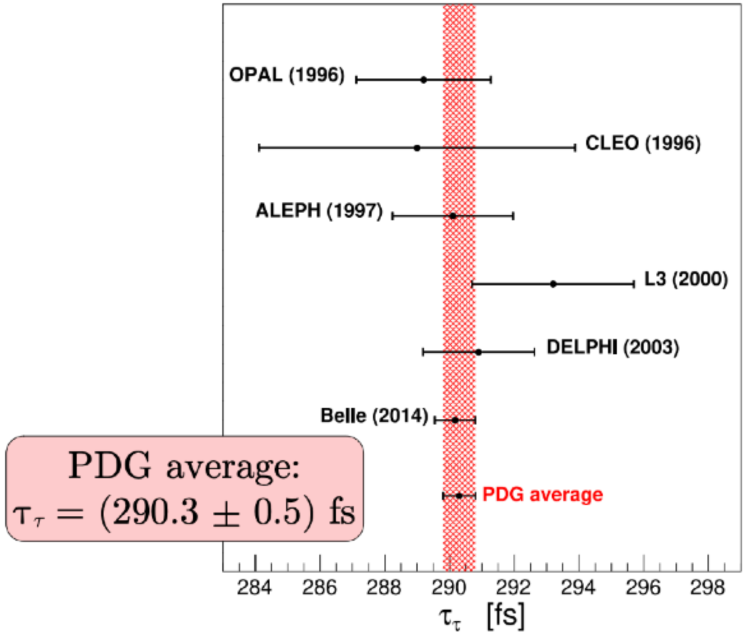
Systematic uncertainty	MeV/c^2
Momentum shift due to the B-field map	0.29
Estimator bias	0.12
Choice of p.d.f.	0.08
Fit window	0.04
Beam energy shifts	0.03
Mass dependence of bias	0.02
Trigger efficiency	≤ 0.01
Initial parameters	≤ 0.01
Background processes	≤ 0.01
Tracking efficiency	≤ 0.01



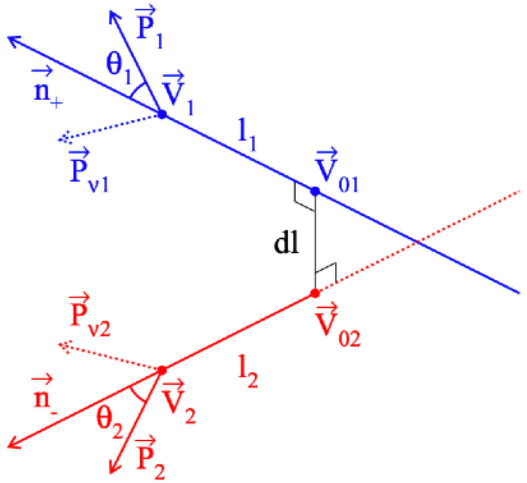
Tau Lifetime Measurement

Exploiting the nano-beam scheme

- Important SM parameter. Its precision has implications in LFU, α_s (m_τ), etc.
- Previous measurements:
  - Z-peak: LEP (DELPHI, L3, ALEPH, OPAL).
  - ϒ-peak: CLEO, BaBar, **Belle** [1].



- The world-leading measurement by Belle[1] uses a **3x3 topology**, with both tau leptons decaying to $3\pi\nu_\tau$.
  - **τ_τ = 290.17 ± 0.53(stat) ± 0.33(syst) fs**

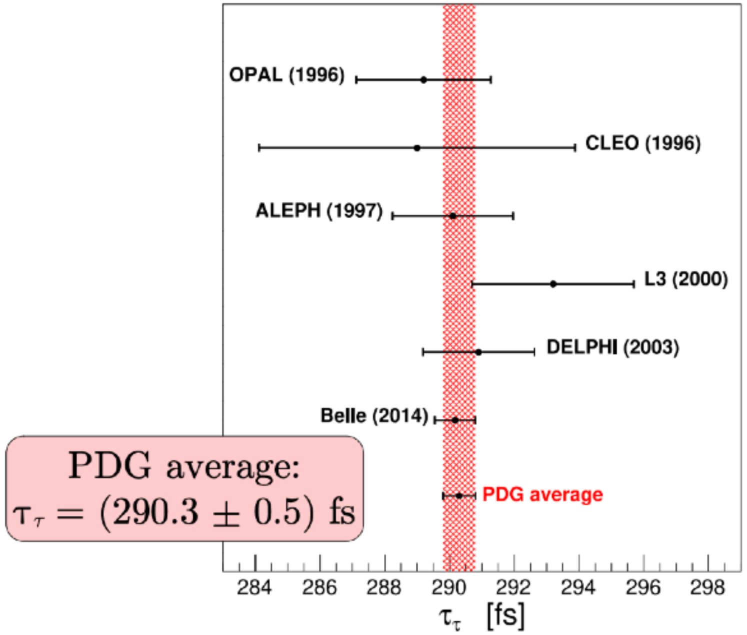


[1] PRL 112, 031801 (2014), arXiv:1310.8503 [hep-ex]

Tau Lifetime Measurement

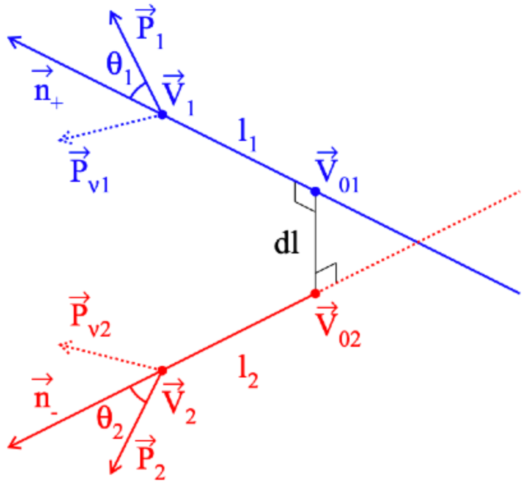
Exploiting the nano-beam scheme

- Important SM parameter. Its precision has implications in LFU, $\alpha_s(m_\tau)$, etc.
- Previous measurements:
  - Z-peak: LEP (DELPHI, L3, ALEPH, OPAL).
  - ϒ-peak: CLEO, BaBar, **Belle** [1].

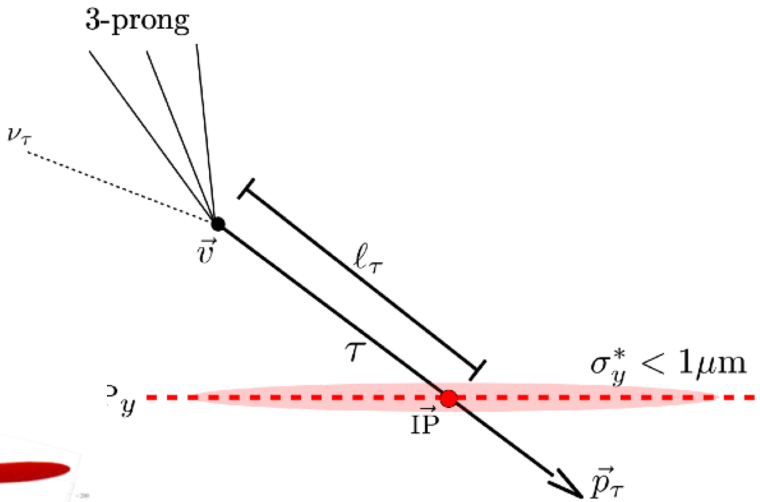


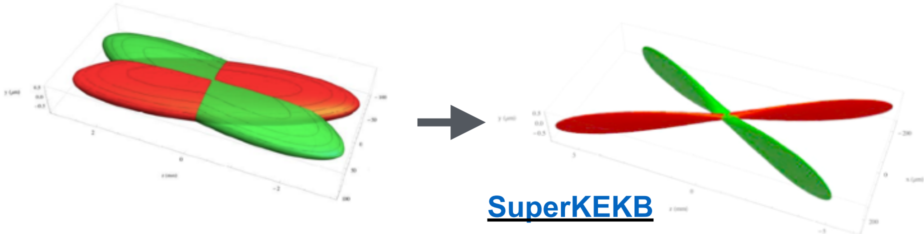
[1] PRL 112, 031801 (2014), arXiv:1310.8503 [hep-ex]

- The world-leading measurement by Belle[1] uses a **3x3 topology**, with both tau leptons decaying to $3\pi\nu_\tau$.
  - $\boldsymbol{\tau_\tau}$ **= 290.17 ± 0.53(stat) ± 0.33(syst) fs**



- **Strategy at Belle II:**
  1. Reconstruct vertex for 3-prong τ. Only one 3-prong = higher statistics.
  2. Estimate the τ momentum $\vec{p}_\tau$. Hadronic decays in both sides.
  3. Find the production vertex. Intersection of $\vec{p}_\tau$ with the plane IP_y.



