Latest Results from Belle II

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On behalf of the Belle II Collaboration

Sixth Colombian Meeting on High Energy Physics 29 Nov to 3 Dec 2021, Colombia

Belle II Collaboration

26 Countries and Regions, 123 Institutions, ~1100 collaborators

Armenia (1), Australia (3), Austria (1), Canada (5), China (12), Czechia (1), France (3), Germany (12), India (9), Israel (1), Italy (9), Japan (16),Malaysia (1), Mexico (3), Poland (1), Russia(6), Saudi Arabia(1), Slovenia(2), South Korea(9), Spain(1), Taiwan(3), Thailand(2), Turkey(1), USA (18), Ukraine (1), Viet Nam(1).

SuperKEKB and Belle II x50 Higher luminosity!!

$$Instantaneus\ Target\ Luminosity:\ L = 6\,x\,10^{35}\,cm^{-22}\,s^{-1}$$

$$Achieved\ Luminosity\,(world\ record):\ L = 3.12\,x\,10^{34}\,cm-2\,s-1;$$

Target (Achieved)

e^+ 4GeV 3.6 A (~0.4 A)

e^- 7GeV 2.6 A (~0.7 A)

Belle II

New superconducting /permanent final focusing quads near the IP

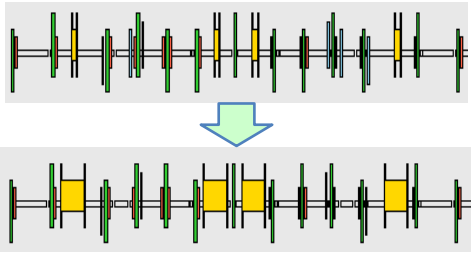
New IP

Colliding bunches

KEKB

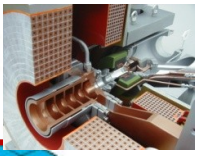
SuperKEKB

Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance

Add / modify RF systems for higher beam current



Positron source

New positron target / capture section

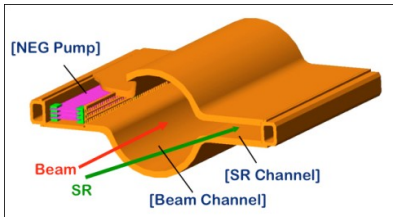
Damping ring

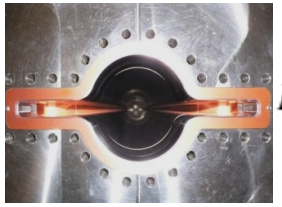
Low emittance positrons to inject

Low emittance gun

Low emittance electrons to inject

TiN-coated beam pipe with antechambers

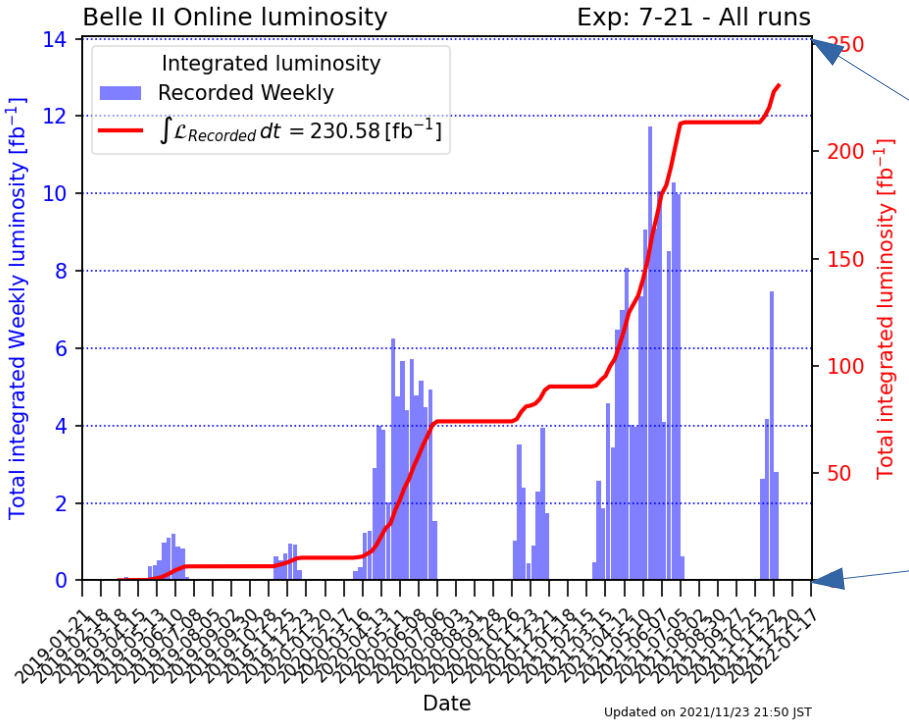


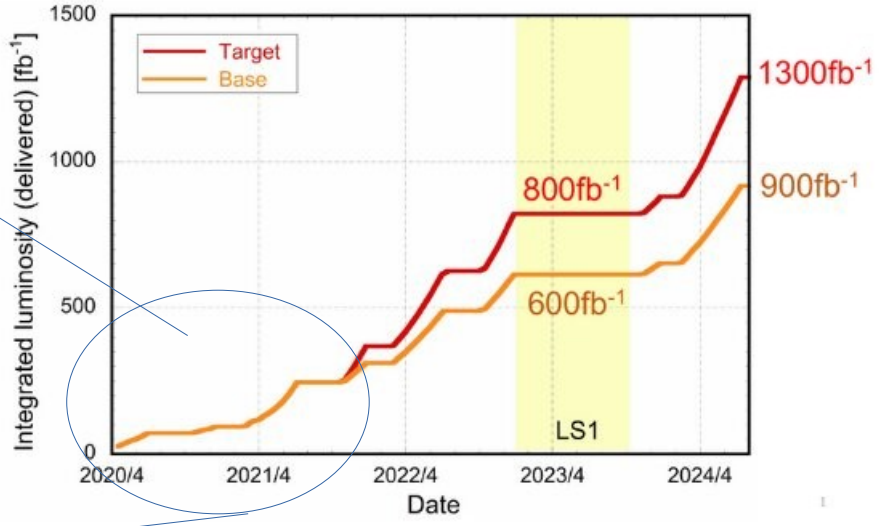


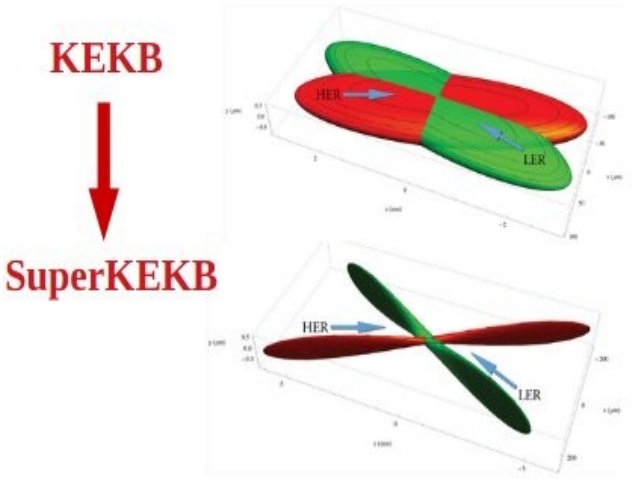
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

3

Luminosity Milestones







- Record instantaneous luminosity: 3.12 x 10 ^{34} cm^{-2} s^{-1};

- Running for the first time above the Y(4S), at ~10.75 GeV.

