technische universität dortmund

UNIVERSITÉ Clermont Auvergne

Meeting contribution: $Z \to \tau^+\tau^-$

FCC-ee Meeting in Clermont-Ferrand

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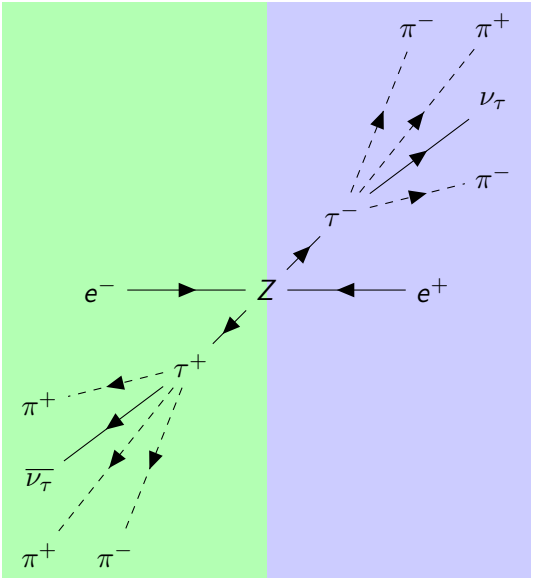
Clermont/Dortmund FCC-ee meeting, November 27

Department of Physics

FUTURE CIRCULAR COLLIDER

LPC Particules PLasmas Univers applicationS
Laboratoire de Physique de Clermont

Reconstruction of $Z \to \tau^- \tau^+$ decays



1. Process:

$e^+ e^- \to Z \to \tau^- \tau^+$

2. Variable of interest:

angle $\theta(e^-, \tau^-)$

- In which direction is the τ^- produced?
- Forward: $\cos(\theta) > 0$
- Backward: $\cos(\theta) < 0$

3. Expectation:

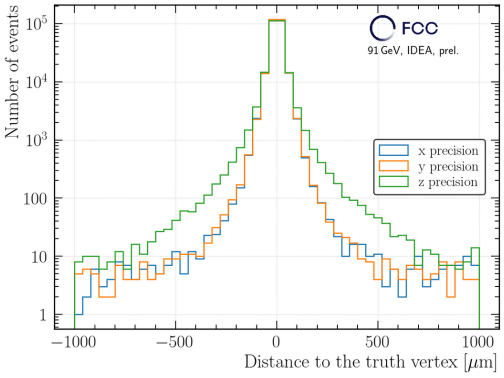
1.7 % more τ^- in Forward direction

4. Goal:

Access angle dependent τ polarization $P_\tau(\cos\theta)$

Vertex Resolution: Problem seems to be factor of 10

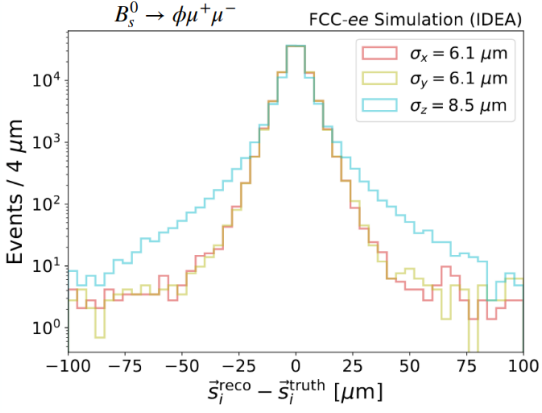
- Vertex positions in mm
- times 1000 for μm



2:00 PM **Time-dependent CP violation in $B_s^0 \to \phi\mu^+\mu^-$ with the IDEA detector concept**

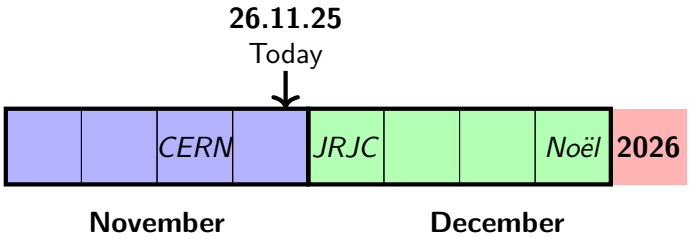
Speaker: Valeriia Lukashenko (University of Zurich (CH))

