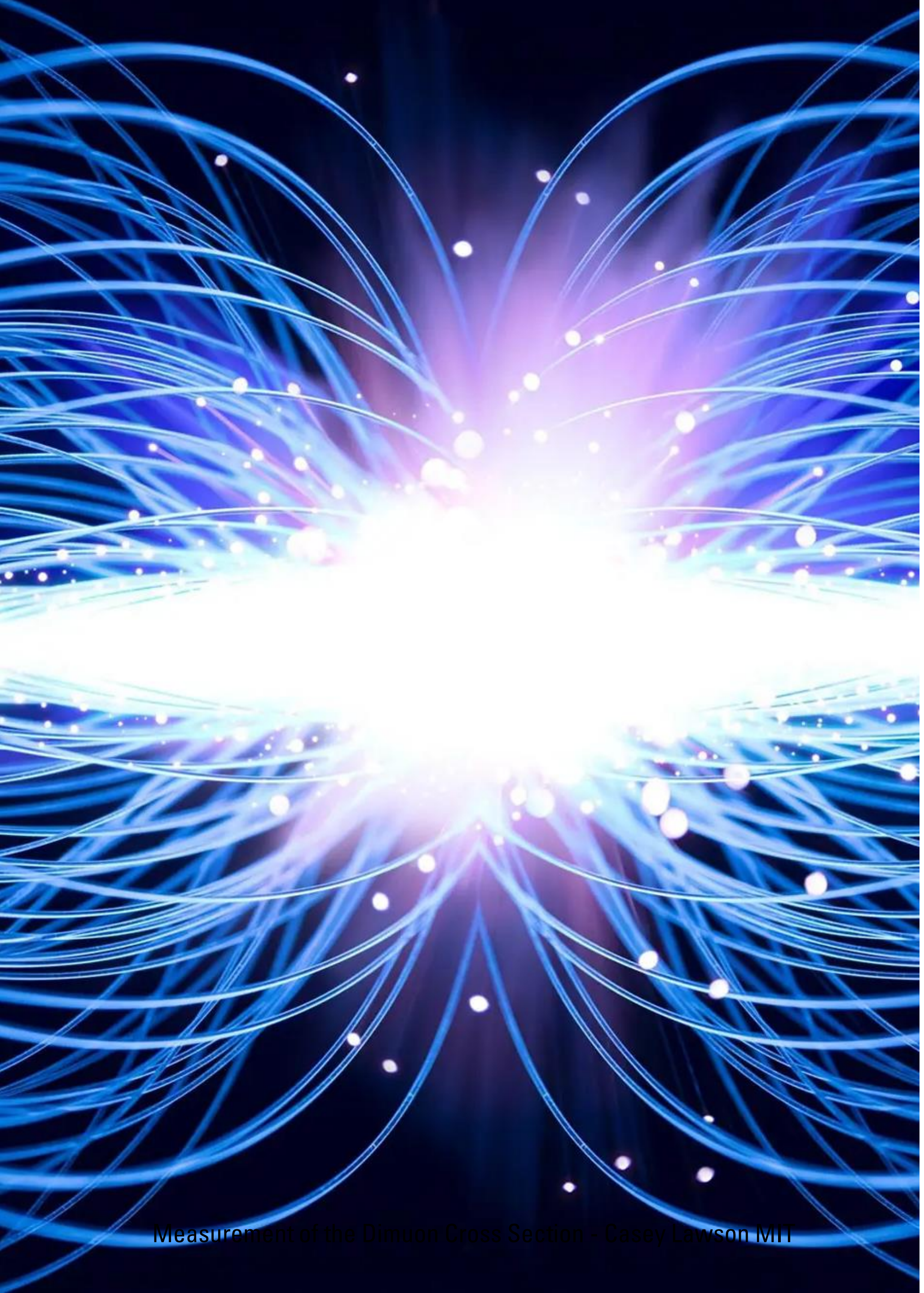
MEASUREMENT OF THE DIMUON CROSS SECTION

Casey Lawson



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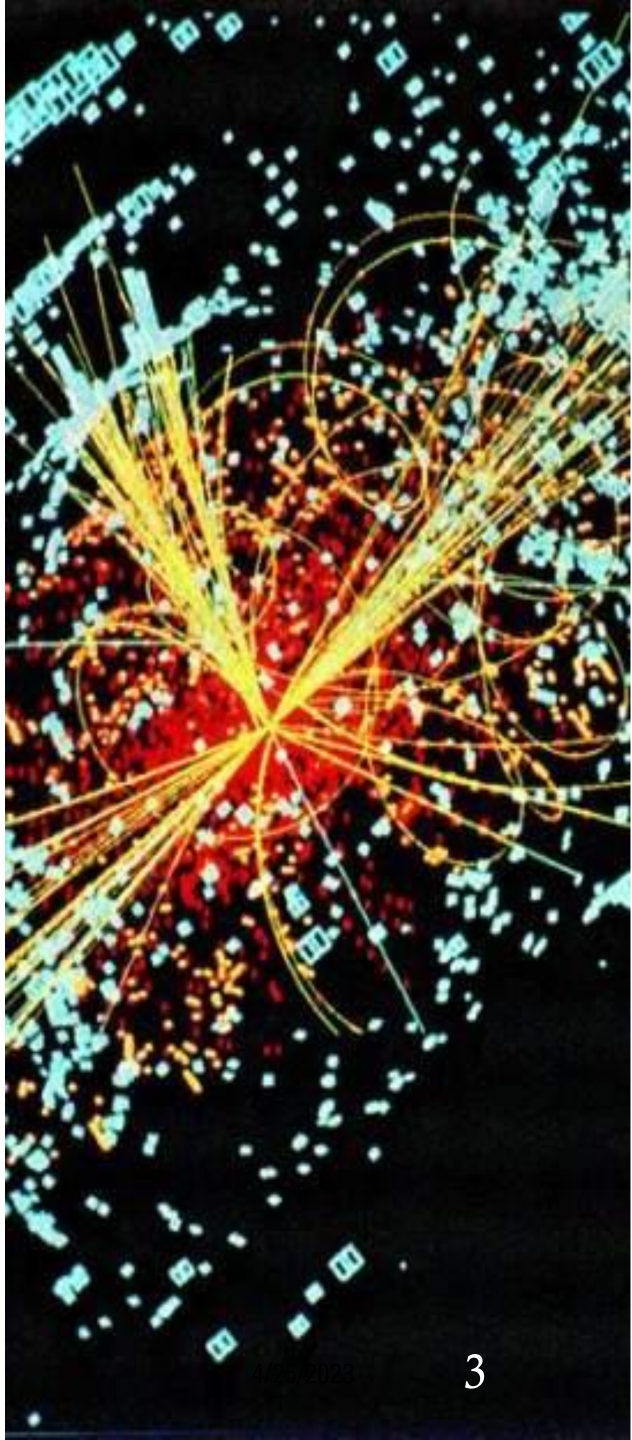
MONTE CARLO SIMULATION

- Samples generated using Whizard and KKMC
- Detector simulation setup in Delphes: IDEA
- Input parameters for luminosity and cross section at 91.2 GeV

91.2 GeV Samples	Generator	Number of Events	Cross Section
$e^+e^- \to \mu^+\mu^-$	KKMC	$9.94 * 10^7$	1515.562
$e^+e^- \to \tau^+\tau^-$	Whizard	$8.45 * 10^6$	1716.135
$e^+e^- \to e^+e^-\mu^+\mu^-$	Whizard	$9.98 * 10^7$	535