- 2023 we will have a ~9 months long shutdown to replace the (incomplete) pixel vertex detector

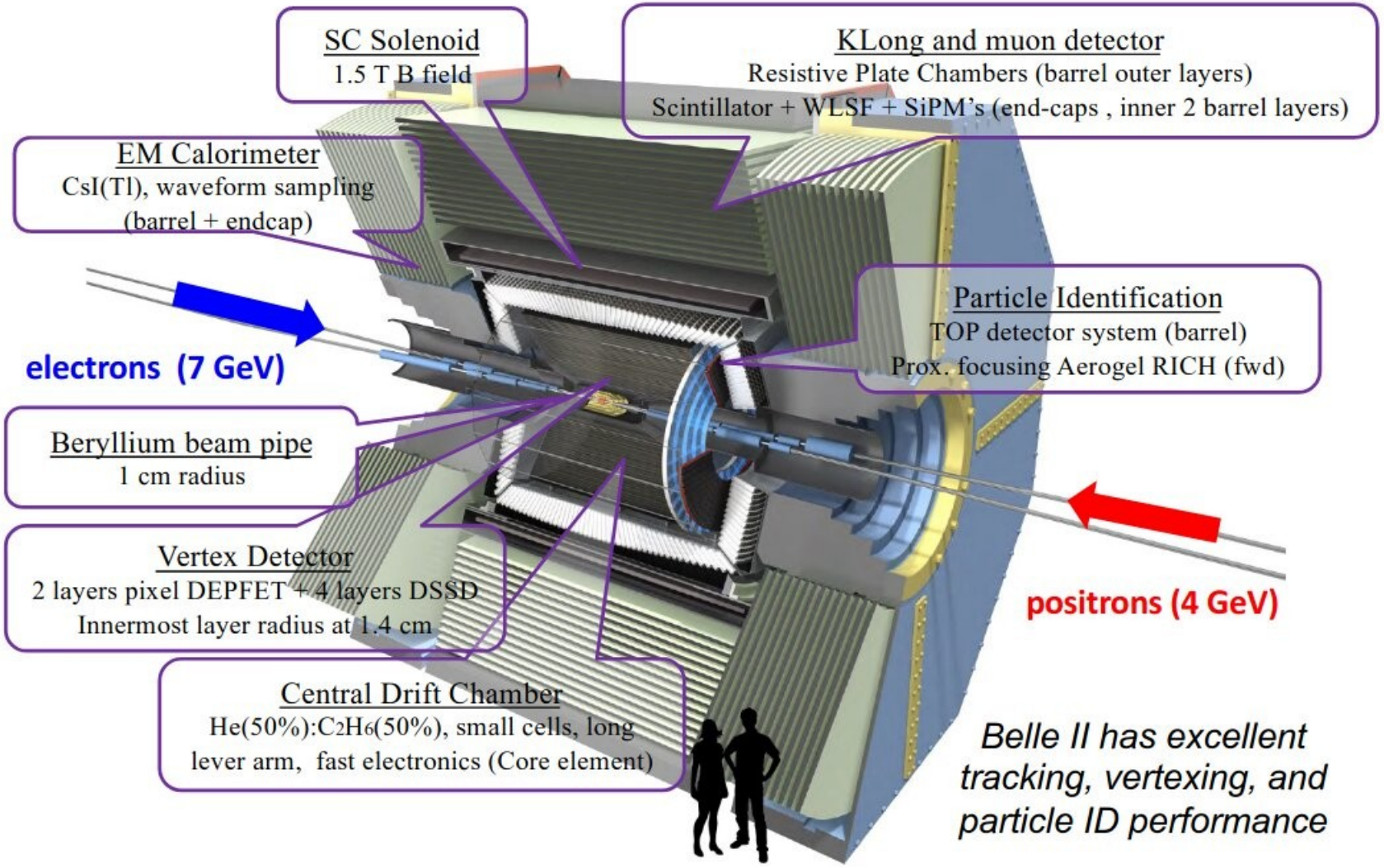
- A second shutdown will probably take place after 2026

50,000 fb^{-1} by 2031

Belle II Luminosity

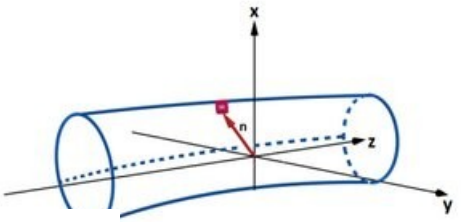
https://confluence.desy.de/display/BI/Belle+II+Luminosity

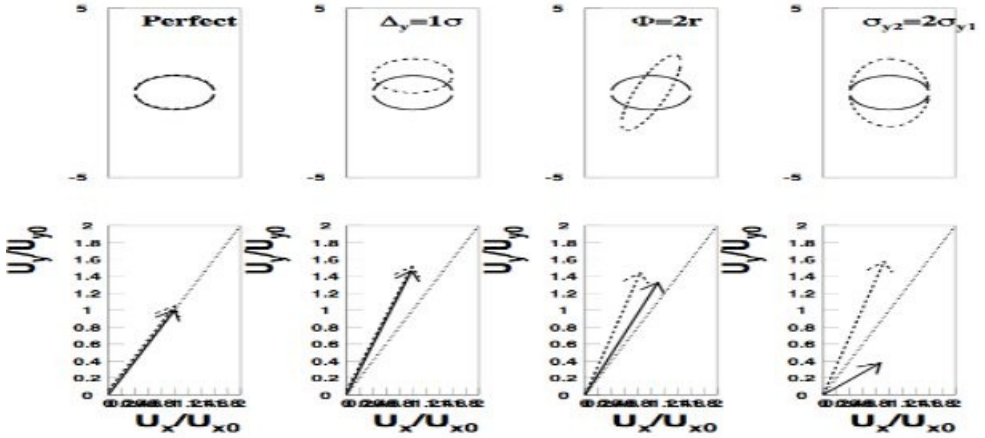
Belle II detector



Large Angle Beamstrahlung Monitor (LABM)