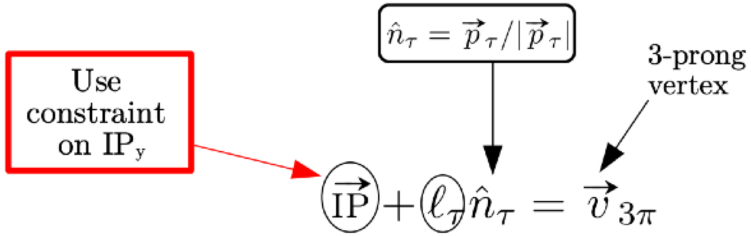


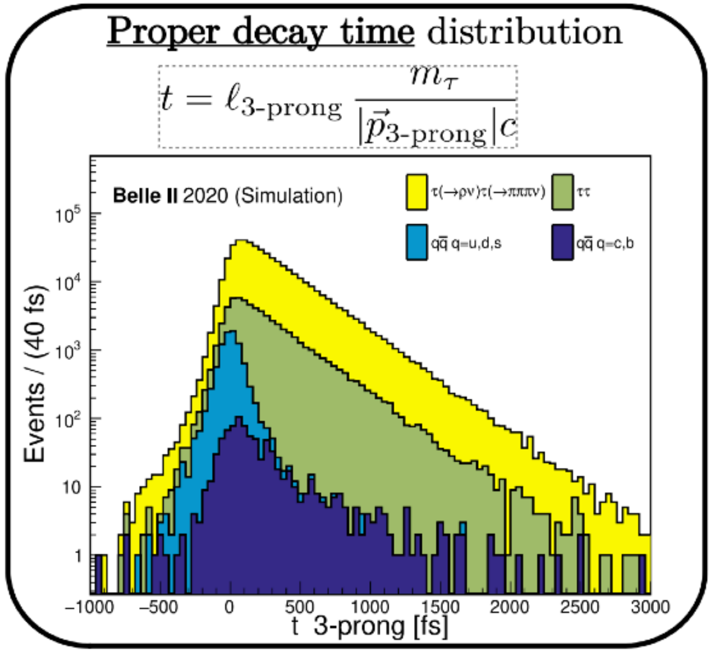
SuperKEKB

Tau Lifetime Measurement

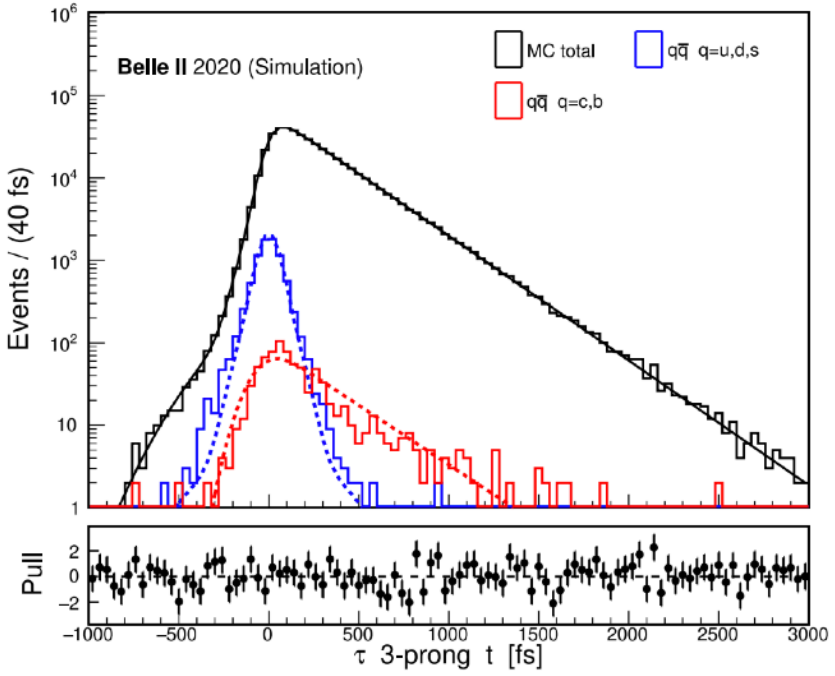
Sensitivity at 200 fb^{-1}

- ℓ_τ reconstruction and IP constrain:





- Lifetime extraction:
  - τ_τ **= 287.2 ± 0.5 (stat) fs**
  - Same statistical uncertainty of Belle.
    (200 fb^{-1} vs 711 fb^{-1})



- τ_τ presents ≃ 3 fs bias.
  (Generated lifetime: 290.57 fs)
  - ISR/FSR losses = underestimation of the proper time.
  - And intrinsic bias in the measurement.

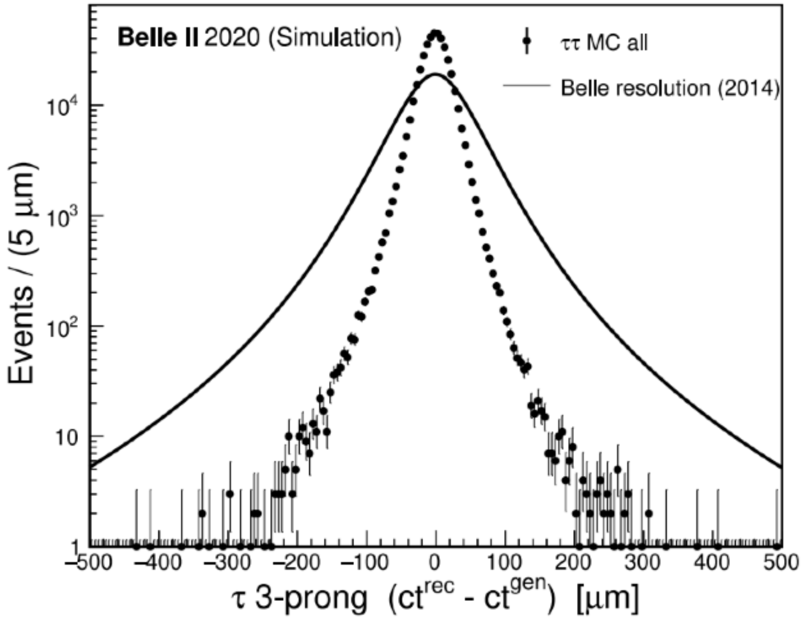
- Exploring other methods at Belle II:
  - Monte Carlo re-weighting method.
  - Revisiting the 3x3 topology.

Tau Lifetime Measurement

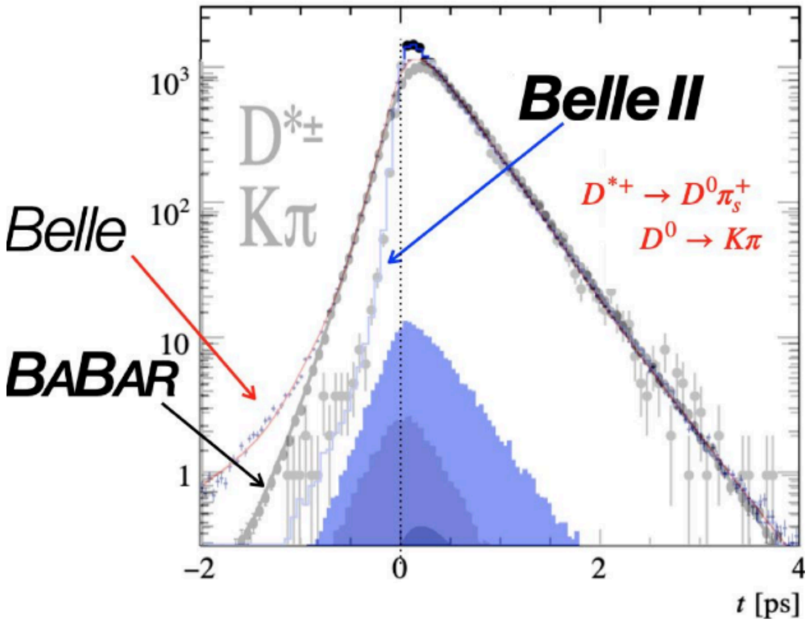
Detector performance

- In MC simulations, the Belle II proper time resolution is **~2x better than Belle.**
  - Due to PXD and smaller beam pipe diameter.