CROSS SECTION

$$\sigma = \frac{N_{obs} - N_{bkg}}{A \cdot \varepsilon \cdot L_{int}}$$

Describes a probability that two particles will interact

- Units of area [b]
- Depends on energy and type of particle

$N_{obs} = number\ of\ observed\ events$

$N_{bkg} = number\ of\ background\ events$

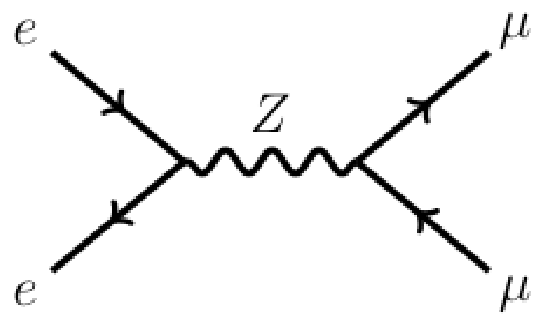
$L_{int} = Integrated\ Luminosity$

$A = Acceptance$

$\varepsilon = Efficiency$

Signal event:

e+e− → μ+μ− at 91 GeV Dimuon production



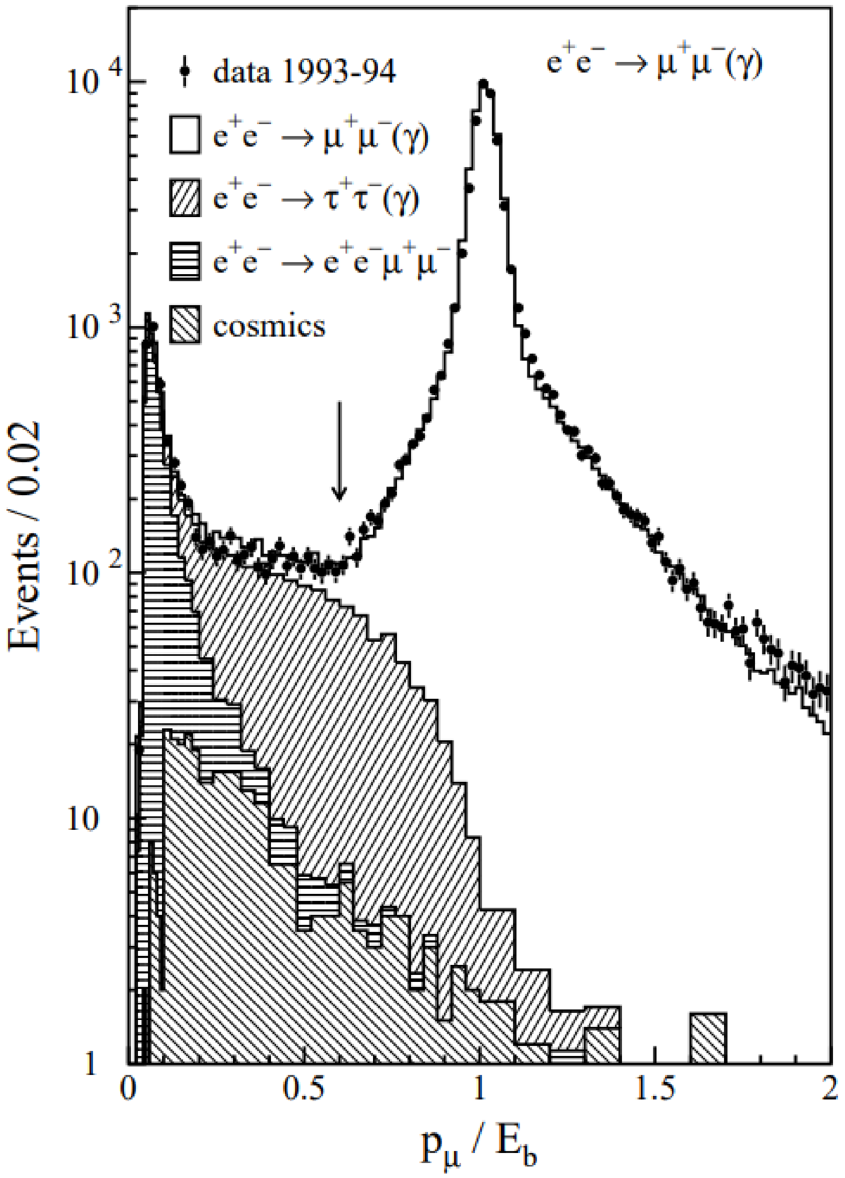
THE L3 COLLABORATION

Measurements of cross sections and forward-backward asymmetries at the Z resonance and determination of electroweak parameters

- Initial parameters for our Monte Carlo simulation
  - LEP Beam L_{int}= 103 pb^{-1}
- Background events

  $e^+e^- \rightarrow \tau^+\tau^-$

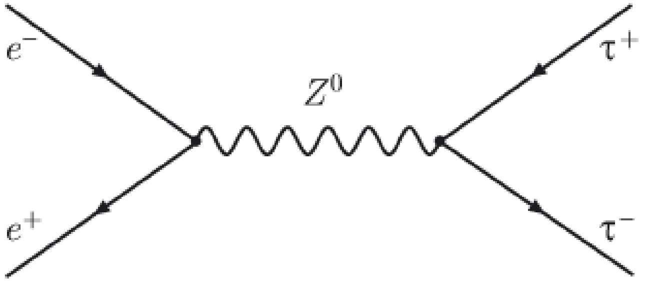
  $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$
- Initial cuts
  - 2 lepton events
  - Cuts on lepton momentum, acolinearity and |cos(θ)|
- Compare results graphically

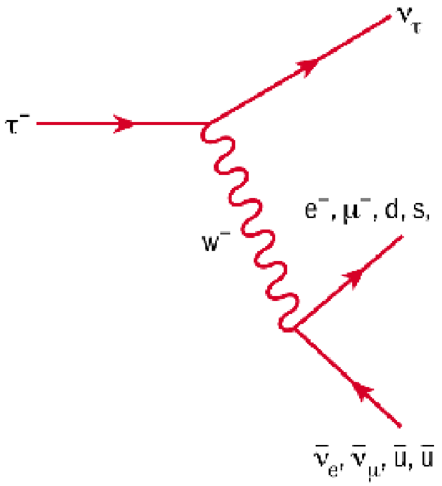


BACKGROUND EVENTS

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

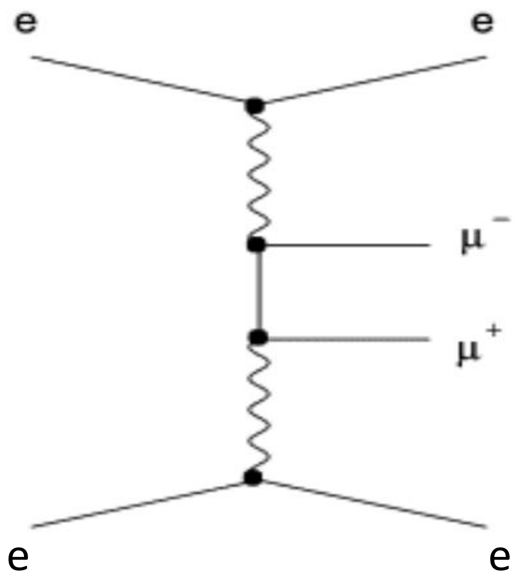
- Requires both taus to decay to a muon
- 17.39% for decay into a tau neutrino, muon, and muon antineutrino
- Cut on muon momentum and acolinearity