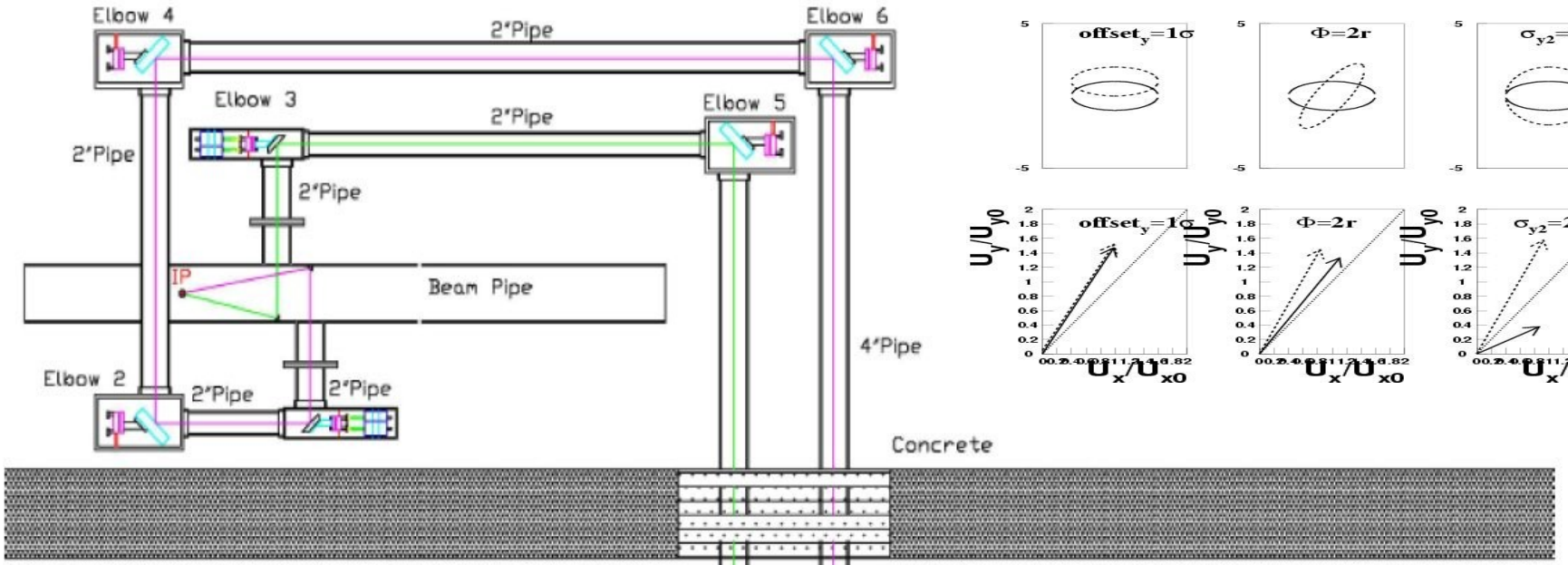
- Bremsstrahlung light produced by the interaction of one beam and the electromagnetic field of the other.
- Useful for nanobeam.
- New kind of beam monitor.
- Based in measurement of polarization.



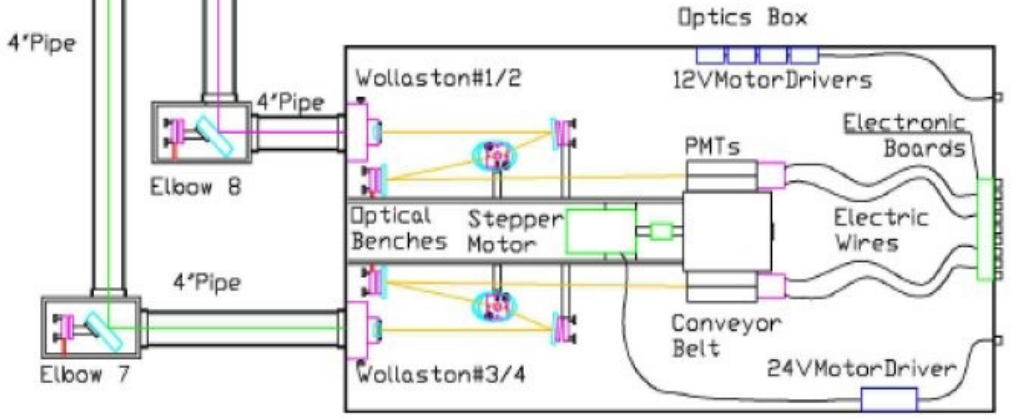


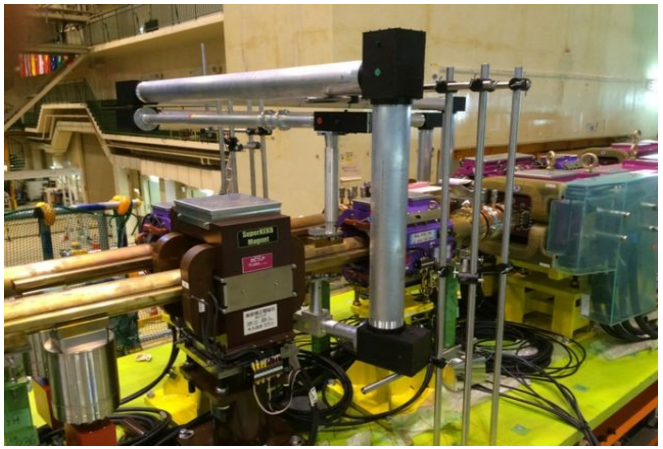
Some examples of Large Angle BMST pattern recognition (collinear beams case)
3 asymmetries are defined (4 are possible)

LABM Diagram



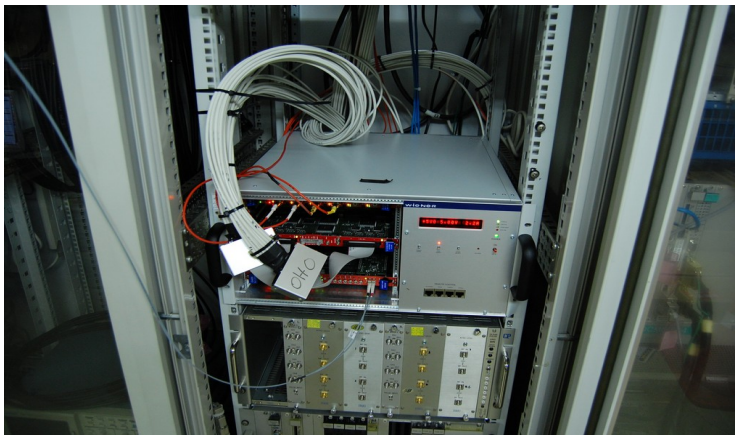
Four telescopes
Two for HER(LER)
32 PMT



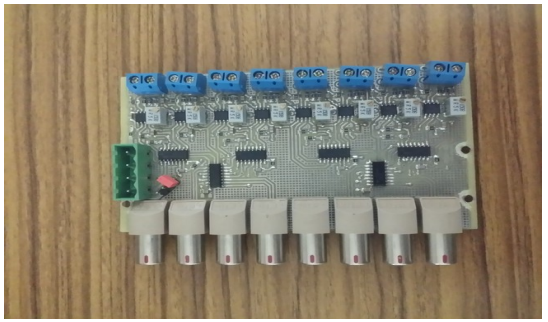


Connection to beam line

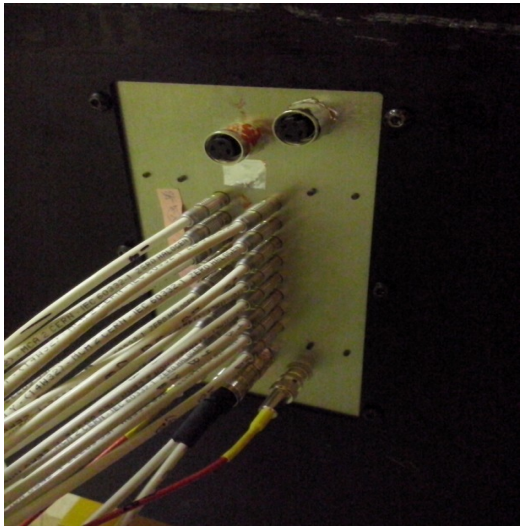
Optical line (4)

