Tau Polarimetry Update

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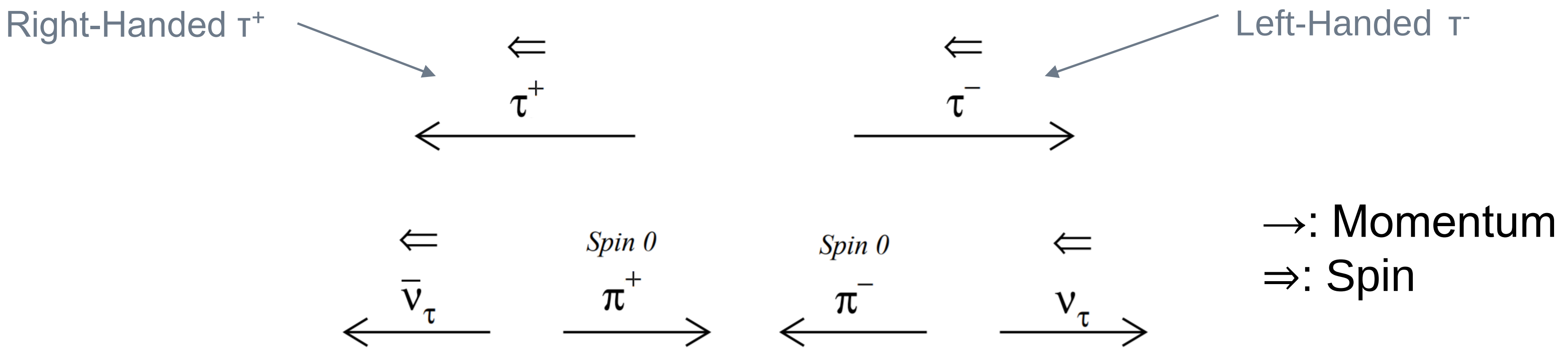
Tau Polarimetry

- The polarization of tau's (P_τ) produced in e^+e^- collisions at 10.58 GeV is related to the electron beam polarization (P_e) through:

$$P_{\tau^-} = P_e \frac{\cos\theta}{1+\cos^2\theta} - \frac{8G_F s g_V^\tau}{4\sqrt{2}\pi\alpha}\left(g_A^\tau \frac{\overrightarrow{|p|}}{p^0} + 2g_A^e \frac{\cos\theta}{1+\cos^2\theta}\right)$$

Note: cosθ defined as the polar angle of the τ^- with respect to the electron beam

- Tau polarization information can be extracted from the kinematics of the tau decay



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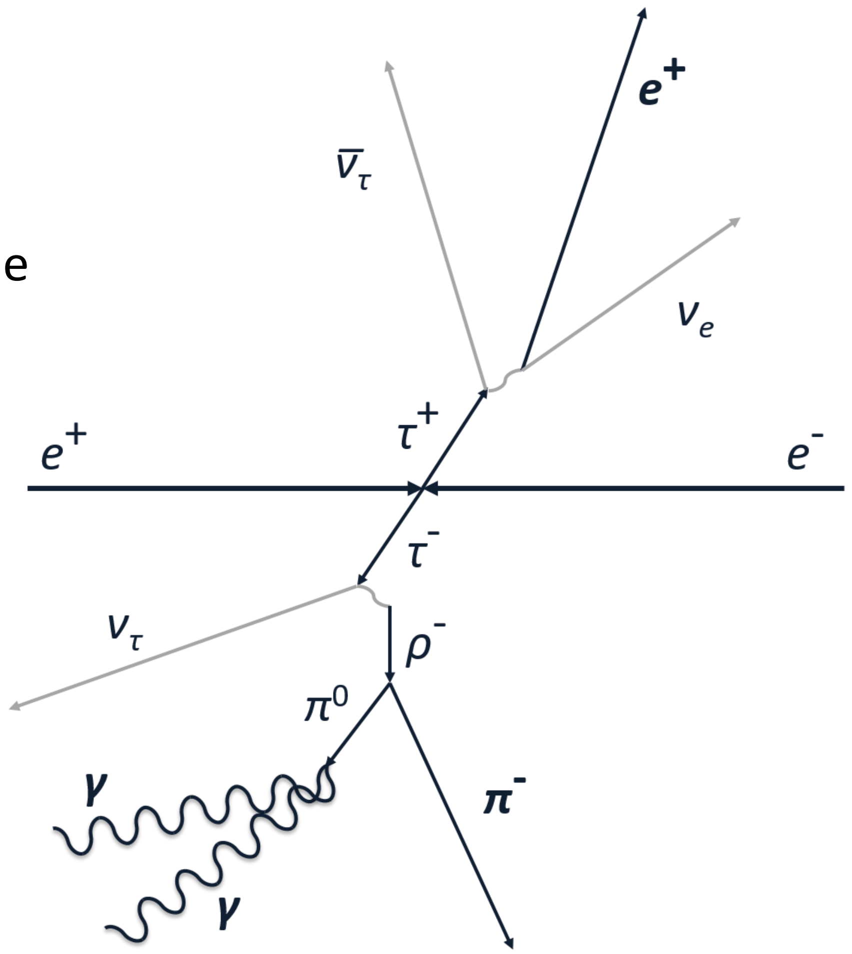
Tau Event Selection