$e^+e^- \to e^+e^-\mu^+\mu^-$

- e^+e^- each produce a photon, which collide and create muons
- e^+e^- very forward, likely in beampipe



MUON MOMENTUM

Cut on Maximum Muon Momentum:

$$P_{max} \geq .6\, E_b$$

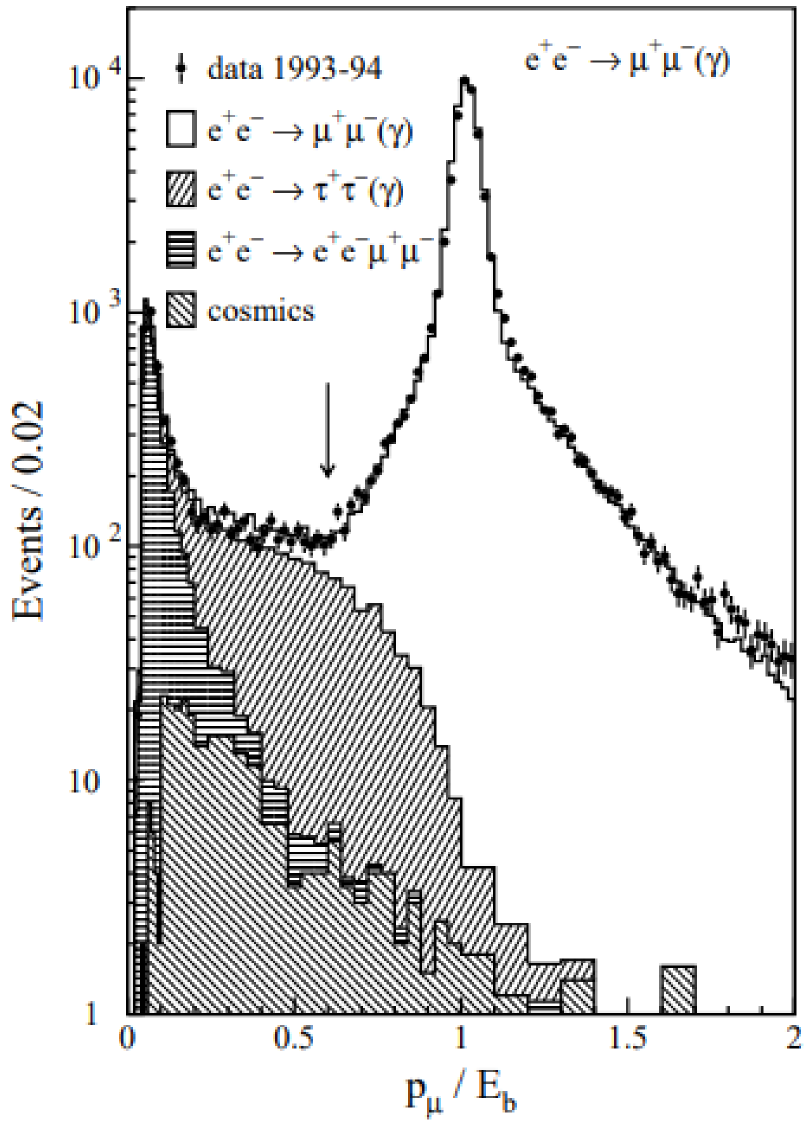
Observations:

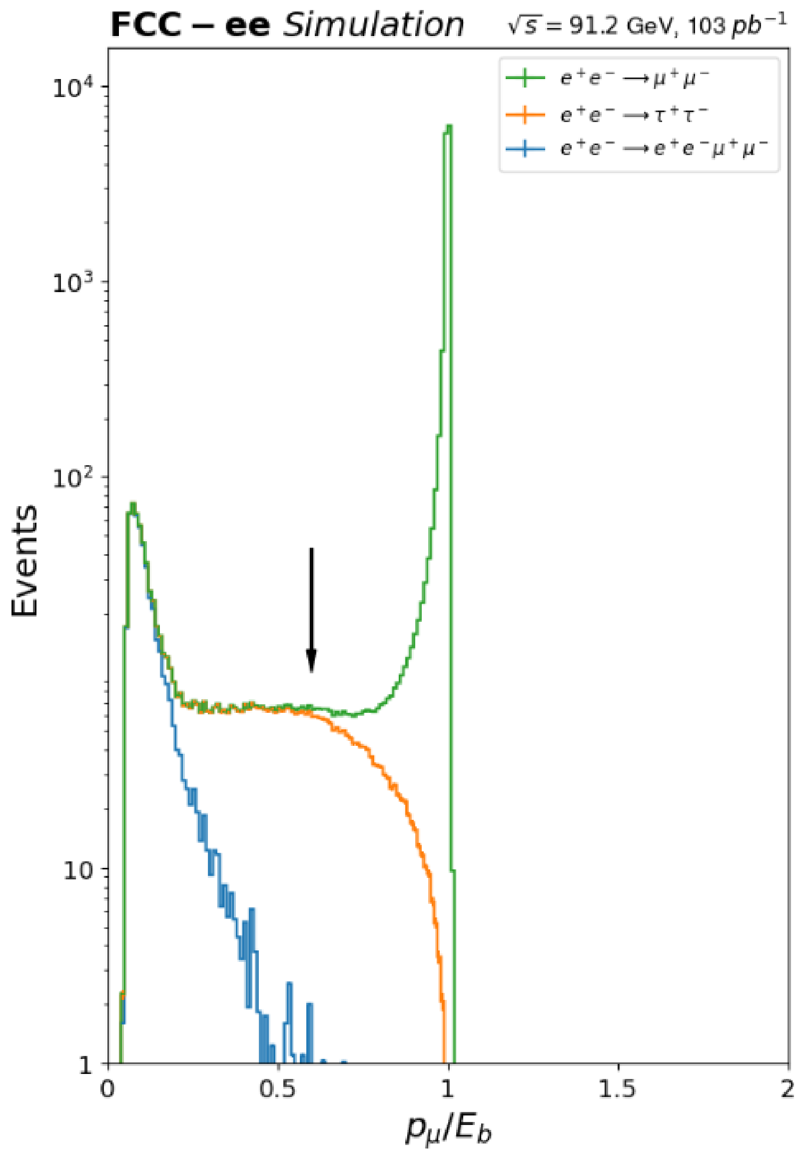
- Resolution on FCC detector is much more precise
- Should improve our cut

Note: Cosmic background is likely negligible

- Difficult to simulate, but if we know the time range of our collision, we can select for that time range and cut out most cosmic background

L3 Collaboration





ACOLINEARITY

Cut on acolinearity angle:

$$Acolinearity < 90°$$

Observations:

- Shape doesn't change much
    - Physics driven, less dependent on detector resolution