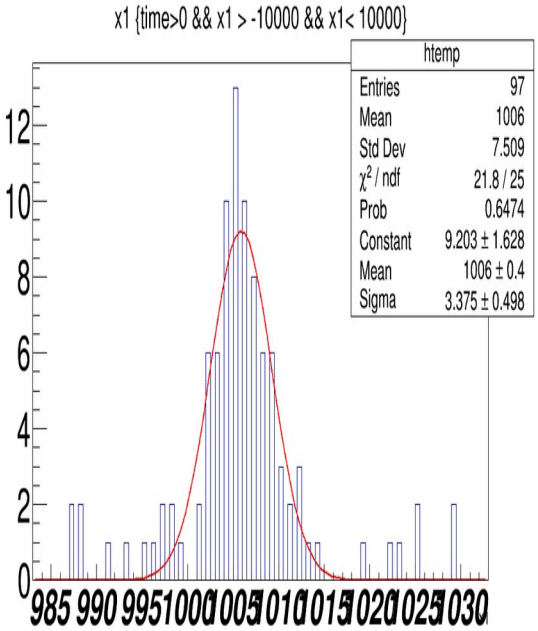


Scaler, Power supply (16)

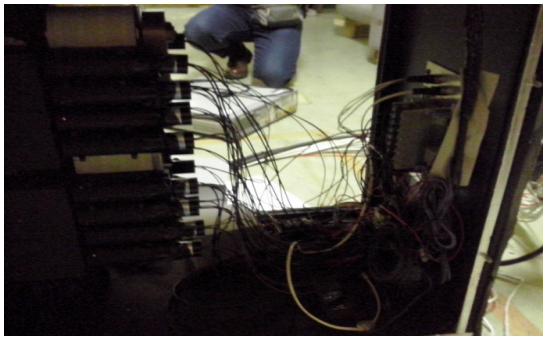


Digitization card (4)



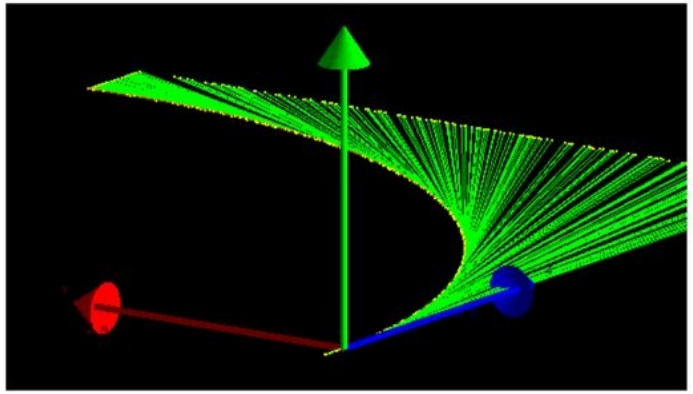


One channel output

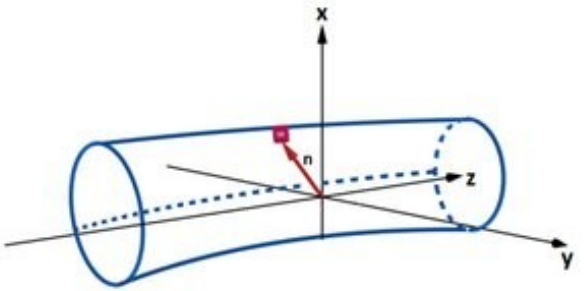


Photomultipliers (32)

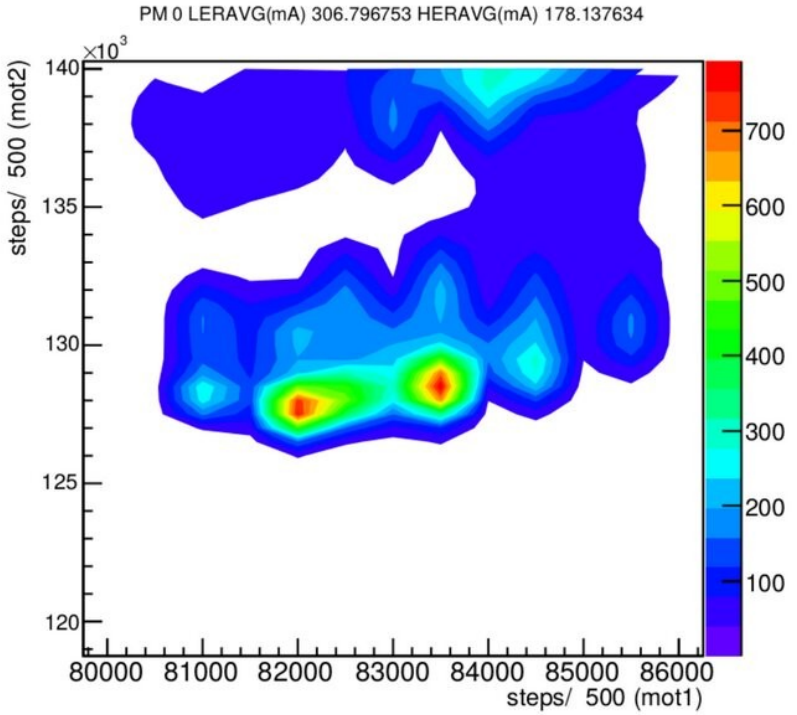
LABM scans



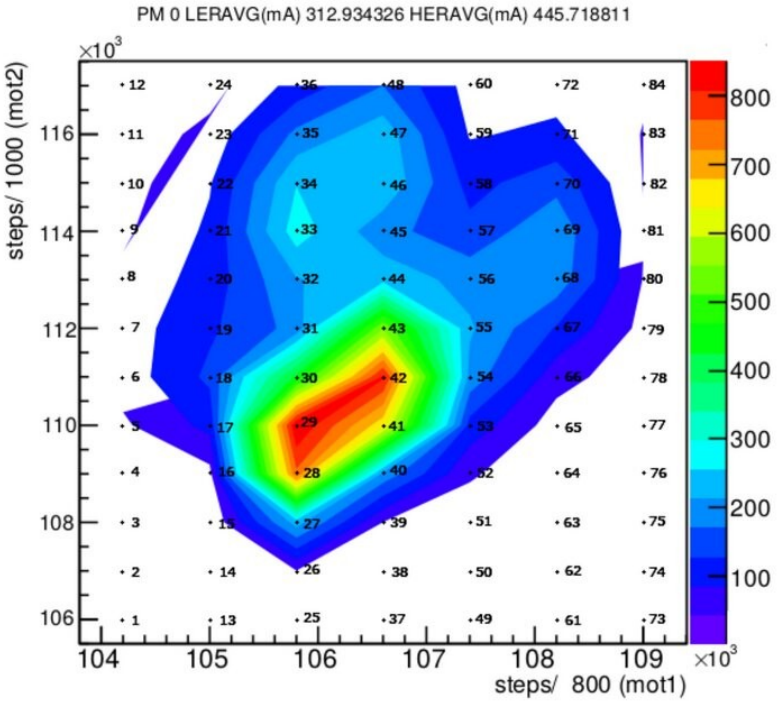
Synchrotron radiation (Geant4)