- As a proof of concept, we have developed Tau Polarimetry at *BABAR* using $\tau^\pm \rightarrow \rho^\pm\nu_\tau \rightarrow \pi^\pm\pi^0\nu_\tau$ decays
- We expect uncertainties to be highly correlated between detectors due to similar designs
- Final measurement performed on total 424.18 fb^{-1}
- Selected tau events in a 1v1 topology, (ρ vs. e or mu)
  - ρ has large branching fraction, e or mu for clean tag
- Signal candidates are defined as a charged particle with a π^0
- $q\bar{q}$ events are eliminated with the lepton requirement
- Angular cuts and a minimum p_T of 350 MeV reduce two photon and Bhabha contamination



- Achieve a 99.9% pure tau-pair sample (0.05% Bhabha,0.05% $\mu^+\mu^-$)
- 88% of selected events contain a $\tau^\pm \rightarrow \pi^\pm\pi^0\nu_\tau$ decay
  - 10% a1 decays, 2% other hadronic

Final systematics

- 21 contributions
- Neutrals dominate 6/7 top systematics

Source	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Combined
π^0 Efficiency	0.0025	0.0016	0.0013	0.0018	0.0006	0.0017	**0.0013**
Muon PID	0.0018	0.0018	0.0029	0.0011	0.0006	0.0016	**0.0012**
Photon Split-off Modelling	0.0015	0.0017	0.0016	0.0006	0.0016	0.0020	**0.0011**
Neutral Energy Scale	0.0027	0.0012	0.0023	0.0009	0.0014	0.0008	**0.0010**
π^0 Mass	0.0018	0.0028	0.0010	0.0005	0.0004	0.0004	**0.0008**
$\pi - \pi^0$ Angular Separation	0.0015	0.0009	0.0016	0.0007	0.0005	0.0005	**0.0007**
π^0 Likelihood	0.0015	0.0009	0.0015	0.0006	0.0003	0.0010	**0.0006**
Electron PID	0.0011	0.0020	0.0008	0.0006	0.0005	0.0001	**0.0005**
Particle Transverse Momentum	0.0012	0.0007	0.0009	0.0002	0.0003	0.0006	**0.0004**
Boost Modelling	0.0004	0.0019	0.0003	0.0004	0.0004	0.0004	**0.0004**
Momentum Scale	0.0001	0.0014	0.0005	0.0002	0.0001	0.0003	**0.0004**
Max EMC Acceptance	0.0001	0.0011	0.0008	0.0001	0.0002	0.0005	**0.0003**
τ Direction Definition	0.0003	0.0007	0.0008	0.0003	0.0001	0.0004	**0.0003**
Angular Resolution	0.0003	0.0008	0.0003	0.0003	0.0002	0.0003	**0.0003**
Background Modelling	0.0005	0.0006	0.0010	0.0002	0.0003	0.0003	**0.0003**
Event Transverse Momentum	0.0001	0.0013	0.0005	0.0002	0.0002	0.0004	**0.0003**
Momentum Resolution	0.0001	0.0012	0.0004	0.0002	0.0001	0.0005	**0.0003**
Rho Mass Acceptance	0.0000	0.0011	0.0003	0.0001	0.0002	0.0005	**0.0003**
Tau Branching Fraction	0.0001	0.0007	0.0004	0.0002	0.0002	0.0002	**0.0002**
$\cos\theta^\star$ Acceptance	0.0002	0.0006	0.0004	0.0001	0.0001	0.0004	**0.0002**
$\cos\psi$ Acceptance	0.0002	0.0003	0.0002	0.0002	0.0002	0.0003	**0.0002**
Quadratic Sum	0.0058	0.0062	0.0054	0.0030	0.0026	0.0038	**0.0029**