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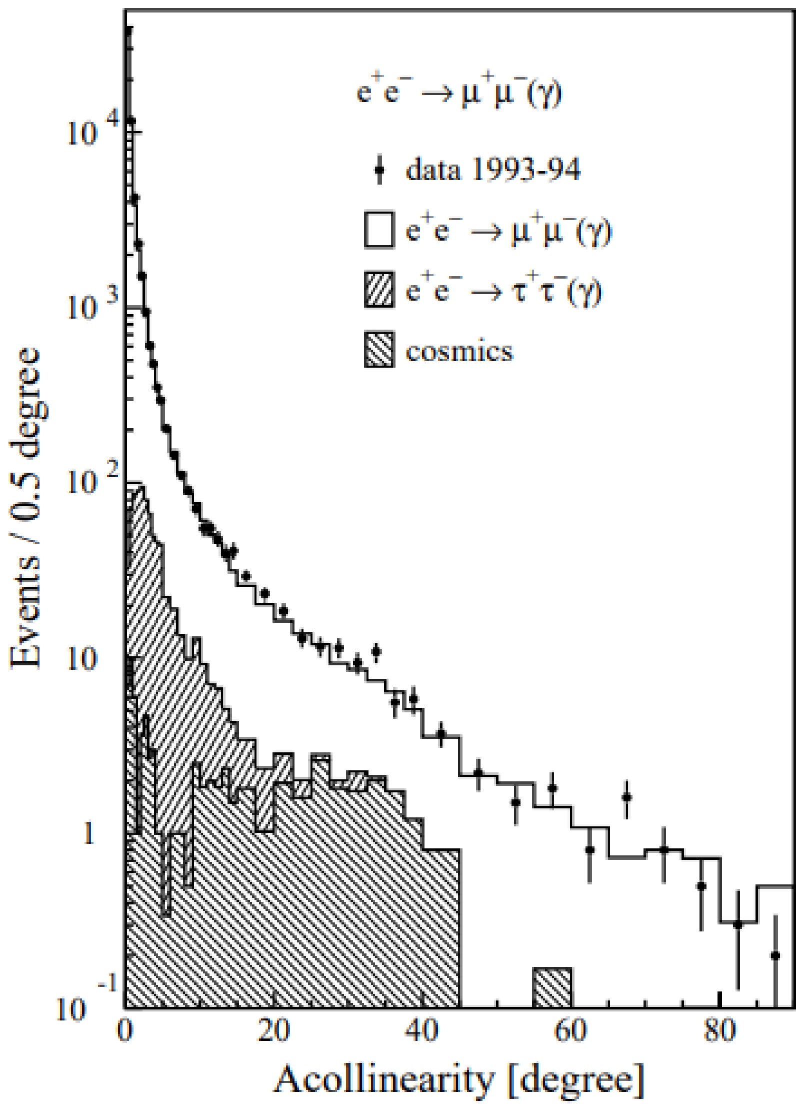
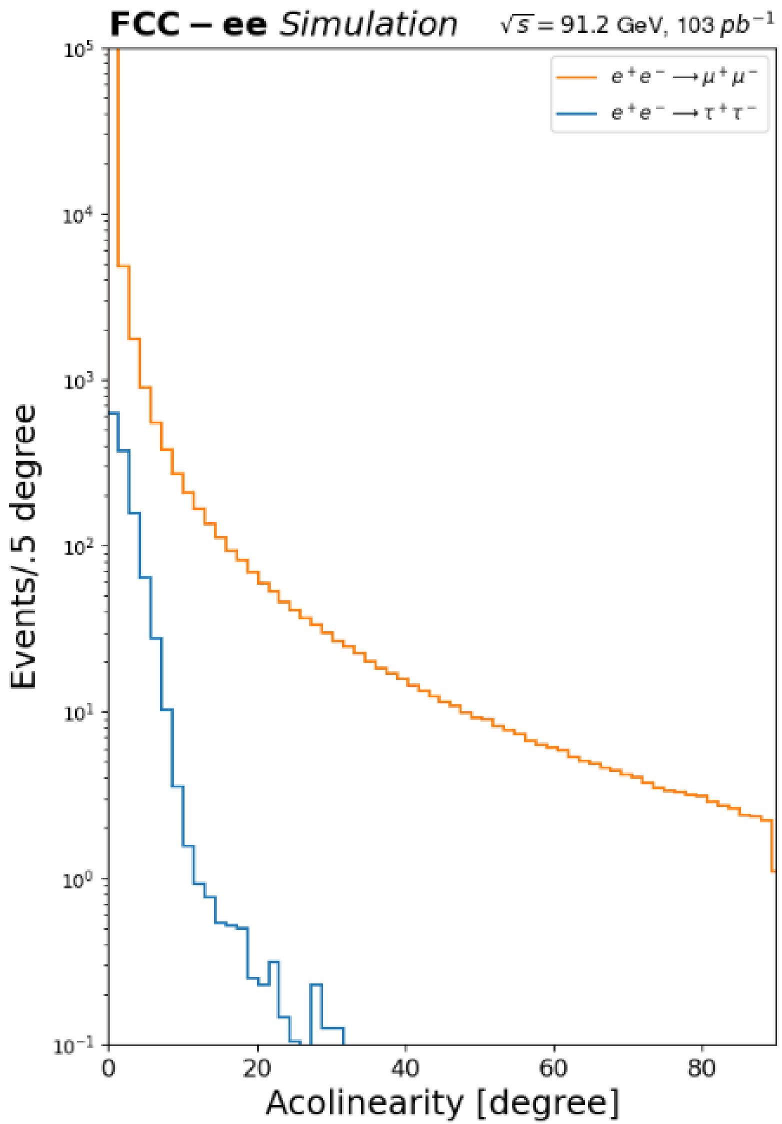
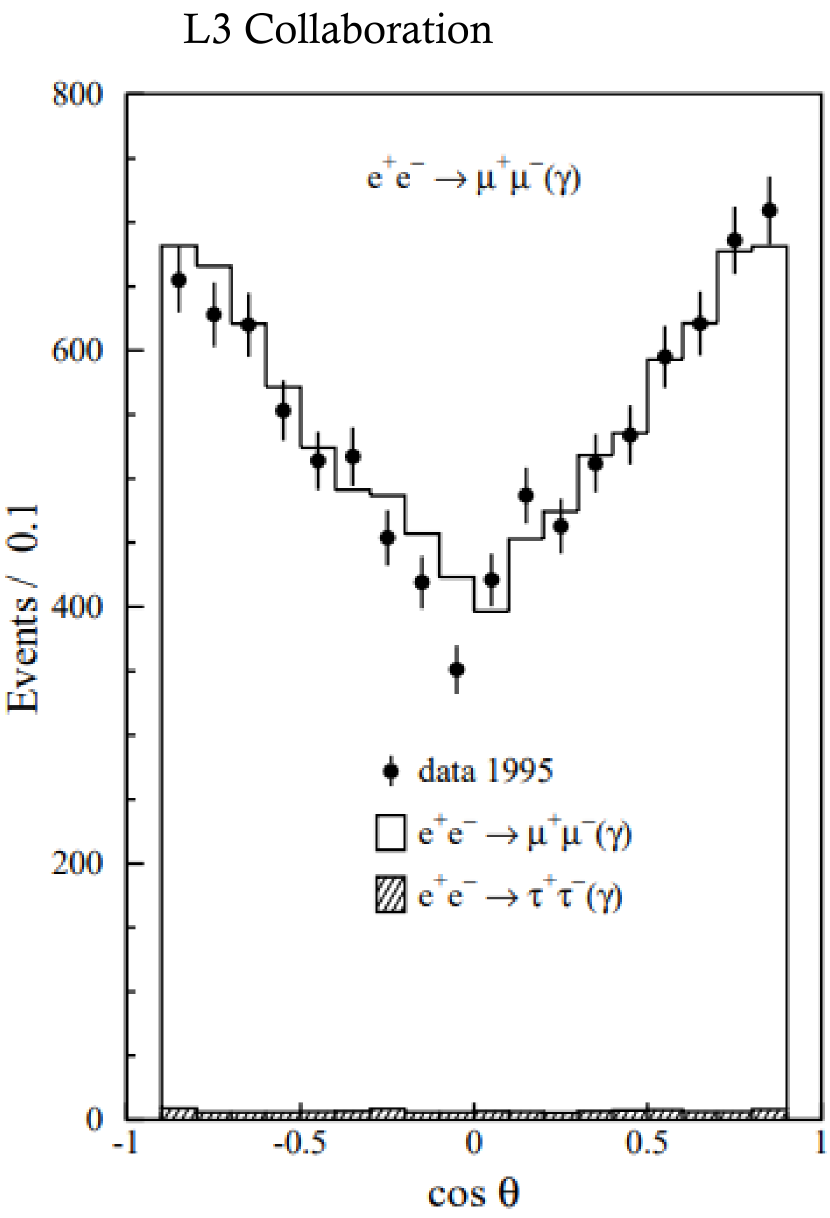