Proper decay time resolution:



- For comparison, the world-best D meson lifetime measurement by Belle II was recently published.
  - Improvement in resolution is confirmed



$$\tau(D^0) = 410.5 \pm 1.1(\text{stat}) \pm 0.8(\text{syst})\ \text{fs}$$

$$\tau(D^+) = 1030.4 \pm 4.7(\text{stat}) \pm 3.1(\text{syst})\ \text{fs}$$

[1] https://doi.org/10.1103/PhysRevLett.127.211801

Lepton Flavor Universality Violation

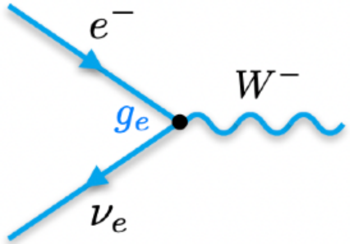
Tests in tau decays

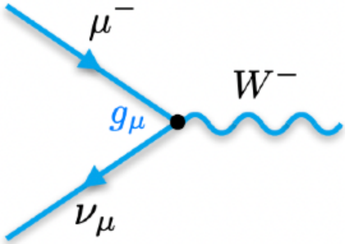
- Flavor anomalies in the SM:
  - a_μ : 4.2σ
  - R(D(*)) : > 3σ;
  - Cabibbo angle anomaly: 2 - 3 σ
  - etc.
- Hints of a new interaction that violates LFU?
- **LFU tests in tau decays: compare rates of leptonic decays.**

$$\left(\frac{g_\mu}{g_e}\right)_\tau = \sqrt{\frac{BF\left[\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau\right]}{BF\left[\tau^- \to e^-\bar{\nu}_e\nu_\tau\right]}\frac{f\left(m_e^2/m_\tau^2\right)}{f\left(m_\mu^2/m_\tau^2\right)}}$$

$$f(x) = -8x + 8x^3 - x^4 - 12x^2 \log x$$

- In the SM: $(g_\mu/g_e) = 1$





- Latest result from BaBar:

$$R_\mu = \frac{BF(\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau)}{BF(\tau^- \to e^-\bar{\nu}_e\nu_\tau)}$$

  - $R\mu$ = 0.976 ± 0.0016 ± 0.0036

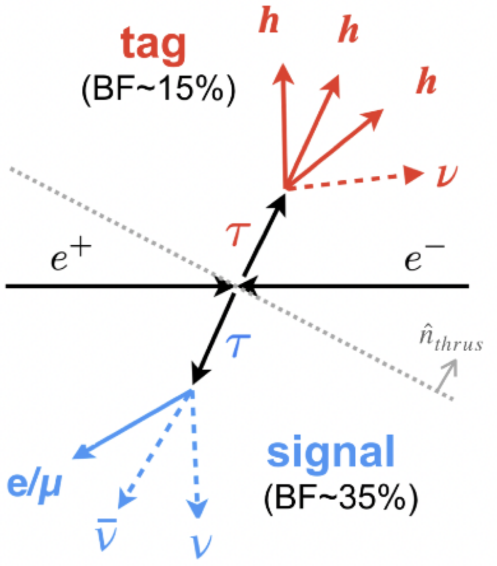
    $(g\mu/g_e)$ = 1.0036 ± 0.0020
  - Int luminosity: 467 fb^{-1}.

	μ
N^D	731102
Purity	97.3%
Total Efficiency	0.485%
Particle ID Efficiency	74.5%
Systematic uncertainties:	
Particle ID	0.32
Detector response	0.08
Backgrounds	0.08
Trigger	0.10
$\pi^-\pi^-\pi^+$ modelling	0.01
Radiation	0.04
$\mathcal{B}(\tau^- \to \pi^-\pi^-\pi^+\nu_\tau)$	0.05
$\mathcal{L}\sigma_{e^+e^-\to\tau^+\tau^-}$	0.02
Total [%]	0.36

- Can we improve this at Belle II?
  - **Yes!** Syst is dominated by PID due to limited size of data and MC samples.

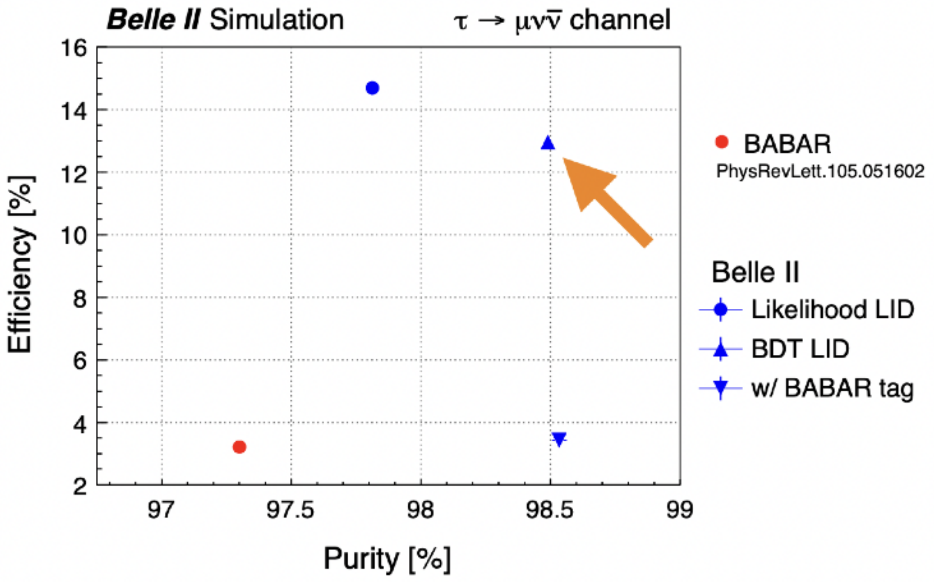
Lepton Flavor Universality Violation

e-μ universality tests with 3x1 topology



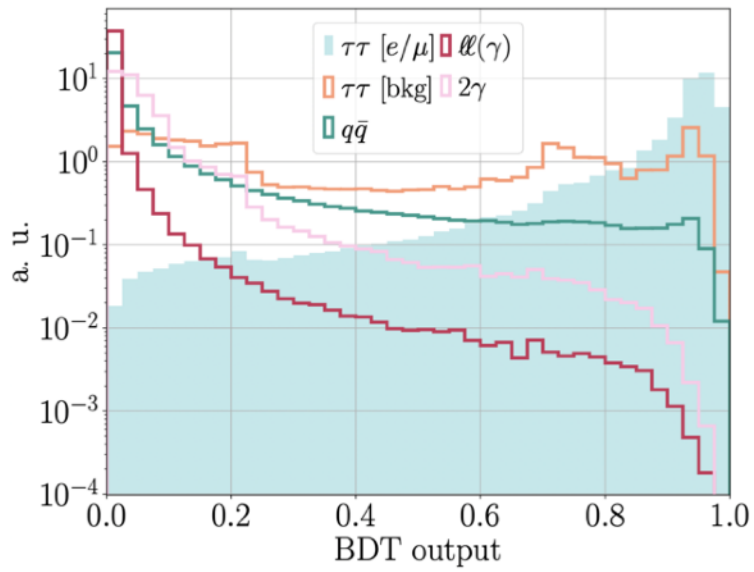
Cut-based performance

- Matches BaBar stat. uncertainty with 100 fb^{-1} of data.
  - Achieved with asymmetric p_t thresholds on lead, sublead and third track on tag side.
  - **x4 higher efficiency** with better purity:



BDT performance

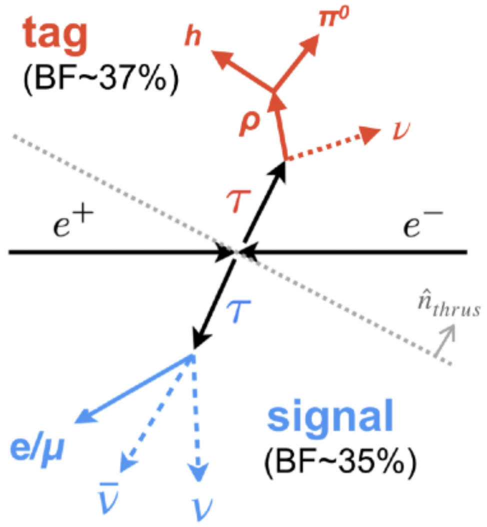
- Training of a XGBoost classifier for combined signal (e or μ in final state).
- 1.7x improvement in efficiency w.r.t. cut-based selection **(x7 than BaBar)**, with a purity of 98%.



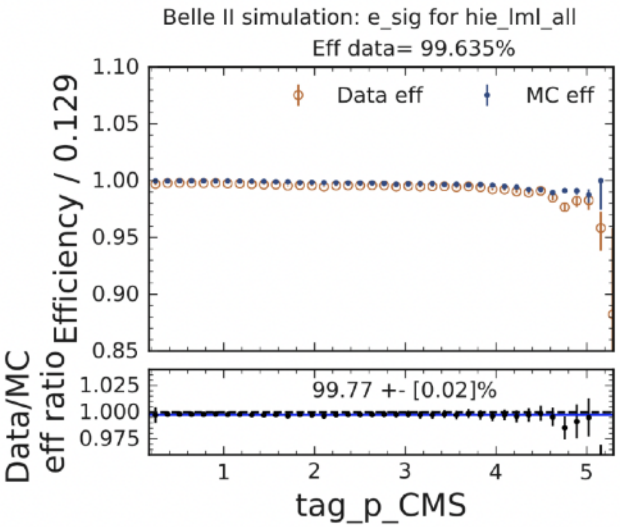
Lepton Flavor Universality Violation

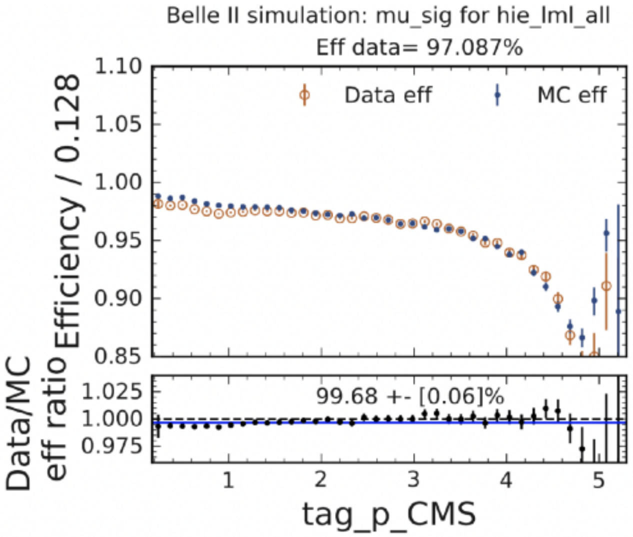
e-μ universality tests with 1x1 topology