Paper Status

- Final measurement:

$$\langle P \rangle = 0.0035 \pm 0.0024_{stat} \pm 0.0029_{sys}$$

- Paper on the arxiv: arXiv:2308.00774
- Paper has been accepted by PRD
- Working on final back-and-forth edits before publication

ReneSANCe MC Generator Updates

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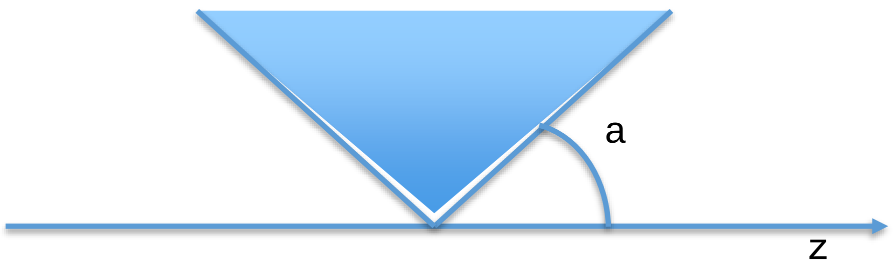
Calculating A_{LR} in the $e^+e^- \to e^+e^-(\gamma)$ process

- ReneSANCe is a “new” MC generator, published June 2020
    - Renat Sadykov, Vitaly Yermolchyk, *Polarized NLO EW e+e− cross section calculations with ReneSANCe-v1.0.0* (2020); DOI:10.1016/j.cpc.2020.107445
- Has special ALR modes which calculate ALR numerator and denominator directly
- Much quicker to calculate ALR with this mode than through event generation