Beamstrahlung radiation



Heat map for one PMT in blue synchrotron in red Beamstrahlung



Points for scan PMT to identify signal and noise

Status and prospects

UPS

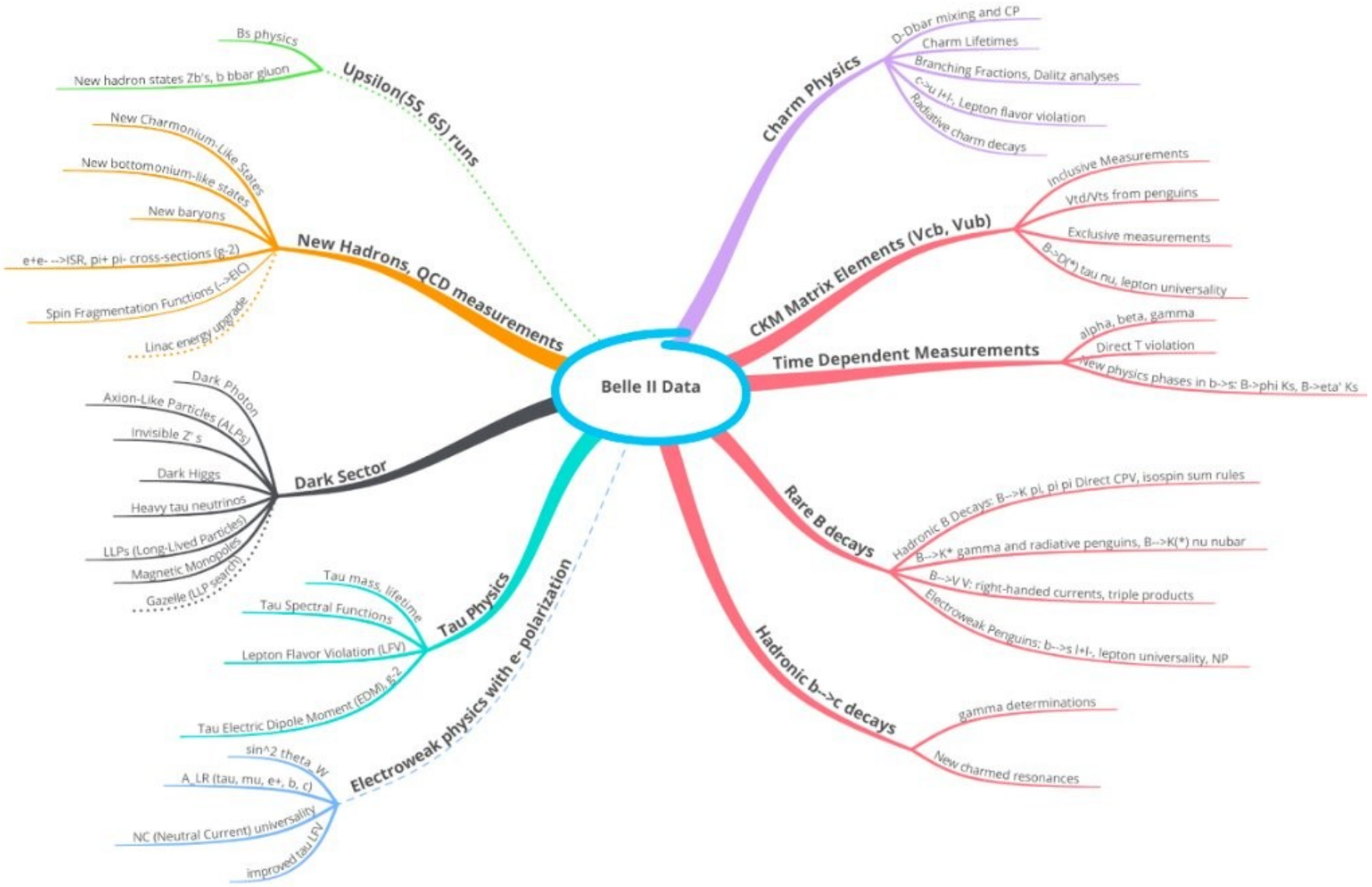
- Hardware, electronics, data worked properly.
- Possible Beamstrahlung signal in two telescopes.
- All problems has been solvable.

DOWNS

- No signal in one telescope.
- Background 10x bigger than expected.

Upgrade in electronics, mechanics and more PMTS in summer 2022.

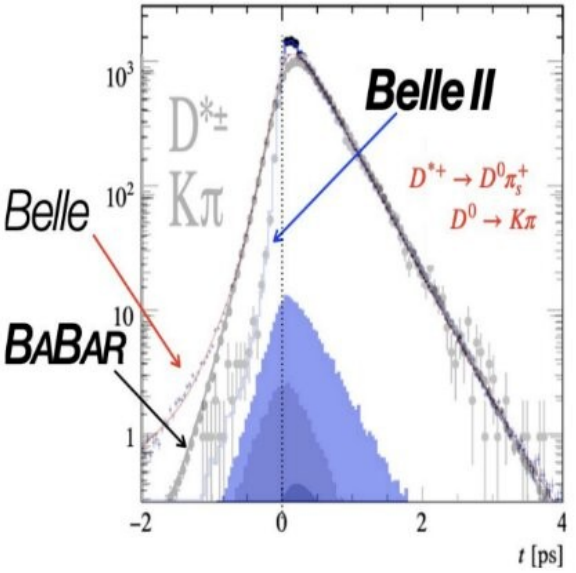
Belle II Physics



The Belle II Physics Book

D^0/D^+ Lifetime

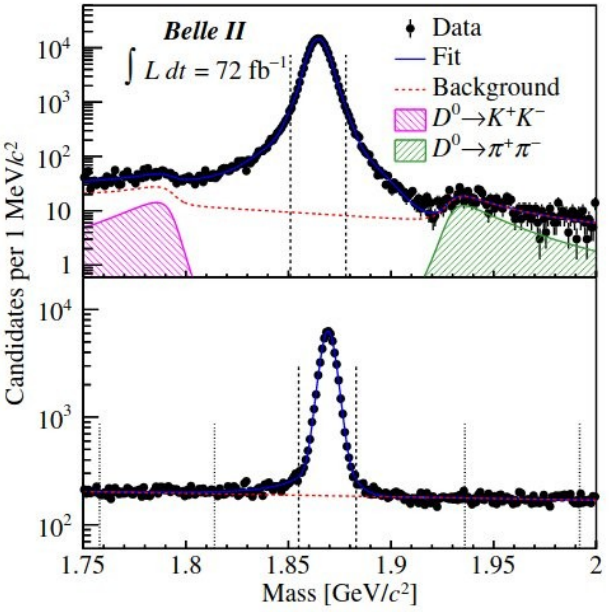
- Main PDG result from FOCUS 20 years old
- Useful for LHCb in D_+^s
- No input from simulation
- Blind analysis
- 2D fit, mass and lifetime
- Mass signal: Two Gaussians + Crystal ball
- Mass background: exponential
- Lifetime: convoluted exponential for signal



	Our result	WA
$\tau(D^0)$ =	(410.5 ± 1.1 ± 0.8) fs	(410.1 ± 1.5) fs
$\tau(D^+)$ =	(1030.4 ± 4.7 ± 3.1) fs	(1040 ± 7) fs

Table I: Systematic uncertainties.