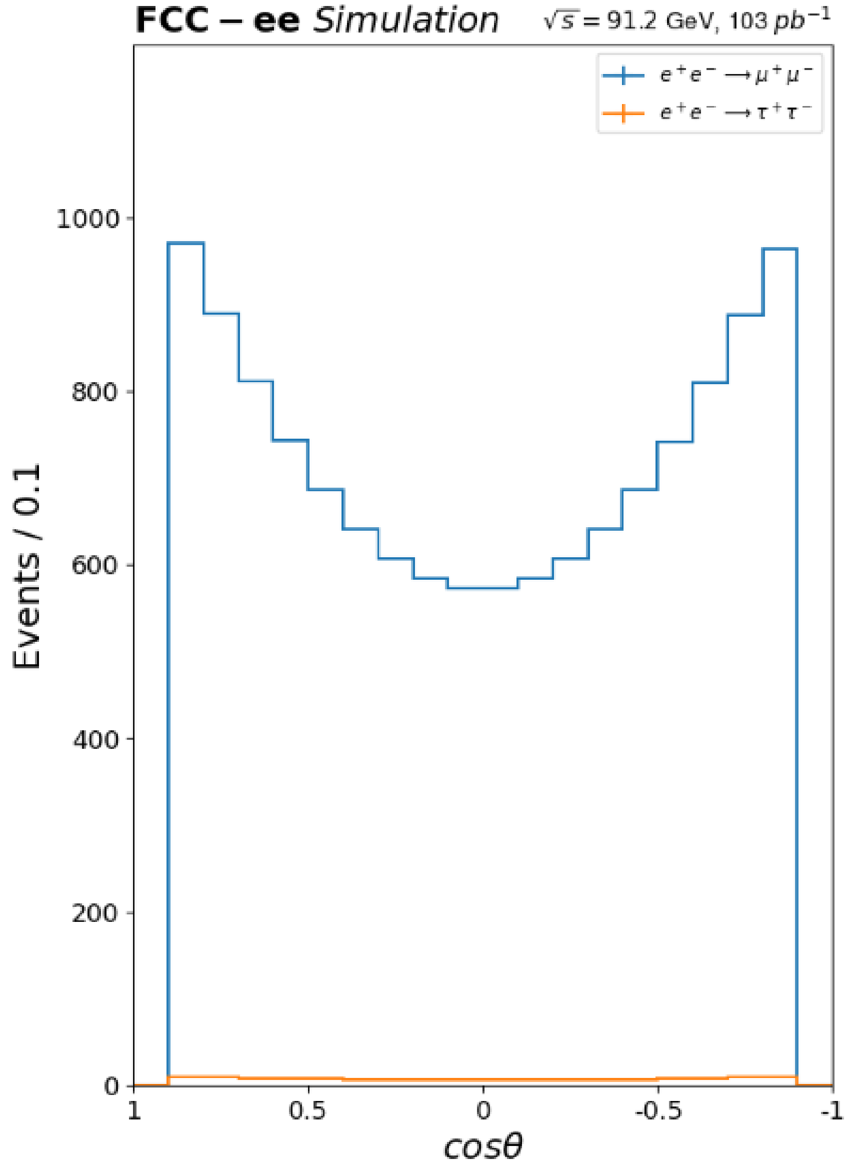


COS (Θ)