Calculating A_{LR} in the $e^+e^- \rightarrow e^+e^-(\gamma)$ process

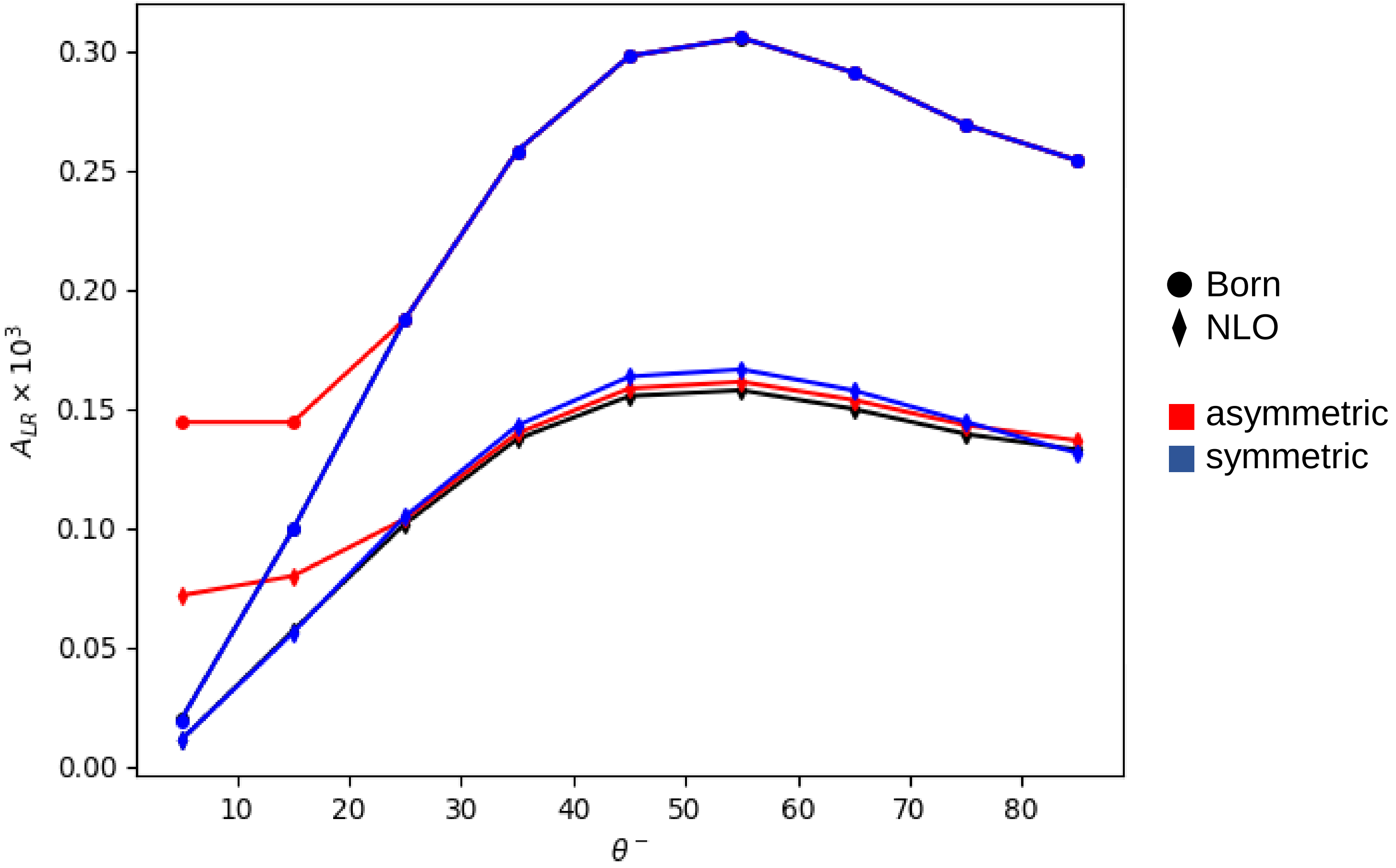
- We compare the generator predictions to recent NLO calculations be Aleksejevs *et al.*
  - A.G. Aleksejevs, S.G. Barkanova, Y.M. Bystritskiy and V.A. Zykunov, "Electroweak Corrections with Allowance for Hard Bremsstrahlung in Polarized Bhabha Scattering". *Phys. Atom. Nuclei* **83,** 463–479 (2020). https://doi.org/10.1134/S1063778820030035
- They integrate ALR as a function of electron direction (cut symmetrically)