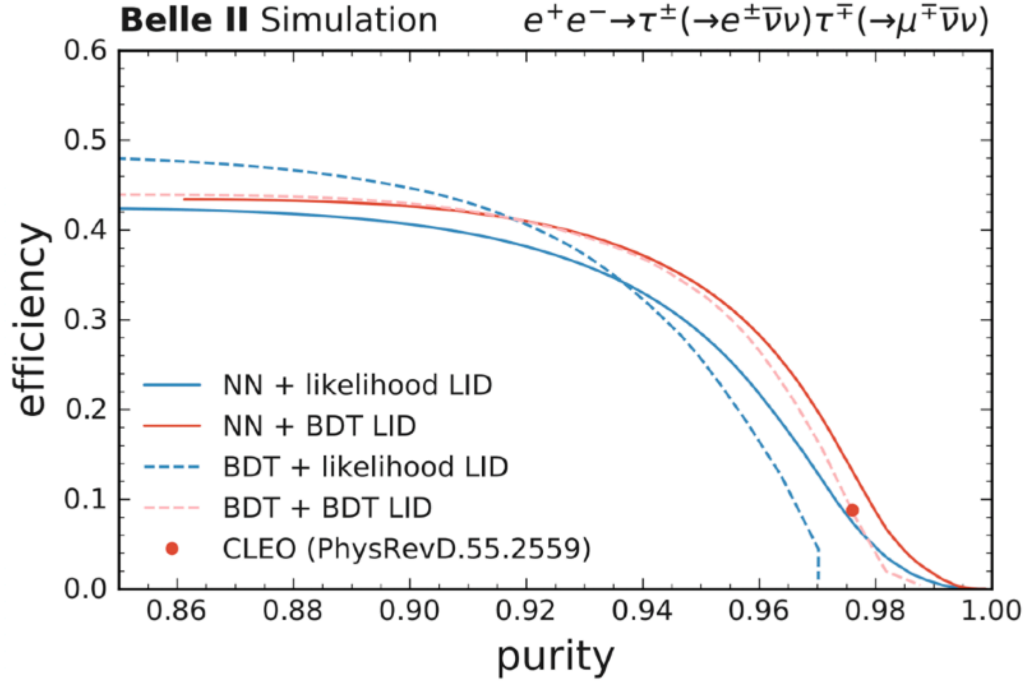
- Unexplored topology for LFU at BaBar and Belle (latest result from CLEO: 3.56 fb^{-1}).
- Optimise pre-selection in event-kinematic variables and discriminate using neural network.



- **Trigger**:
  - ϵ_{trg} = **96 - 100%** for e-channel.
  - ϵ_{trg} = **85 - 99%** for μ-channel.





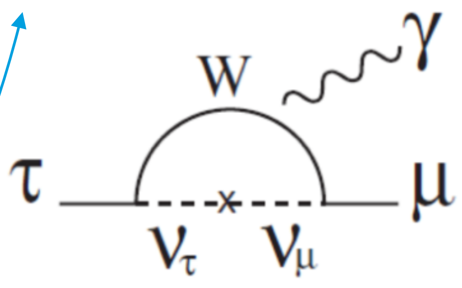


Charged Lepton Flavor Violation

Clear signature for physics beyond the SM

- Quarks change generations.
- Neutrinos change flavor.
  - Lepton Flavor Violation (LFV) is an established fact, but only in neutrinos.
- What about charged leptons?
  - Neutrinos with mass —> CLFV
  - But extremely suppressed.

SM case:
BR ~10^{-54}



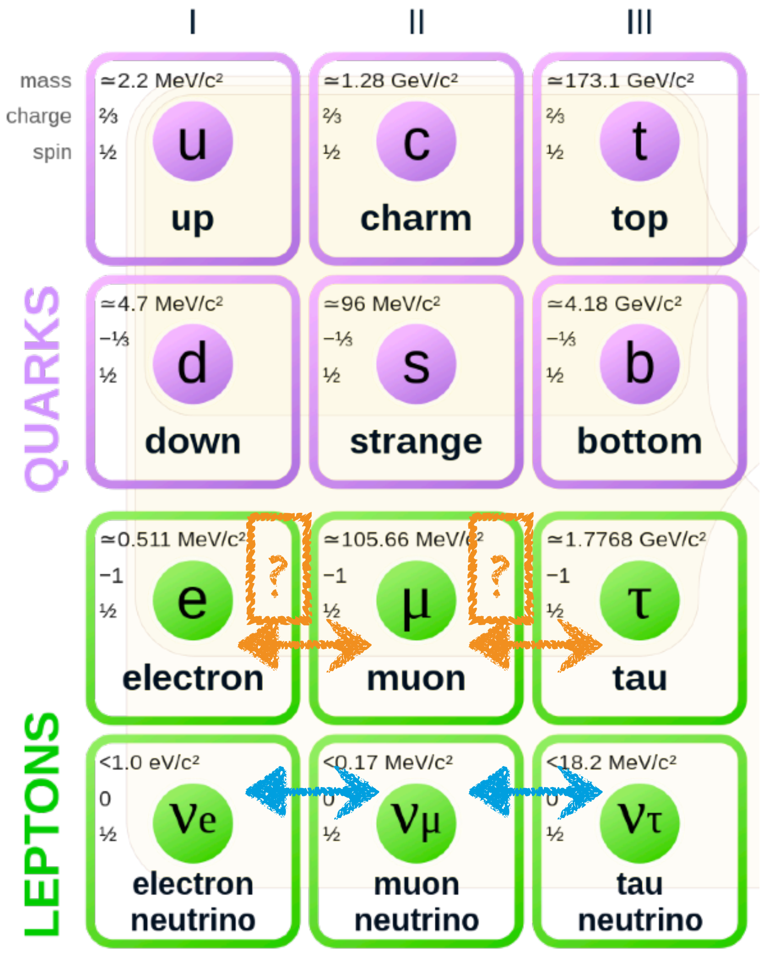


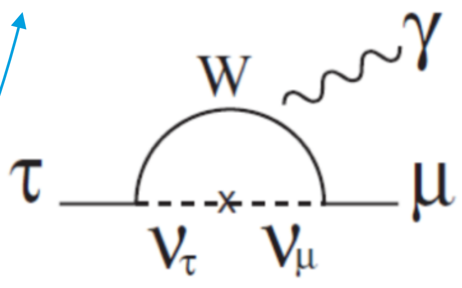
Figure: Wikipedia

Charged Lepton Flavor Violation

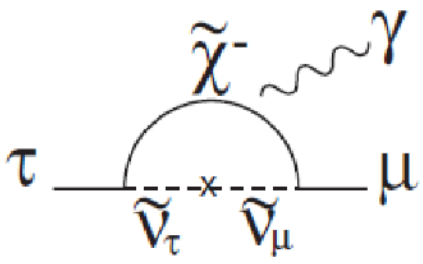
Clear signature for physics beyond the SM

- Quarks change generations.
- Neutrinos change flavor.
  - Lepton Flavor Violation (LFV) is an established fact, but only in neutrinos.
- What about charged leptons?
  - Neutrinos with mass —> CLFV
  - But extremely suppressed.
- **Observation of CLFV is a clear signature of New Physics!**

SM case:
BR ~10^{-54}



NP case:
BR ~10^{-7} - 10^{-10}



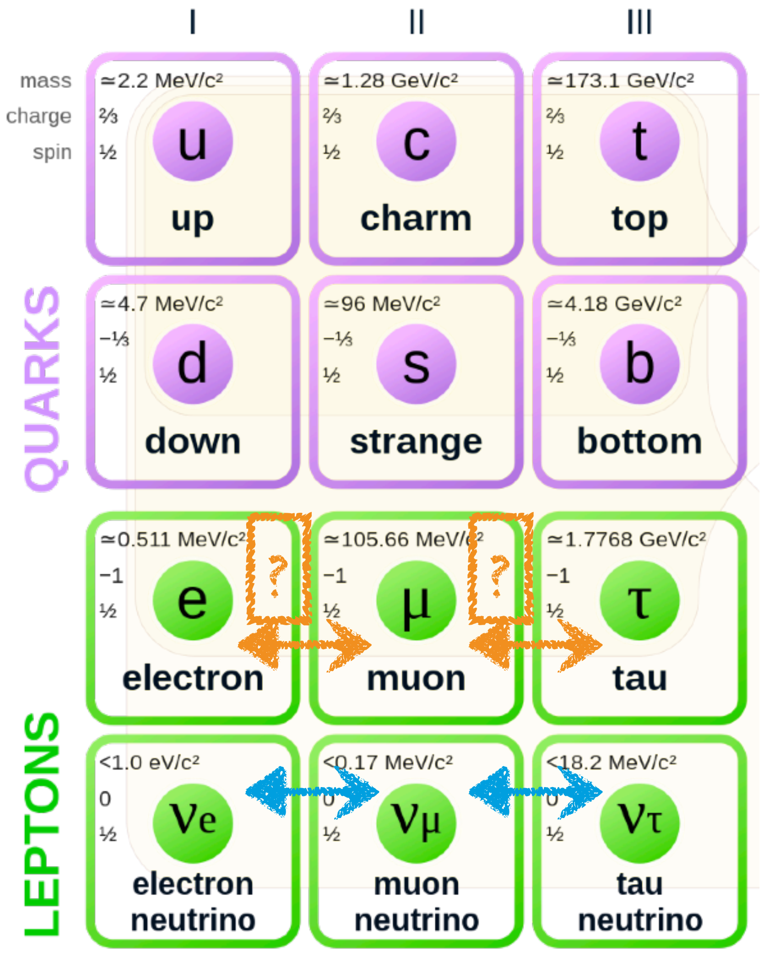


Figure: Wikipedia

Charged Lepton Flavor Violation

Clear signature for physics beyond the SM

- Quarks change generations.
- Neutrinos change flavor.
  - Lepton Flavor Violation (LFV) is an established fact, but only in neutrinos.
- What about charged leptons?
  - Neutrinos with mass —> CLFV
  - But extremely suppressed.
- **Observation of CLFV is a clear signature of New Physics!**