Distribution of the polar angle defined by the negative muon

|cos θ| < 0.9





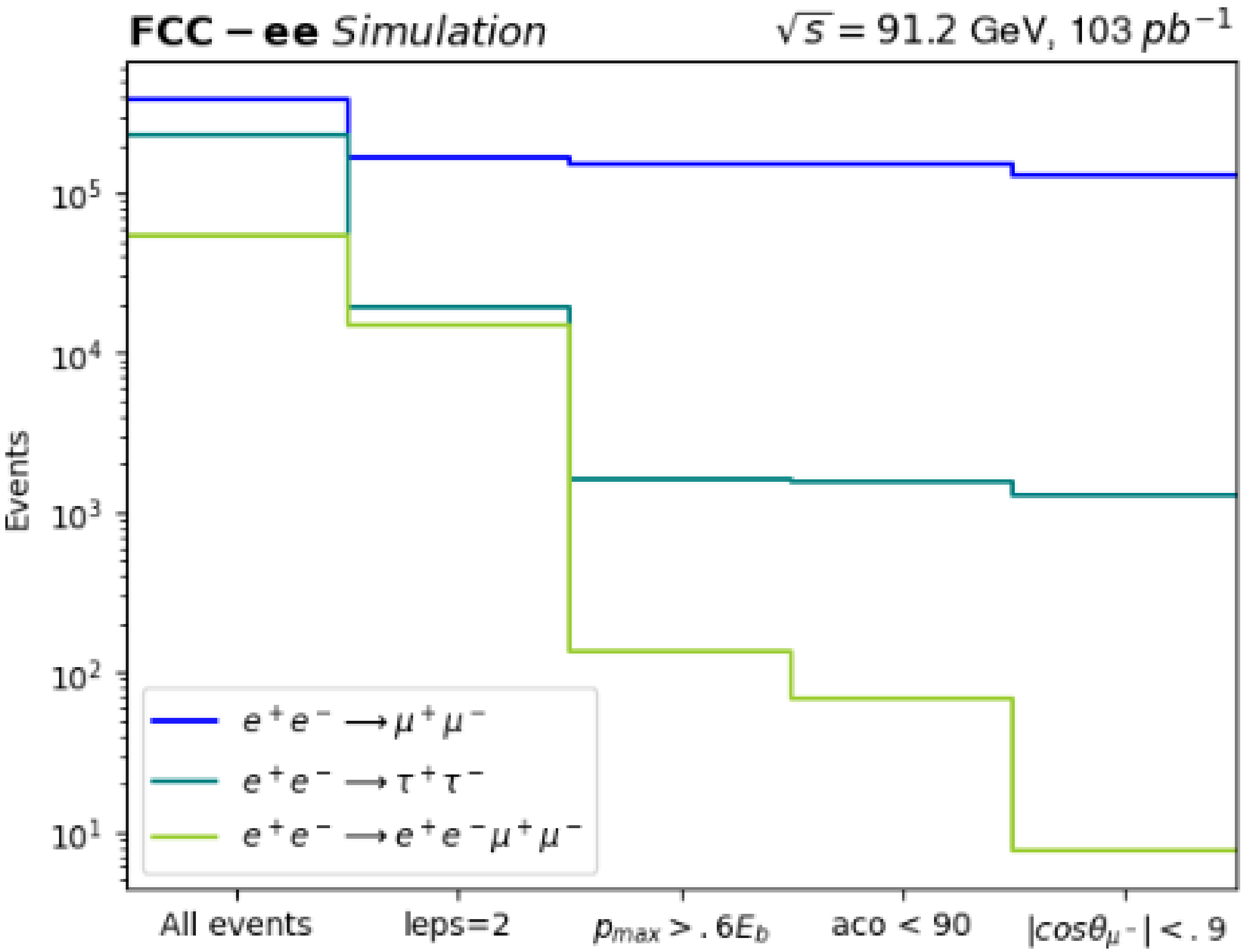
ACCEPTANCE

$$Acceptance = N_{selected}/N_{total}$$

Event	Acceptance
e+e− → μ+μ−	83.25 %
e+e− → τ+τ−	.73 %
e+e− → e+e−μ+μ−	$1.3 * 10^{-4}$ %

Lose the most events at lep = 2 cut

- Critical to have a detector that covers the largest possible fiducial volume



CALCULATING DIMUON CROSS SECTION

$N_{obs} - N_{bkg}$ = 1.3*10^5 events

Acceptance = 83.25 %

L_{int}= 103 pb^{-1}

$$\sigma = \frac{N_{obs} - N_{bkg}}{A \cdot \varepsilon \cdot L_{int}} = 1515 \pm 4 \text{ pb}$$ (Input of our Monte Carlo)

Note on Efficiency Measurement:

- Delphes simulation set to 99% efficient, which is inaccurate for actual detector
- FCC detector efficiency can be determined by having 2 layers to detect muons
  - Inner Tracker
  - Muon Chamber

SOURCES OF UNCERTAINTY

1. Data Statistics

- Uncertainty based on Gaussian statistics

$$Statistical\ Uncertainty = \sqrt{N_{obs} + N_{Background}}$$

2. Systematic Uncertainties

- Characteristic of Monte Carlo Simulation

$$Acceptance\ Uncertainty = \sqrt{\frac{\frac{N_{selected}}{N_{Total}} \cdot (1 - \frac{N_{selected}}{N_{Total}})}{N_{Total}}}$$

3. Luminosity

- From LEP paper

Luminosity Uncertainty= .9 ‰

TOTAL UNCERTAINTY

$$\sigma = \frac{N_{obs} - N_{bkg}}{A \cdot \varepsilon \cdot L_{int}}$$

$$Total\ Uncertainty = \sqrt{\left[\frac{\partial\sigma}{\partial N_{obs}}^{2} \cdot (\sigma_{N_{obs}} + \sigma_{N_{bkg}})^{2}\right] + \left[\frac{\partial\sigma}{\partial A}^{2} \cdot \sigma_{A}^{2}\right] + \left[\frac{\partial\sigma}{\partial L_{int}}^{2} \cdot \sigma_{L_{int}}^{2}\right]}$$

Source	Absolute Uncertainty [pb]	Percent Uncertainty
Statistical	4.24	2.8 ‰
Acceptance	.068	.04 ‰
Luminosity	1.37	.9 ‰
Total	4.46 pb	2.9 ‰

FCC

- Monte Carlo events normalized with new luminosity
  - KKMC for signal events, WHIZARD for background events
- Optimize cuts and compare uncertainties

	Luminosity $[ab^{-1}]$	Total Signal Events
L3	$1.03 * 10^{-4}$	$1.5 * 10^{5}$
FCC	150	$1.5 * 10^{11}$

OPTIMIZING THE CUT ON MUON MOMENTUM

$$Significance = \frac{signal}{\sqrt{signal + background}}$$

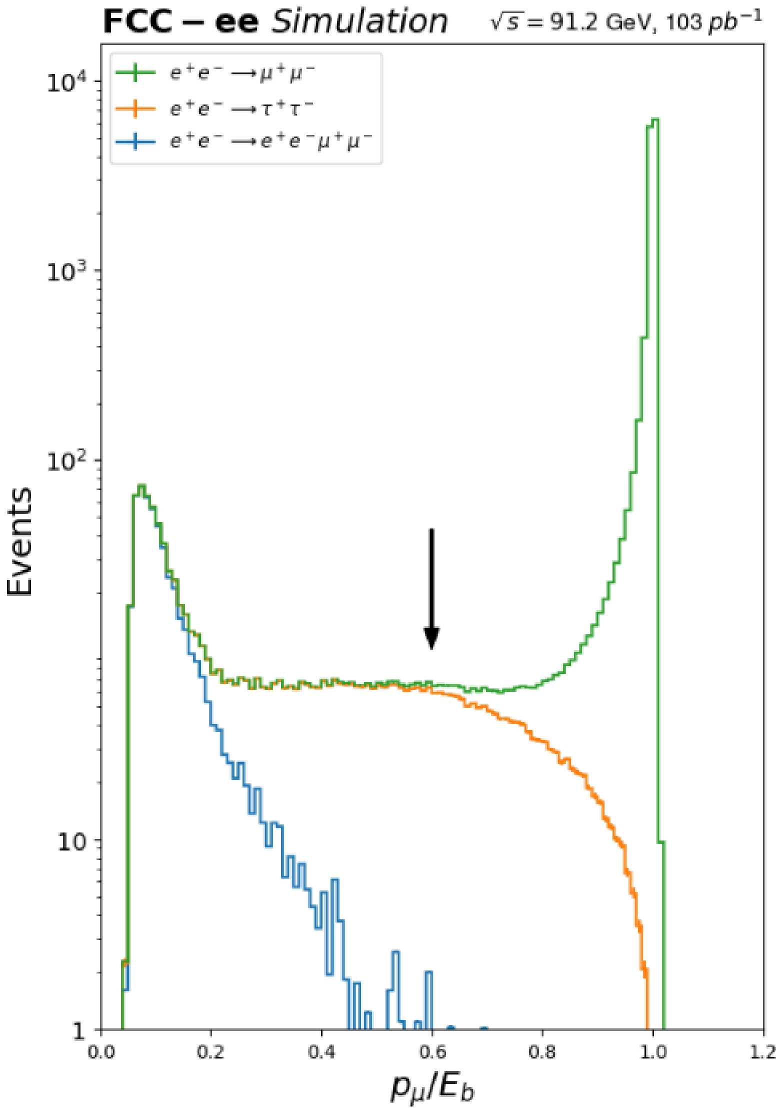
Old Cut: $\frac{\rho_\mu}{E_b} \geq .6E_b$