$$a < \theta_{e^-} < 180° - a$$



Comparisons

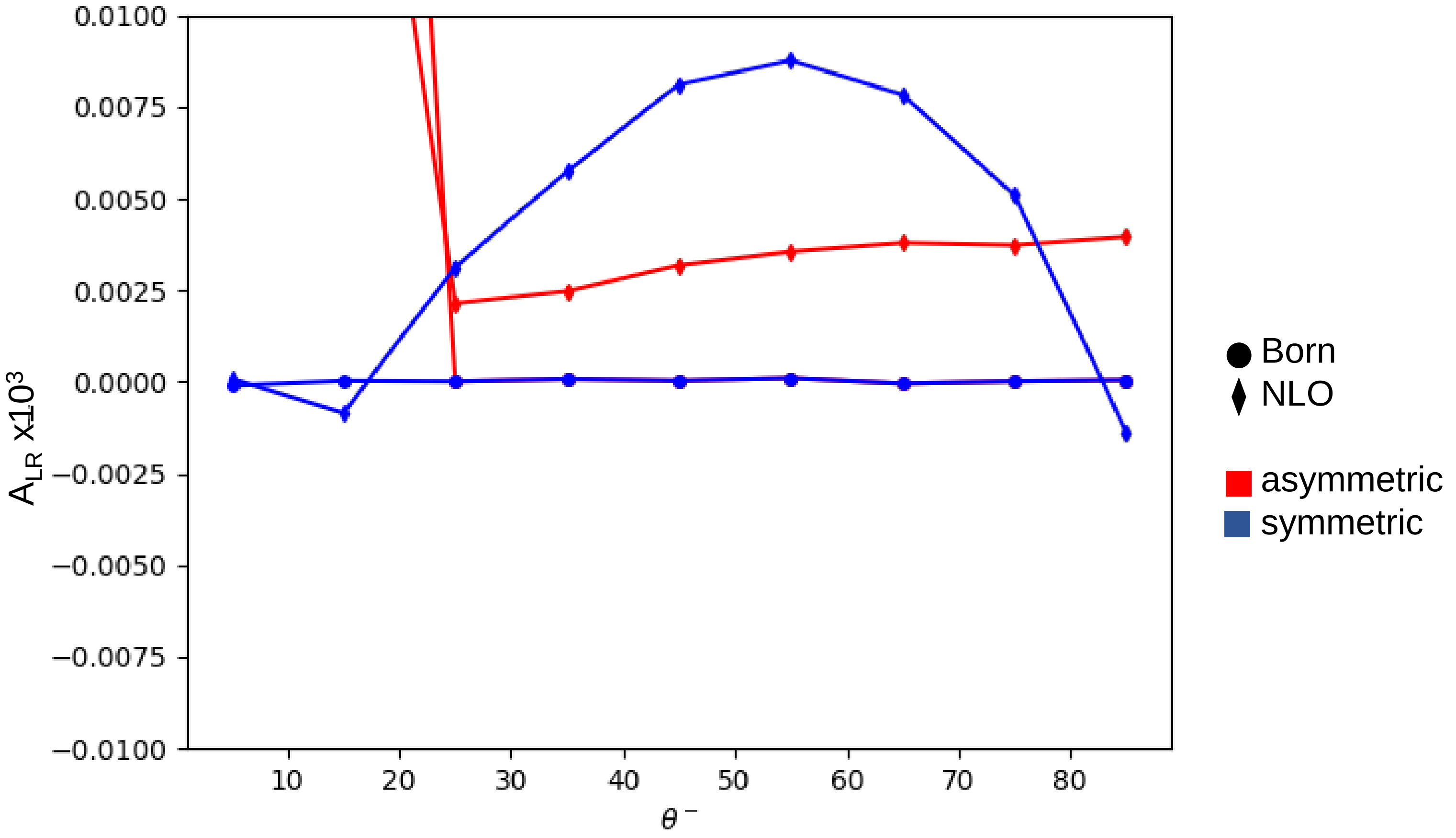
- Aleksejevs et al. state they calculate ALR by requiring $|\cos\theta^+| \leq \cos 20^\circ$
- I ran the generator in two modes, one where $|\cos\theta^+| \leq \cos 20^\circ$ (asymmetric) and one where $|\cos\theta^+| \leq |\cos\theta^-| < a$ (symmetric)
- We understand the deviation below 20 to be due to the shift in the positron becoming the less constrained particle



Comparisons

- Looking at the differences (ReneSANCe-Aleksejevs) we see the Born level calculations are in good agreement
- The NLO differences are understood to be leading NNLO terms present in ReneSANCe