- At Belle II an increase in the signal efficiency will be achieved thanks to:
  - **Higher trigger efficiencies.**
  - **Improvements in the reconstruction.**
- In addition to a better understanding of background channels.

$\boldsymbol{\tau \to \ell\ell\ell}$ ← Can be competitive with early Belle II data

$\tau \to \ell K_s, \Lambda h$

$\tau \to \ell V_0(\to hh')$

$\tau \to \ell P^0\ (\to \gamma\gamma)$

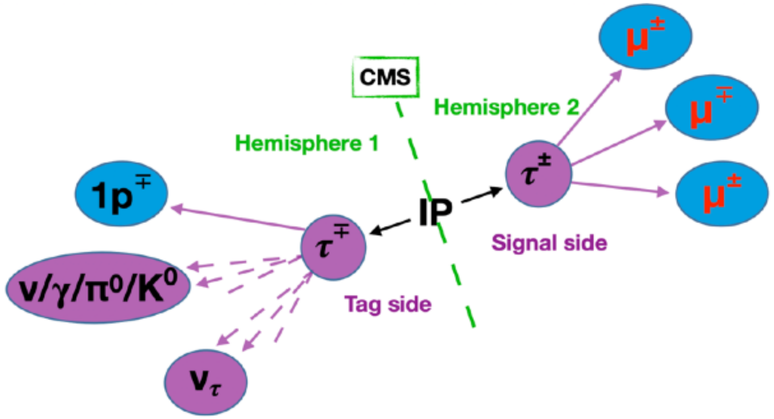
$\tau \to \ell hh'$

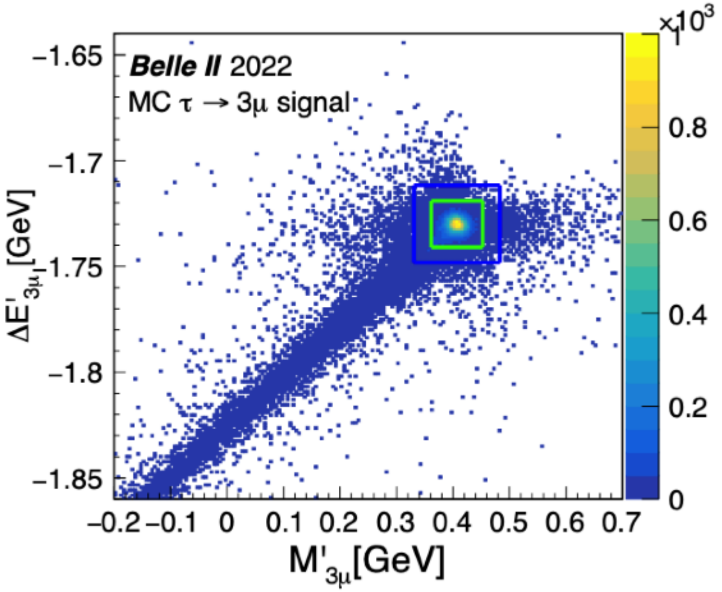
$\boldsymbol{\tau \to \ell\gamma}$ ← Stronger backgrounds, hard to control.

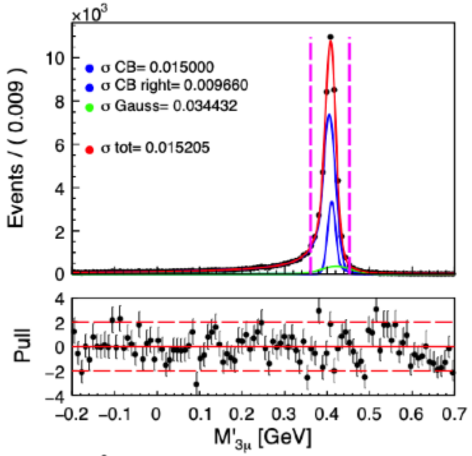
LFV $\tau^+ \to \ell^+\ell^-\ell^+$

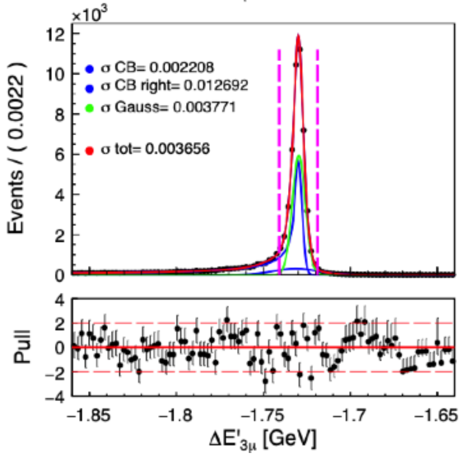
At Belle II

- Selection and analysis strategy are established.









- Optimization with kinematic cuts
  to constraint the phase space of the signal.

- After cuts:
  - **Efficiency: 15.79%** (vs 7.6% @ Belle)

- **Potential to be competitive with current dataset.**

- TO-DO:
  - Data vs MC comparisons.
  - Systematics evaluation.

- Exploring inclusive tagging strategies.
  - Increase on efficiency. Potential improvements on limits.

Upper limits on CLFV tau decays

Current bounds and projection of expected ULs

- Neutrinoless 2-body or 3-body decays to 52 final states.
- In some SM extensions, cLFV decays are expected at rates only one order of magnitude below present bounds.

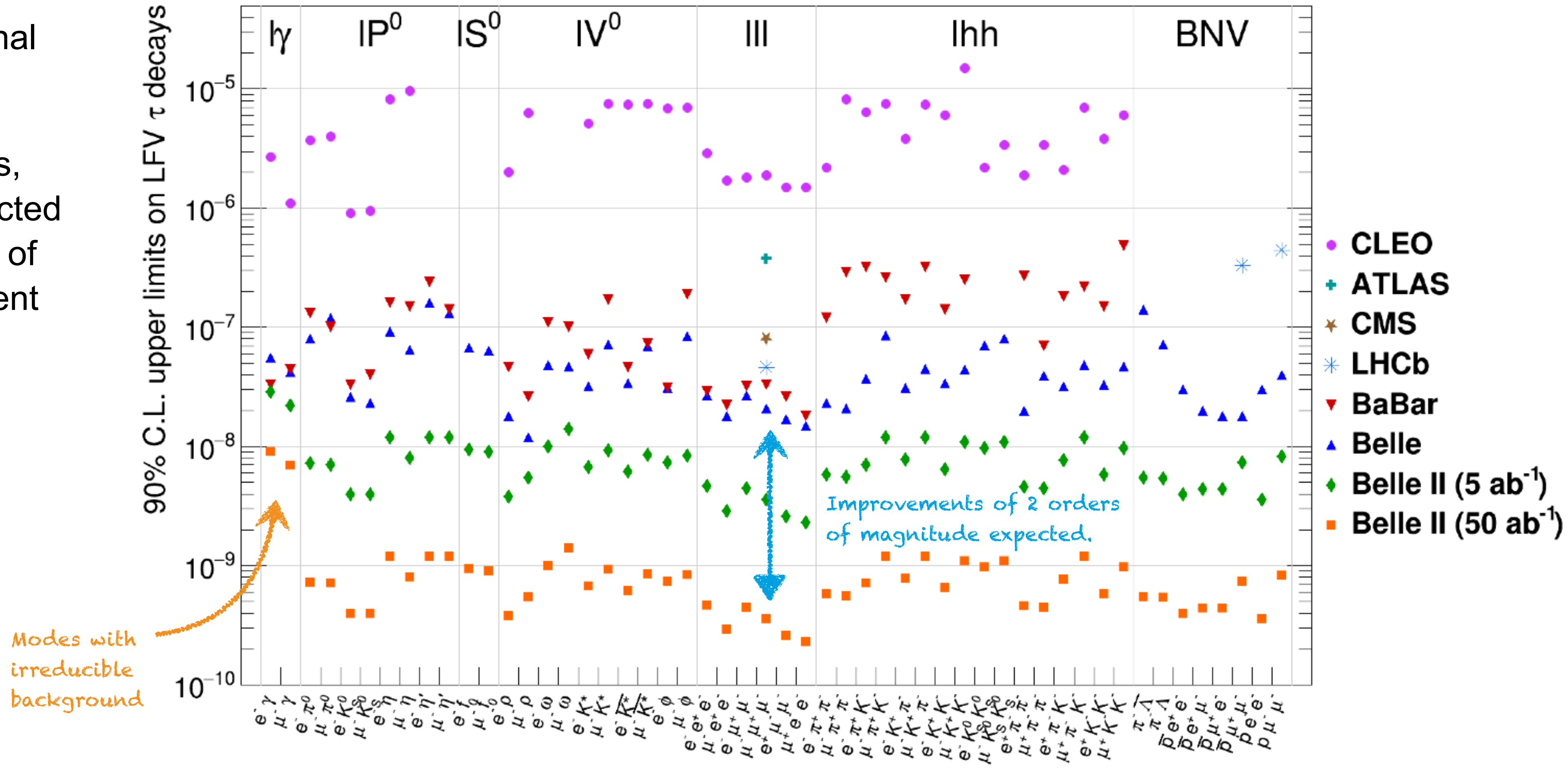
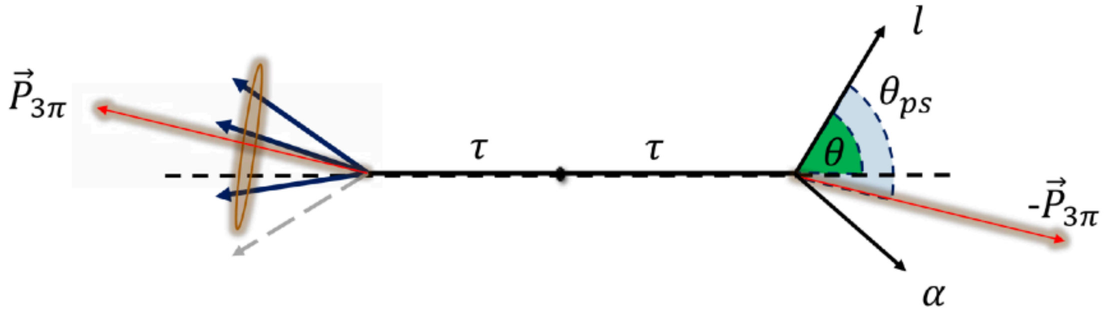