Source	$\tau(D^0)$ [fs]	$\tau(D^+)$ [fs]
Resolution model	0.16	0.39
Backgrounds	0.24	2.52
Detector alignment	0.72	1.70
Momentum scale	0.19	0.48
Total	0.80	3.10



World Best Result !!

Phys, Rev. Lett. 127, 211801 (2021)

τ Mass

The least precise measurement for leptons

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

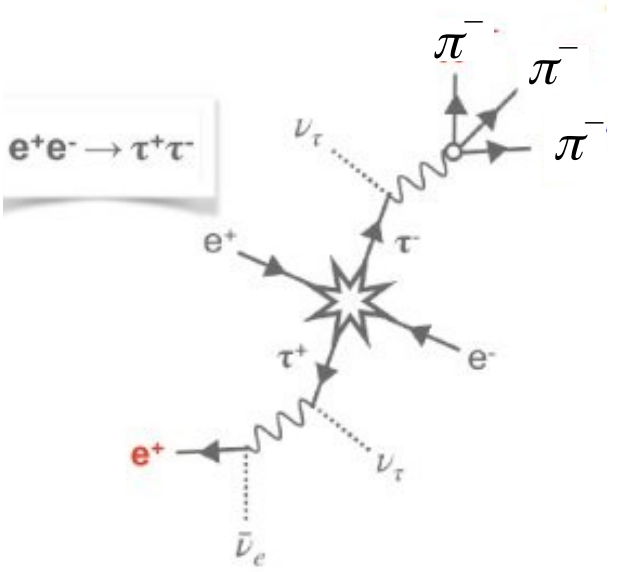
Measured in the decay mode $\tau \to 3\pi\nu$, using a pseudomass technique developed by the **ARGUS** collaboration.

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

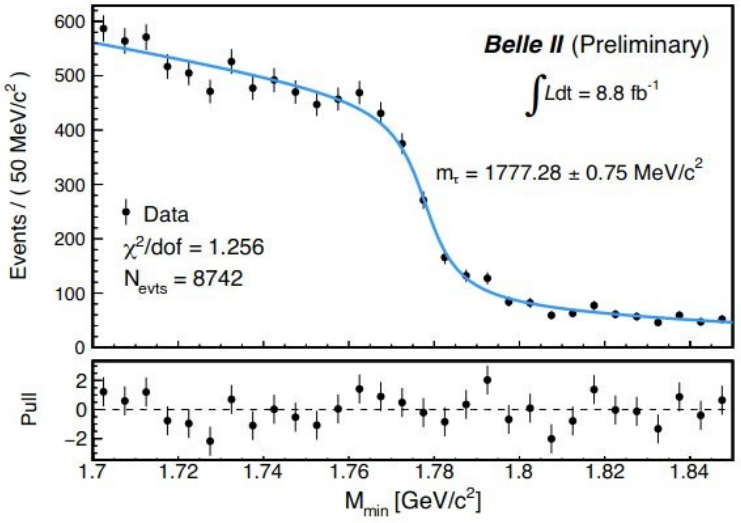
$$M_{\text{min}}^2 = 2E_h(E_\tau - E_h) + m_h^2 - 2|\vec{p}_h|(E_\tau - E_h) < m_\tau^2$$



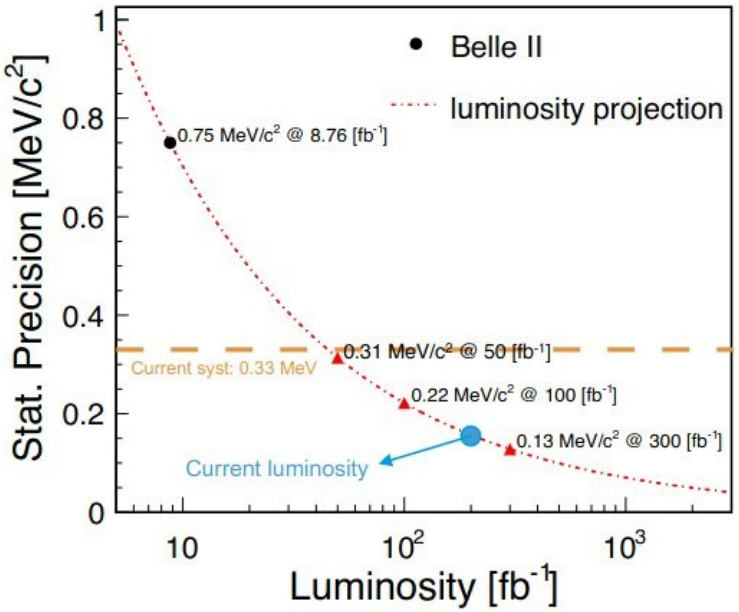
Then, the distribution of the pseudomass is fitted to an empirical edge function, and the position of the cutoff indicates the value of the mass.

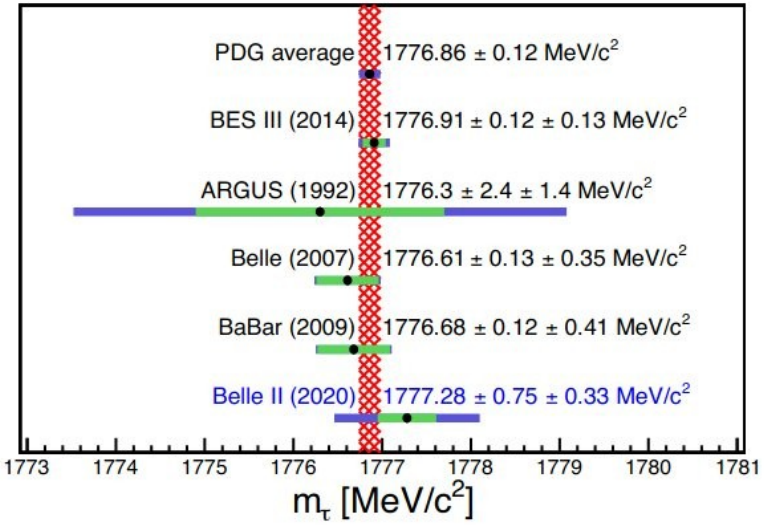
Fit to edge in the p.d.f in the cutoff region

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



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	$\leq$ 0.01
Initial parameters	$\leq$ 0.01
Background processes	$\leq$ 0.01
Tracking efficiency	$\leq$ 0.01