FCCee_flavour.pdf



Secondary vertex resolution

Timeline: The End of the year



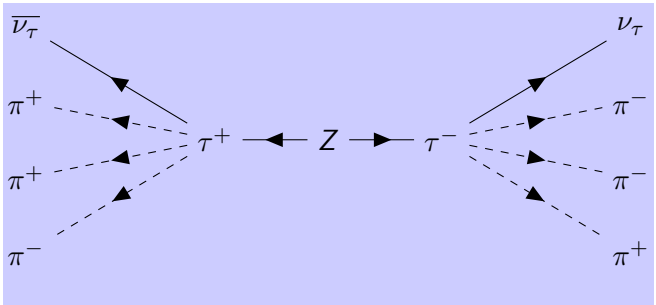
DPG spring meeting 2026:

- 15 - 20 March 2026 in Erlangen-Nürnberg
- Abstract **Deadline: 15 December** 2025
  - Which study should be presented?

ToDo's:

- Documentation (fit)
- Tau-Lifetime Measurement
- ISR correction
- Granularity study?

Thanks for listening!



Thanks for listening!

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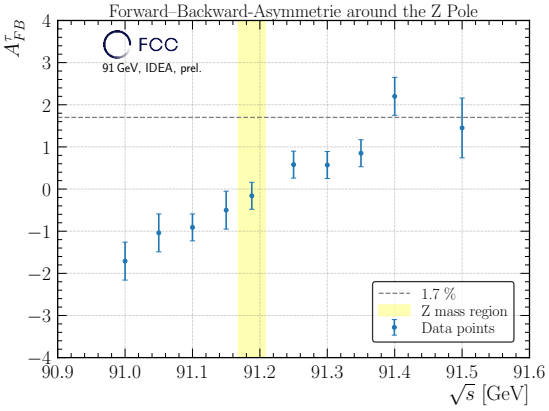
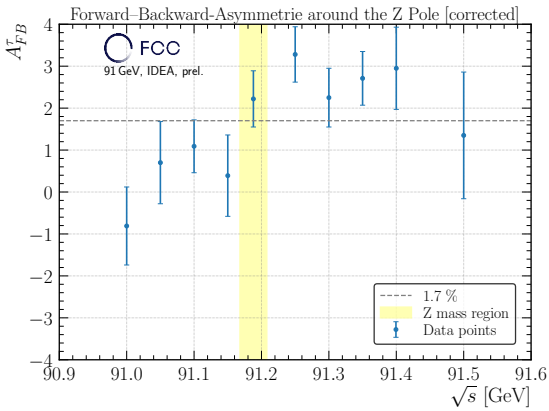
Start of appendix

Last week: Need of ISR correction (boosted Z^0 decays)

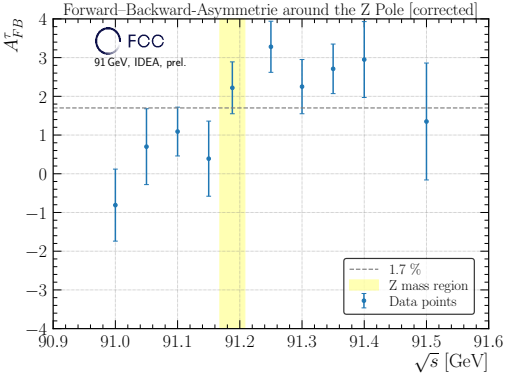
Without Filter:



Only events with Z^0-Boson in rest



Asymmetry in dependence of collision energy



New Value for official sample: (truth data)

Forward-Backward assymetry

$$A_{\text{FB}} = \frac{N_F - N_B}{N_F + N_B} = (1.7 \pm 0.5) \cdot 10^{-3}$$

$$\approx \frac{3}{4} A_e A_\tau \approx 0.017 = 17 \cdot 10^{-3}$$

-------- PYTHIA Event Listing (hard process) ----------

no	id	name	status	mothers	daughters	colours	p_x	p_y	p_z	e	m
0	90	(system)	-11	0 0	0 0	0 0	0.000	0.000	0.000	91.200	91.200
1	11	(e-)	-12	0 0	3 0	0 0	0.000	0.000	45.600	45.600	0.001
2	-11	(e+)	-12	0 0	4 0	0 0	0.000	0.000	-45.600	45.600	0.001
3	11	(e-)	-21	1 0	5 0	0 0	0.000	0.000	43.380	43.380	0.000
4	-11	(e+)	-21	2 0	5 0	0 0	0.000	0.000	-45.600	45.600	0.000
5	23	(Z0)	-22	3 4	6 7	0 0	0.000	0.000	-2.220	88.980	88.952
6	15	tau-	23	5 0	0 0	0 0	-21.701	-4.700	37.398	43.529	1.777
7	-15	tau+	23	5 0	0 0	0 0	21.701	4.700	-39.618	45.451	1.777
			Charge sum: 0.000			Momentum sum:	0.000	0.000	-2.220	88.980	88.952