Figure: CLFV @ Snowmass 2021 arXiv:2203.14919 (2022)

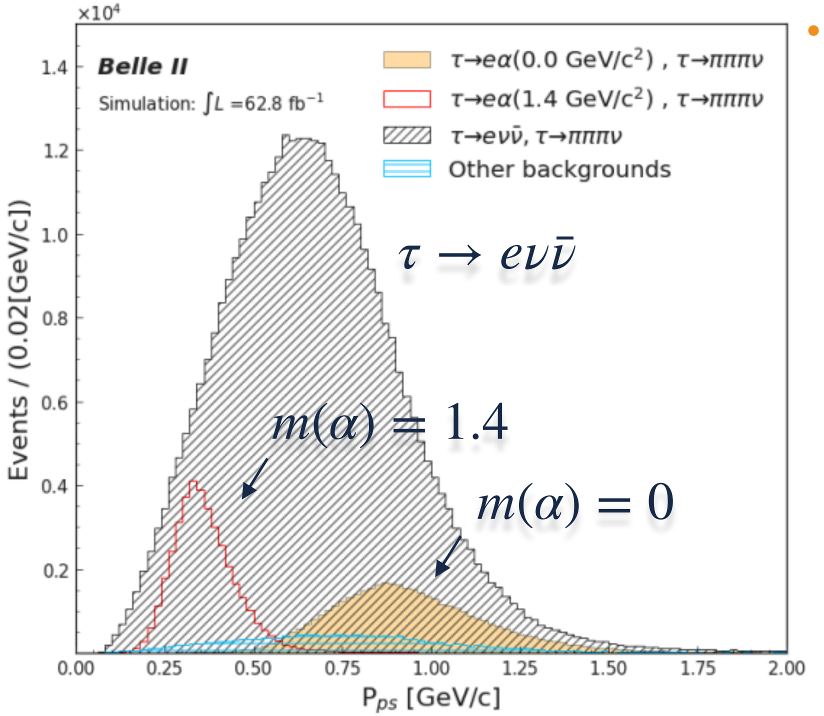
LFV $\tau^- \to \ell^- + \alpha$

Search for an invisible boson

- It probes the existence of a long-lived invisible gauge boson boson α.
  - Possible DM candidate.
- Peaking signal in a two-body decay spectrum in the τ lepton rest frame (TRF).
- Since we cannot access to the TRF due to the missing neutrino, a pseudo-TRF is built with the following assumptions:
  - $E_\tau = E_{\text{cms}}/2, \quad \hat{p}_\tau \approx \vec{p}_{\text{tag}}/|\vec{p}_{\text{tag}}|$



- Fit full spectrum with:
  - SM expectation
  - SM + NP expectation and compare likelihood of the two models
- Large smearing due to imprecise boost direction (undetected ν).



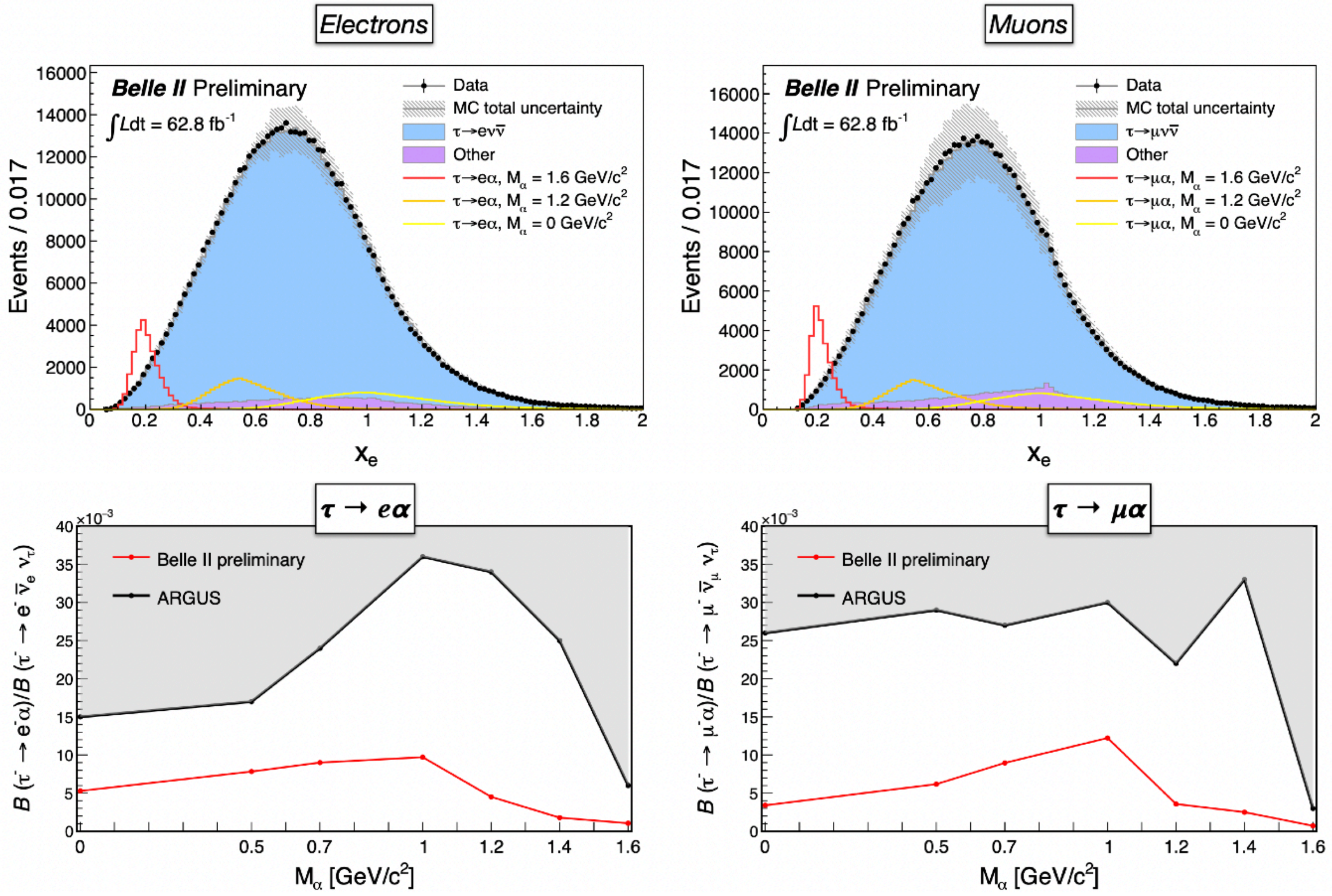
- Main sources of syst uncertainties:
  - Lepton ID efficiency & fake rate
  - Trigger efficiency
  - Pi0 reconstruction efficiency (for veto)

LFV $\tau^- \to \ell^- + \alpha$

Results (preliminary)

- No signal observed.
  - $\tau \to \ell + \alpha$ MC channels shown with a BR of 5%.