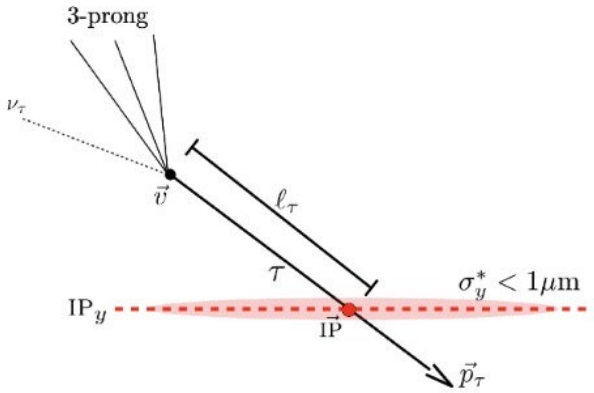


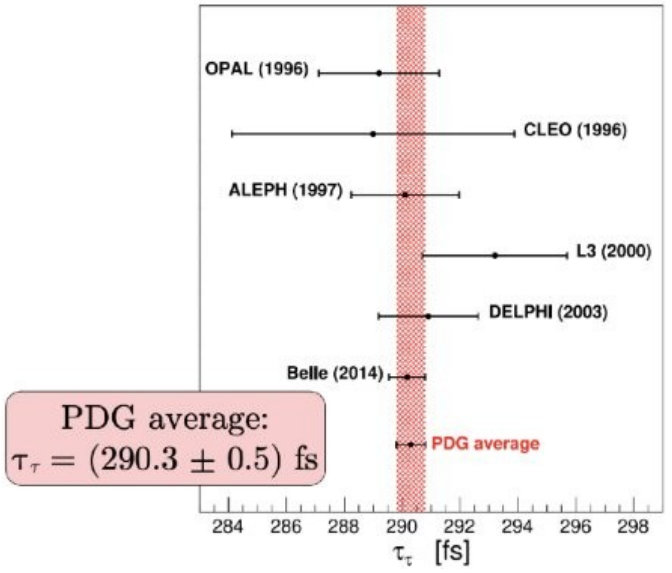


Blue: statistical; Green: systematic

τ Mass

3 prong in one side for Belle II
-Better statistics
3 prong in two sides for Belle





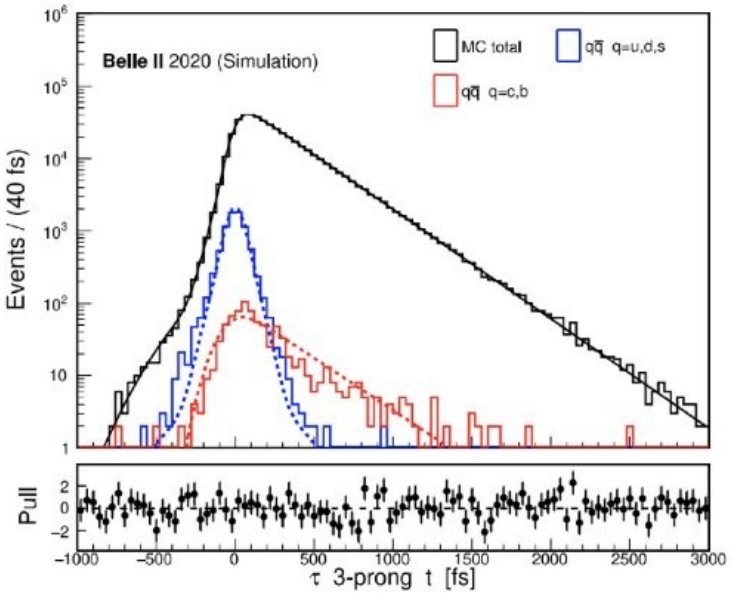
- ℓ_τ reconstruction and IP constrain:

Use constraint on IP_y

$\hat{n}_\tau = \vec{p}_\tau / |\vec{p}_\tau|$

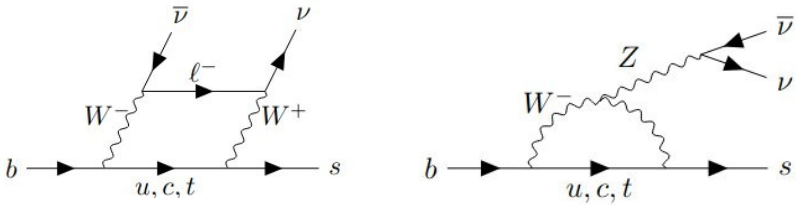
3-prong vertex

$$\vec{IP} + \ell_\tau \hat{n}_\tau = \vec{v}_{3\pi}$$



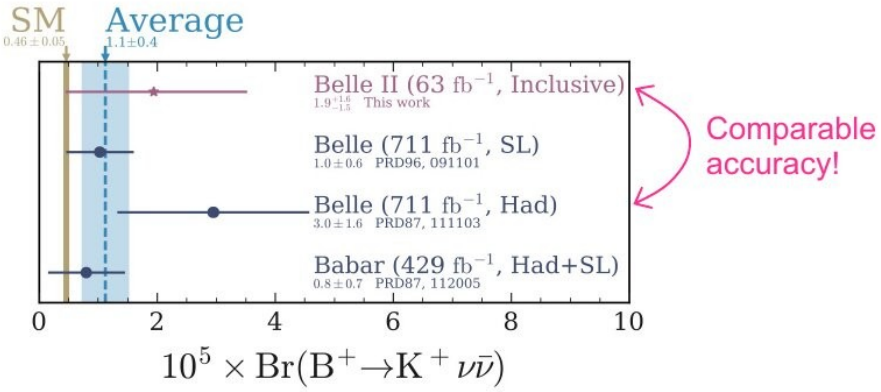
- Lifetime extraction:
  - **τ_τ = 287.2 ± 0.5 (stat) fs**
  - Same statistical uncertainty of Belle.
    (200 fb^{-1} vs 711 fb^{-1})