-------- End PYTHIA Event Listing ----------

Tau polarization ($e^+e^- \to Z \to \tau^+\tau^-$)

Forward-Backward asymmetry ($e^+e^- \to Z \to \tau^+\tau^-$)

- Count τ^+/τ^- in Forward/Backward direction: $A_{\mathrm{FB}} = \frac{N_F - N_B}{N_F + N_B} = \frac{3}{4} A_e A_\tau$

Tau polarization ($e^+e^- \to Z \to \tau^+\tau^-$)

- Average tau polarization: $\langle P_\tau \rangle = -A_\tau$
- Angle dependent τ polarization: $P_\tau(\cos\theta) = -\frac{A_\tau(1+\cos^2\theta)+2A_e\cos\theta}{(1+\cos^2\theta)+2A_\tau A_e\cos\theta}$

- Production angle: $\cos\theta = \frac{\vec{p}_{\tau^-} \cdot \vec{p}_{e^-}}{|\vec{p}_{\tau^-}||\vec{p}_{e^-}|}$

Tau polarization ($e^+e^- \to Z \to \tau^+\tau^-$)

- τ parameters to reconstruct: charge, direction (from decay vertex)

τ leptons

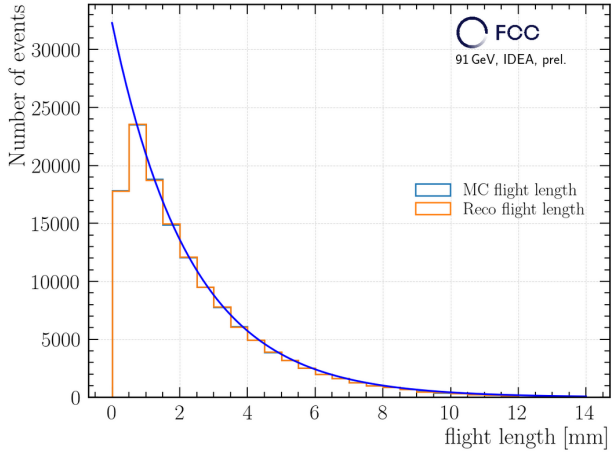
- Very **short lifetime** (3×10^{-13} s)
- Multiple final states possible (leptonic/hadronic(1,3,5,... prong))
- **Undetected neutrinos**

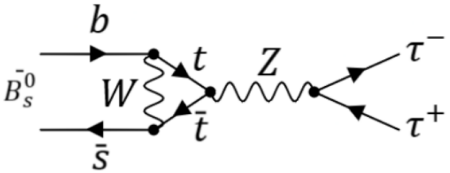
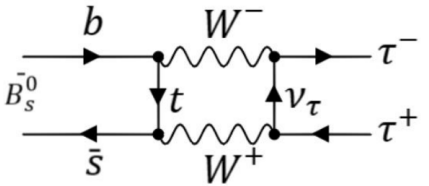
- 1. Reconstruct decay vertex of τ
  - Need of at least 3 prongs
  - Charge comes for free
- 2. Approximate τ momentum $\hat{p}_\tau$ with line reconstructed vertex and primary vertex
  - Good information about the momentum's direction
  - Enhance by reconstruct both sides
  - Loose information of momentum taken by ν_τ
  - Z in rest: $|\vec{p}_\tau| = \sqrt{E_\tau^2 - m_\tau^2} \approx 45,5\text{GeV}$

Lifetime from Vertex postion test

```
x = np.linspace(0,14,100)
VIEW  INSERT  CELL  KERNEL  WIDGETS  HELP
y = (1 / L_mean) * np.exp(-x / L_mean)*(len(mc)/1.8)
plt.plot(x, y)

plt.show()
```



Outlook: Tau polarization ($Z \to \tau\tau$ & $B_s^0 \to \tau\tau$)

- Decay is **suppressed** the **SM** ($< 7.8 \times 10^{-7}$)