- Upper limits at 95% C.L. are imposed for $\mathrm{BR}(\tau \to \ell\alpha)/\mathrm{BR}(\tau \to \ell\bar{\nu}\nu)$
- Best limits to the date.



arxiv:2212.03634

Summary

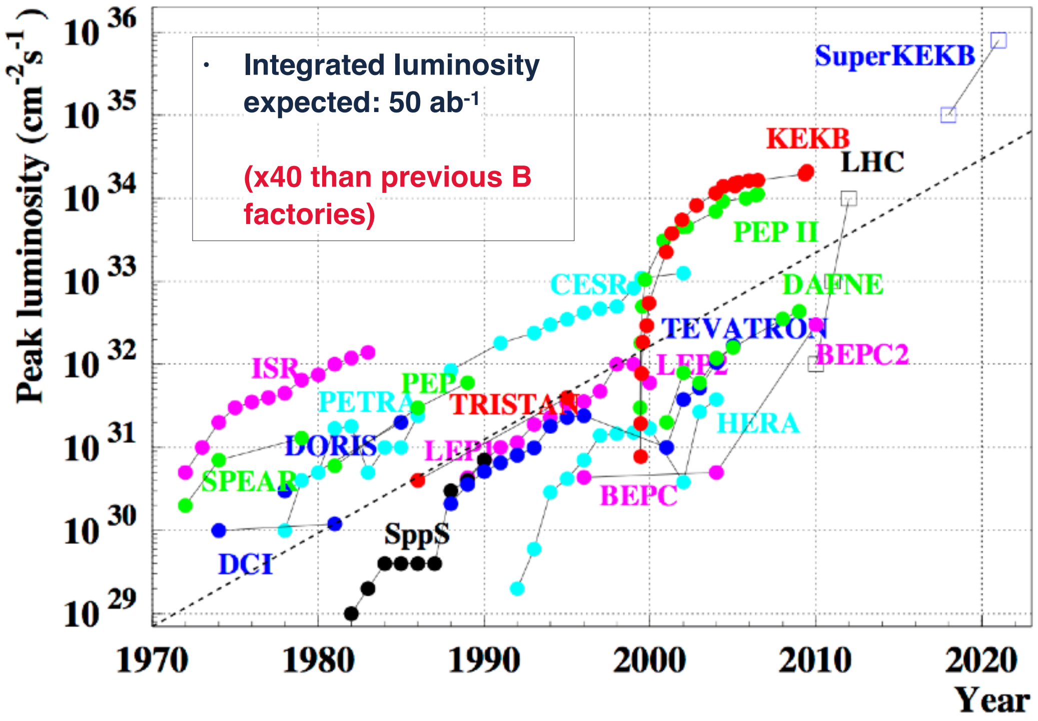
- Since its discovery, the tau lepton has been studied at every e^+e^- collider in operation, improving the measurements with every upgrade.
  - **In Belle II we are motivated, and ready to reach new limits in the precision.**
- **Tau mass studies** with the early data show potential for an update in the measurement of m_τ using the pseudomass technique. Updated measurement with reduced systematics in preparation.
- First studies of **tau lifetime measurements** very promising, with an update in the measurement feasible in the coming months. Several methods explored.
- Tests of **lepton flavor universality** with both 3x1 and 1x1 topologies show high efficiency in reconstruction. Working on the estimation of systematic uncertainties.
- First searches of **lepton flavor violation** at Belle II in preparation. Significant improvements in reconstruction efficiency with respect to previous B-Factories observed.
- Stay tuned! Results are coming.

Thank you

Backup

SuperKEKB

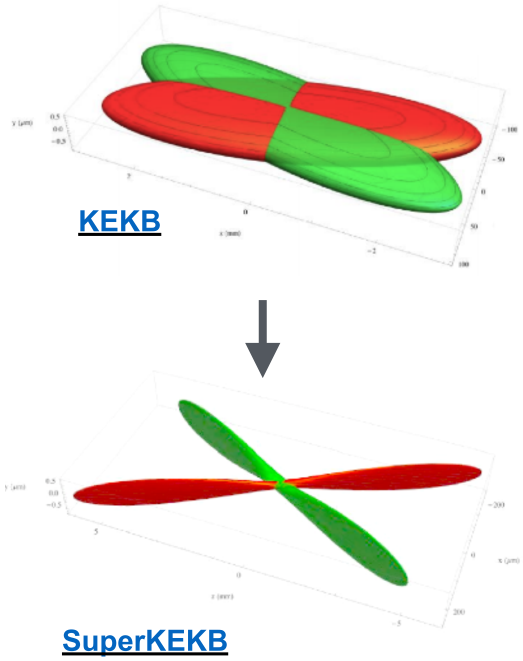
A B factory of next generation

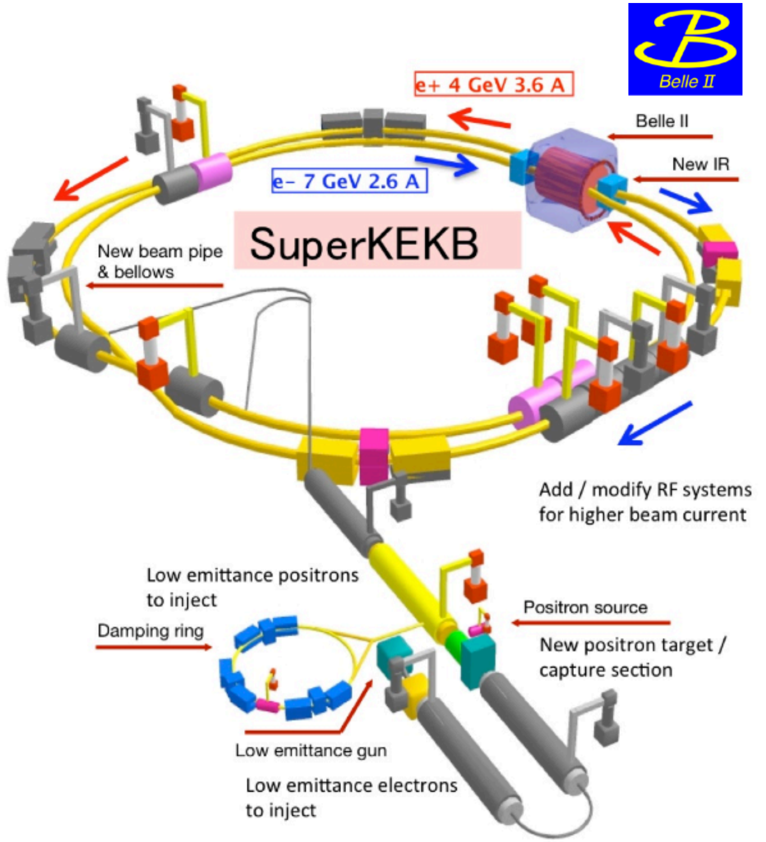


- Integrated luminosity expected: 50 ab^{-1}

(x40 than previous B factories)

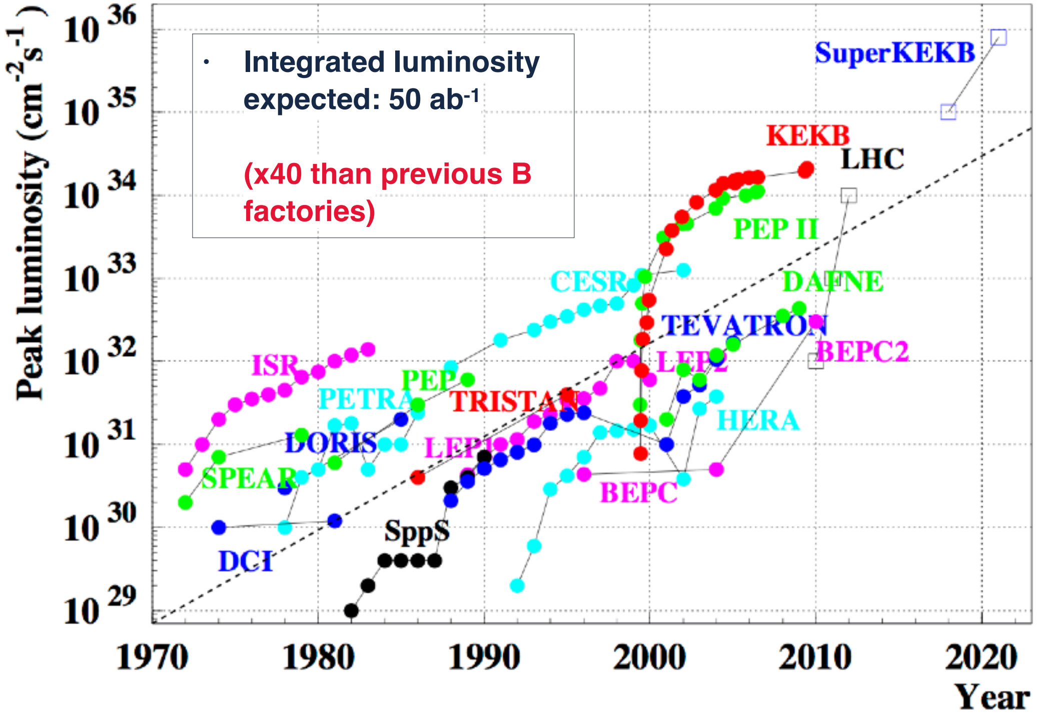
"Nano-beams": vertical beam size is 50nm at the IP.