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

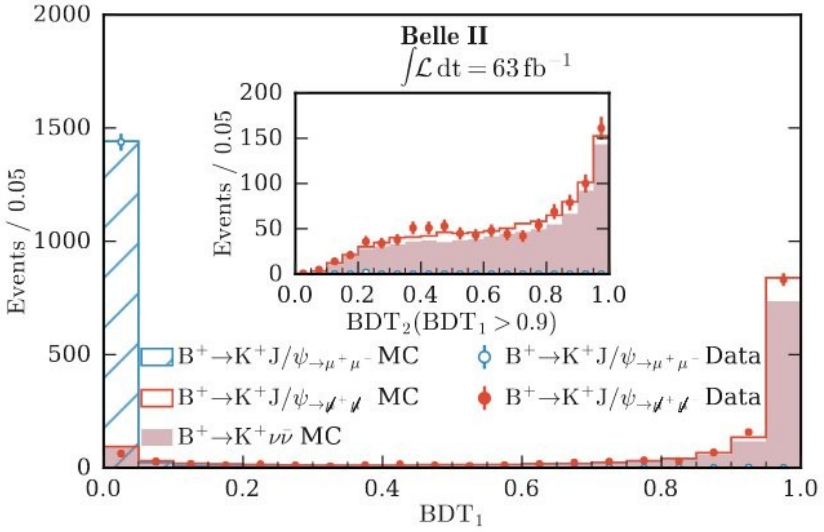


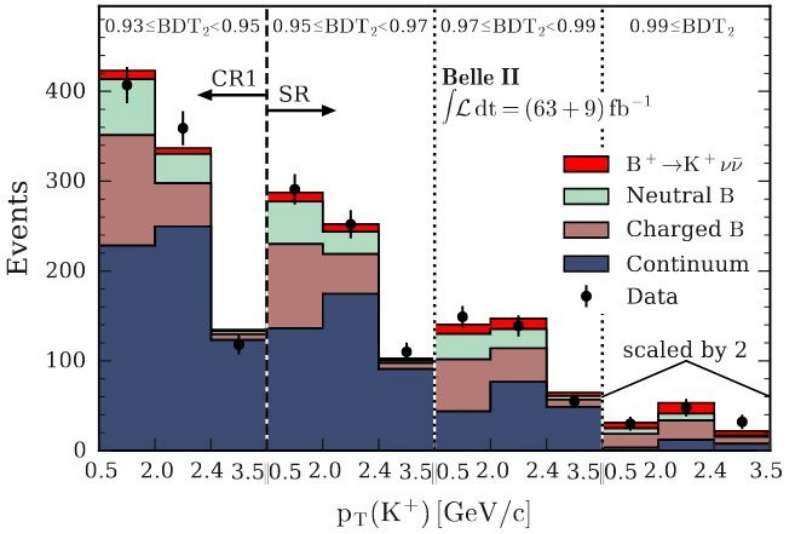
- Flavor changing neutral current
- SM prediction is 4.6 x 10^{-06}
- Enhancement means physics BSM
- Measuring a limit helps in constraining models for Leptoquarks, Axions, Dark matter.

Analysis based in BDT, use well known
$B^+ \to K^+$ J/Ψ is used as validation.
Inclusive tagging: 4% Efficiency (Belle II)
Semileptonic: 0.2 % Efficiency (Belle)



$$Observed\,(Expected)$$
$$B^+ \to K^+ \ \nu\bar{\nu} \ < \ 4.1(1.9)\,x\,10^{-5}\,@\,90\,\%\,CL$$





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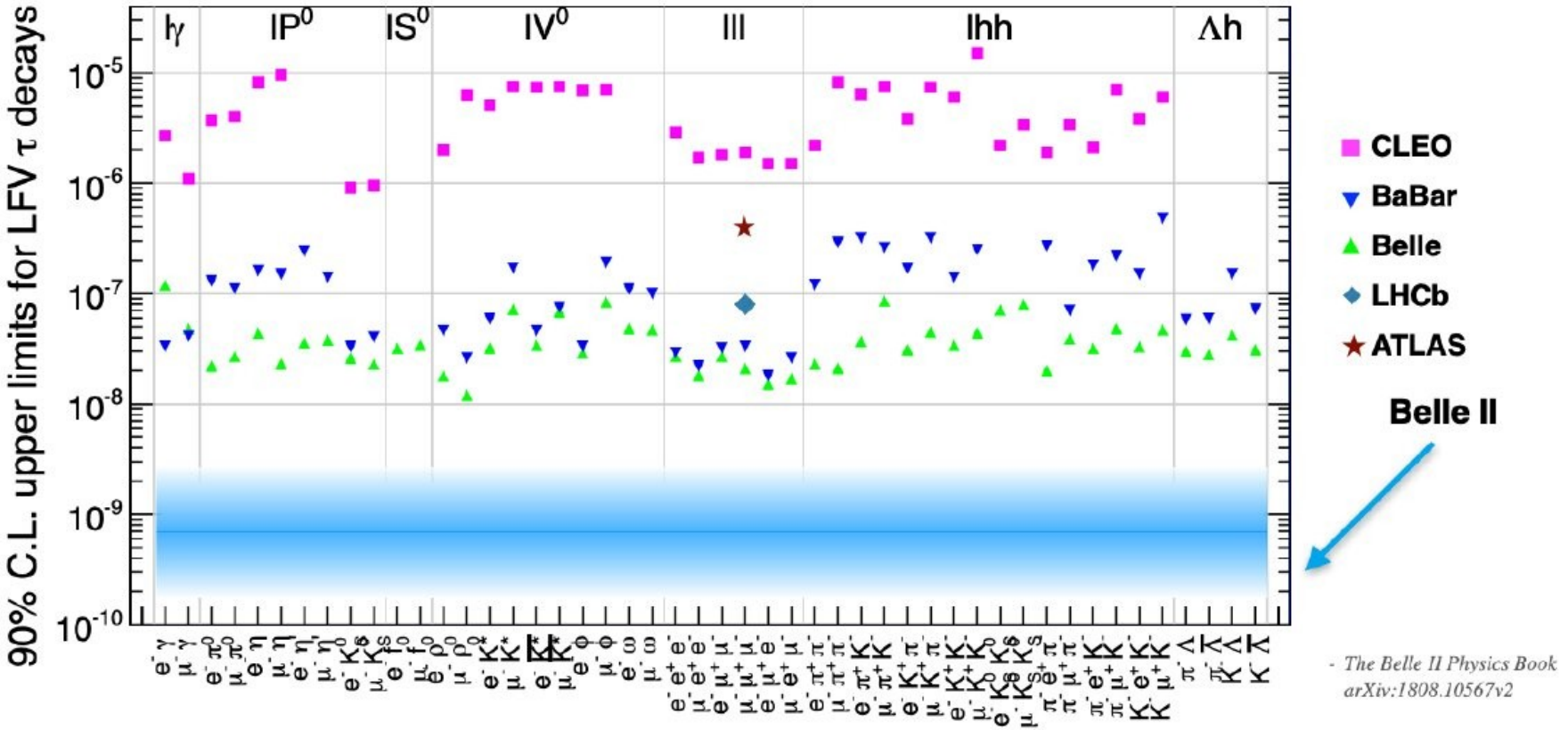
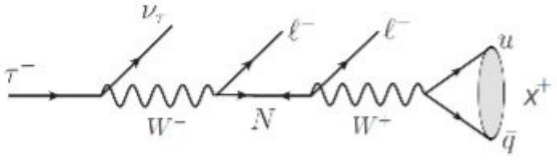
Lepton Flavor violation in τ



- The Belle II Physics Book arXiv:1808.10567v2



Also we can look for LNV !!!

$$\tau^{\mp} \rightarrow X^{\pm} l^{\mp} l^{\mp} \nu_{\tau}$$

The Belle II Physics Book

Conclusions

- SuperKEK is increasing in delivering luminosity. It is hard but we are progressing to achieve goal. Beam Monitoring it is a very promising tool.
- The Upgraded Detector is working smoothly and new tools in Beam, Software, Tagging allowed us to get competitive result with less data than Belle
- First steps in τ physics have been taken. We expect exciting results over the next years in Belle II.
- A very rich physics programs is ahead and we are already having highly competitive results in D lifetimes, $B^+ \to K^+ \nu \bar{\nu}$, Z', ALP, etc
- We are working in multiple searches for NP.

Mucha física bacana, GRACIAS