15x zoom
compared to previous

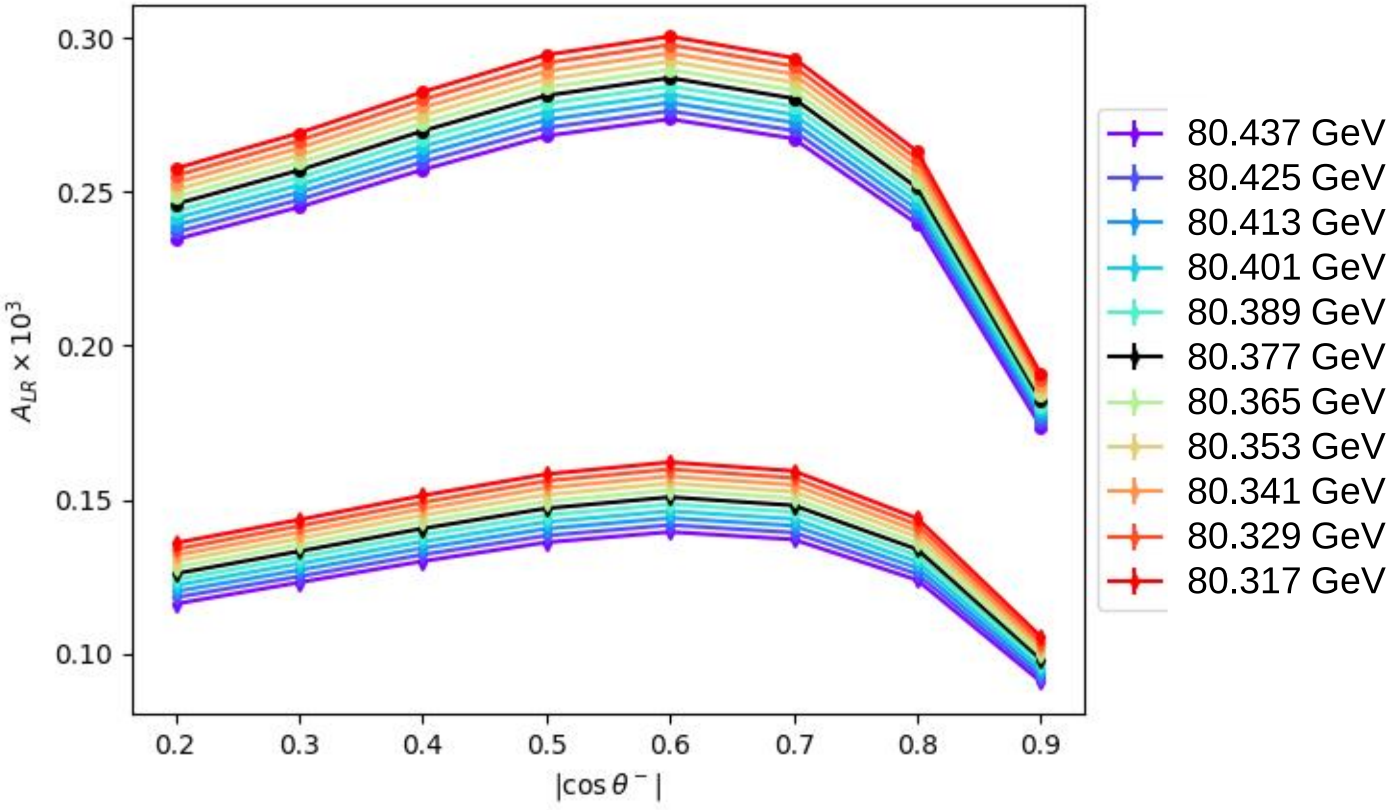


$\sin^2\theta_W$ Sensitivity

- As a proxy to varying the value of $\sin^2\theta_W$ in the MC we vary the W mass