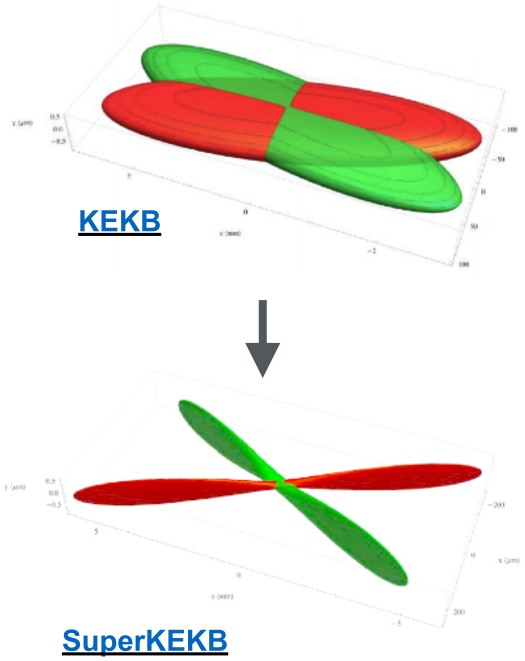


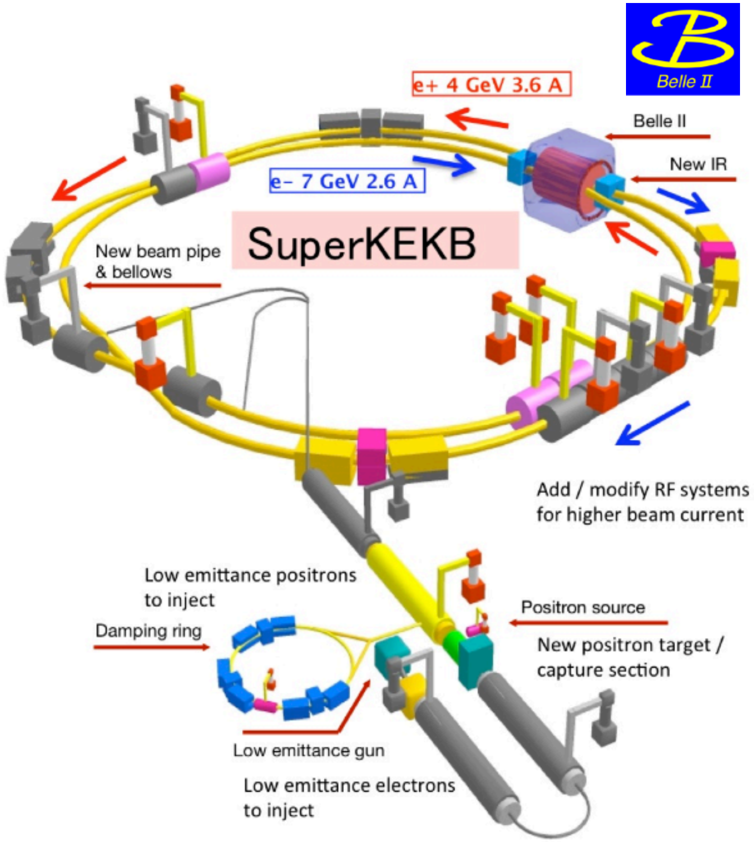
SuperKEKB

A B factory of next generation



"Nano-beams": vertical beam size is 50nm at the IP.



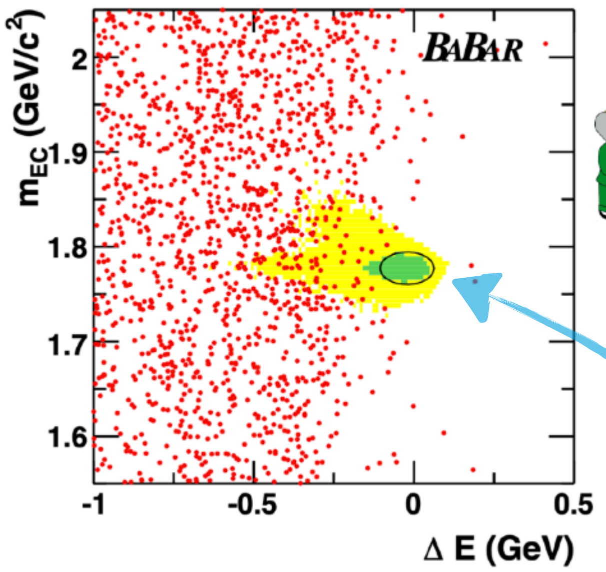


- Challenges at L=6×10^{35} cm^{-2} s^{-1}:
  - **Higher background** (Radiative Bhabha, Touschek, beam-gas scattering, etc.).
  - **Higher trigger rates** (High performance DAQ, computing).

$\tau^+ \to \ell^+\gamma$

Highest non-SM branching ratio

- Considered the golden modes for search of CLFV.
  - τ's rate production (10^{10}/yr) is much lower w.r.t. μ's in dedicated facilities (10^{11} /sec).
  - However, BSM branching ratios can be orders of magnitude larger than in associated muon decays.
- Searching for signal events in a 2D region.



Phys.Rev.Lett. 104 (2010) 021802

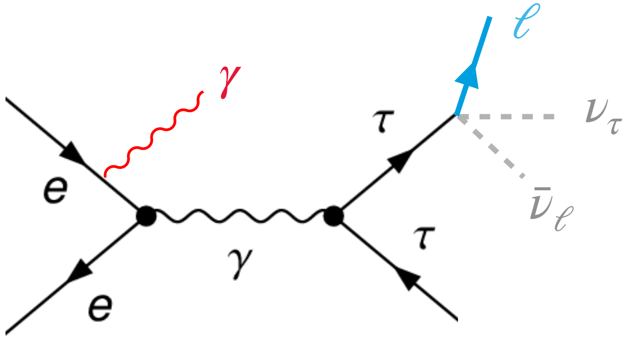
- Strongest UL for $\tau^+ \to e^+\gamma$ from BaBar

BR($\tau^+ \to e^+\gamma$) < 3.3 x 10^{-8}

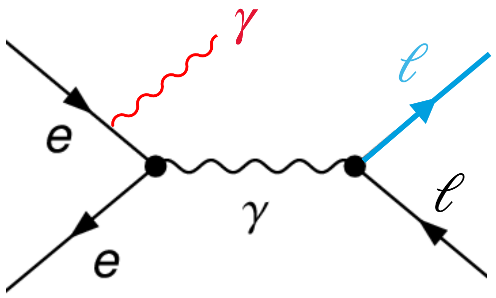
Signal region (2σ)

- Searches at Belle II in progress.

Irreducible background



Mis-id tagging

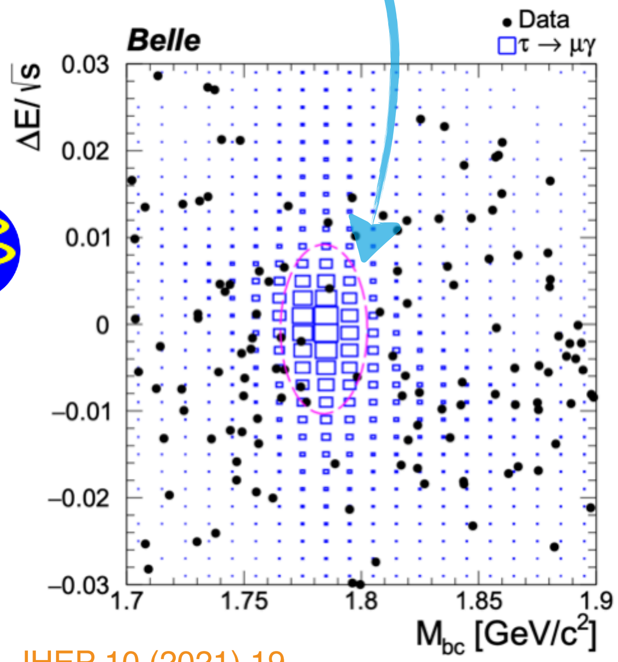


- Most recent result from Belle, setting the strongest UL for $\tau^+ \to \mu^+\gamma$

BR($\tau^+ \to \mu^+\gamma$) < 4.2 x 10^{-8}

$$M_{\rm bc} = \sqrt{(E^{\rm CM}_{\rm beam})^2 - |\vec{p}^{\,\rm CM}_{\ell\gamma}|^2},$$

$$\Delta E/\sqrt{s} = (E^{\rm CM}_{\ell\gamma} - \sqrt{s}/2)/\sqrt{s},$$



JHEP 10 (2021) 19

Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

Michel Hernandez Villanueva
michel.hernandez.villanueva@desy.de
Orcid: 0000-0002-6322-5587