$Significance = 379.53$

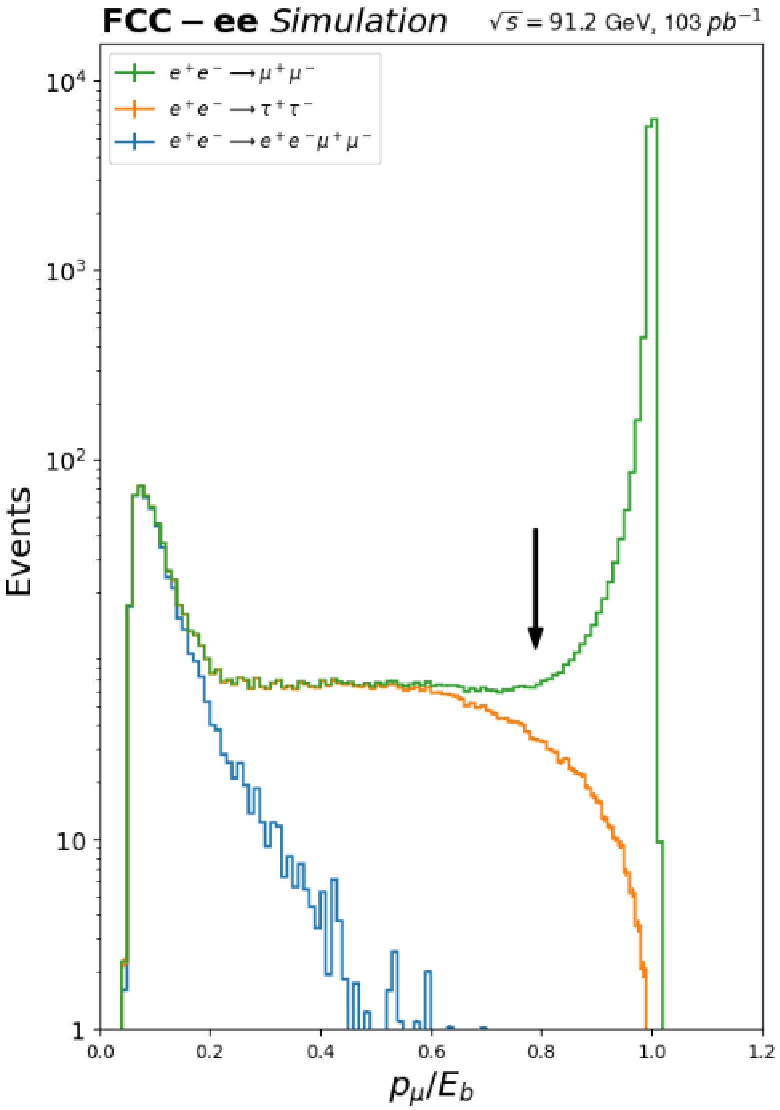
Optimized Cut: $\frac{\rho_\mu}{E_b} \geq .79E_b$

$Significance = 380.36$

Old Cut: $\frac{\rho_\mu}{E_b} \geq .6E_b$

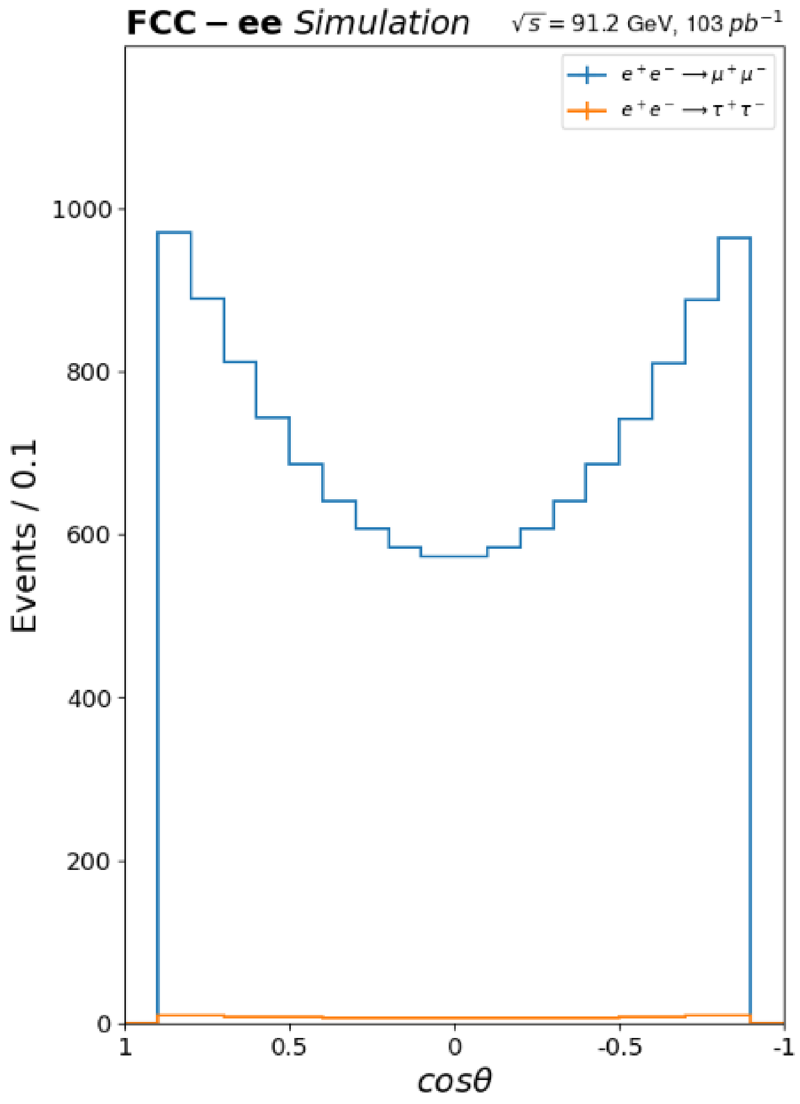


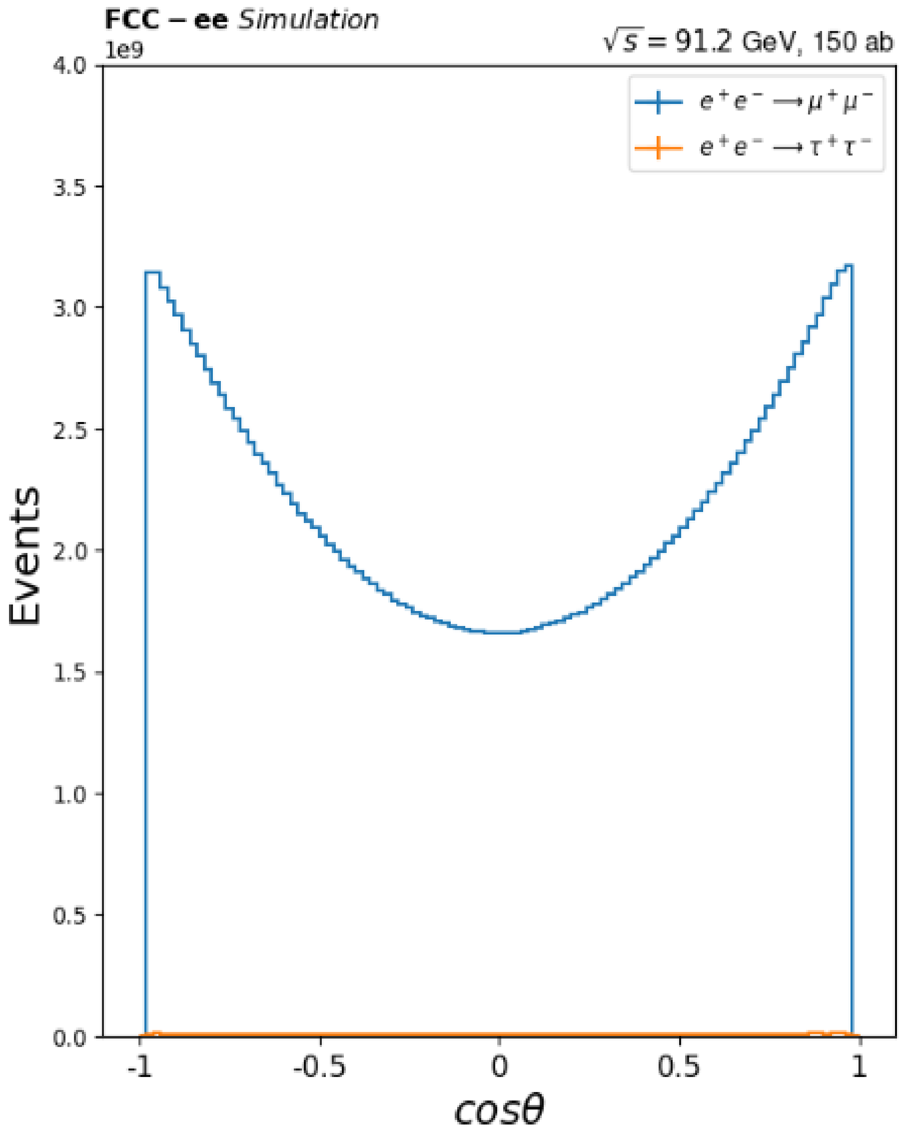
New Cut: $\frac{\rho_\mu}{E_b} \geq .79E_b$



COS THETA

- Old Cut: $|\cos\theta| < 0.9$
- New Cut: $|\cos\theta| < 0.98$





ACCEPTANCE FOR FCC

e+e– → μ+μ–

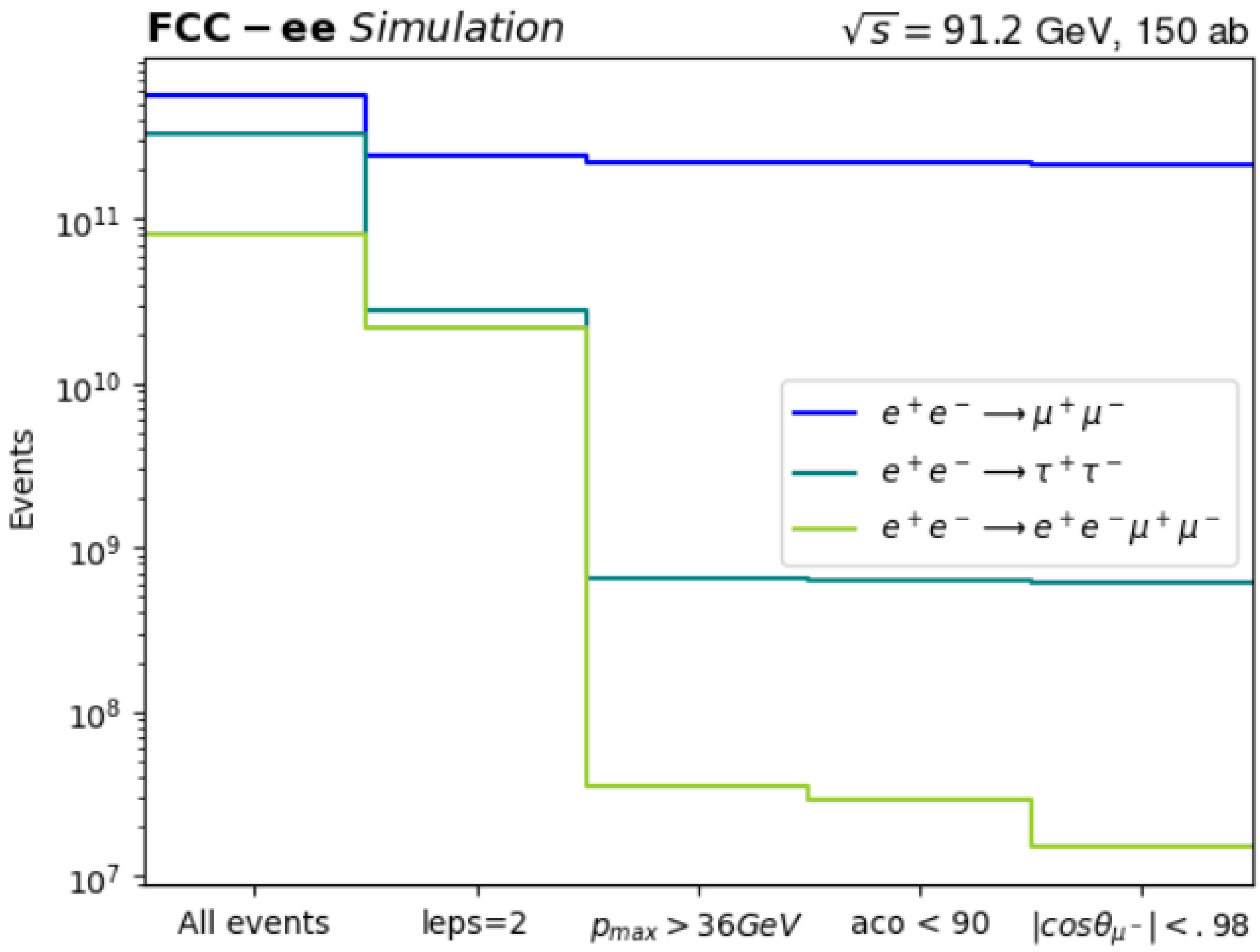
$Acceptance\ = 94.25\ \%$

e+e– → τ+τ–

$Acceptance\ =.23\%$

e+e– → e+e–μ+μ–

$Acceptance\ = 1.8 * 10^{-4}\ \%$



COMPARING UNCERTAINTIES

Source	L3 Replication	FCC
Statistical [‰]	2.8	.002
Acceptance [‰]	.04	.02
Luminosity [‰]	.9	.1
Total Uncertainty	2.9 ‰	.1 ‰

Need many more Monte Carlo Events to bring these uncertainties down. Ideally, we would like to simulate all the events we expect from the FCC

Additional Sources of Systematic Uncertainty to consider:

- Beam Energy Spread
- Final State Radiation

SYSTEMATIC UNCERTAINTIES

Examining with and without Final State Radiation

	Total Events	Acceptance
FSR on	$1.56 * 10^5$	94.582 ± .002 %
FSR off	$1.56 * 10^5$	94.248 ± .002%

Examining Beam Energy Spread ± 1%

	Total Events	Acceptance
Beam Energy +1%	$1.56 * 10^5$	94.249 ± .002 %
Beam Energy -1%	$1.56 * 10^5$	94.250 ± .002 %

Statistical Uncertainty of acceptance = .002%

.3% change in acceptance

- Switching off FSR is drastic, since the FSR describes the data well, so this is an extreme estimate

Within our statistical fluctuations

- Need to produce more Monte Carlo Events to assess the real systematic uncertainty

CONCLUSION

Important elements to consider:

- Additional sources of uncertainty
  - Location of detector could be a significant source of uncertainty
- Measuring detector efficiency by measuring independent muon events

Improving our Monte Carlo Simulation

- Add more events and ensure accuracy

THANK YOU

Thank you to Christoph Paus And Jan Eysermans

Sources:

The L3 Collaboration: *Measurements of cross sections and forward-backward asymmetries at the Z resonance and determination of electroweak parameters*