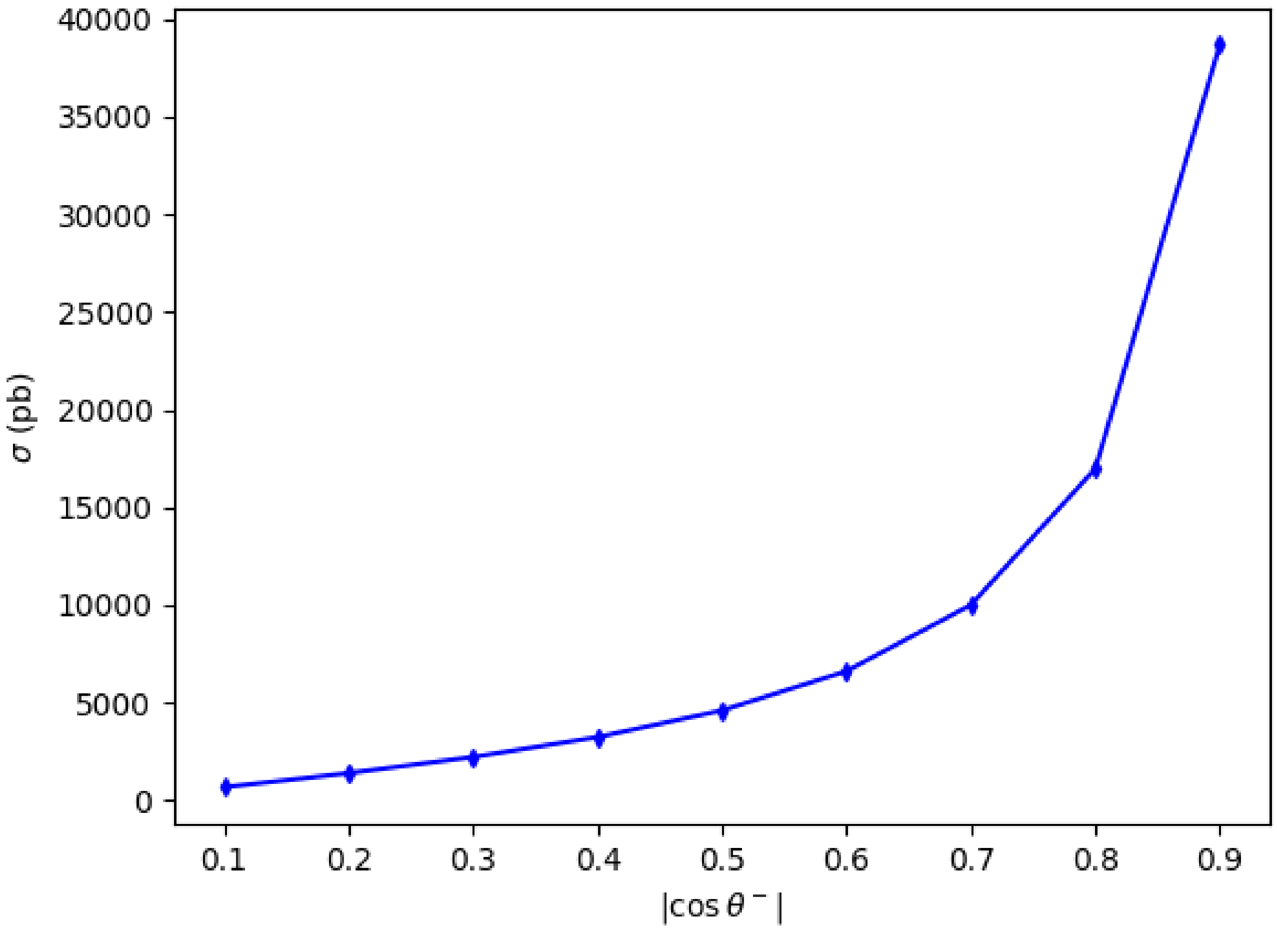
$$\sin^2\theta_W = 1 - \frac{m_W^2}{m_Z^2}$$

- Varied in steps of 12 MeV (world average experimental uncertainty)



$\sin^2\theta_W$ Sensitivity

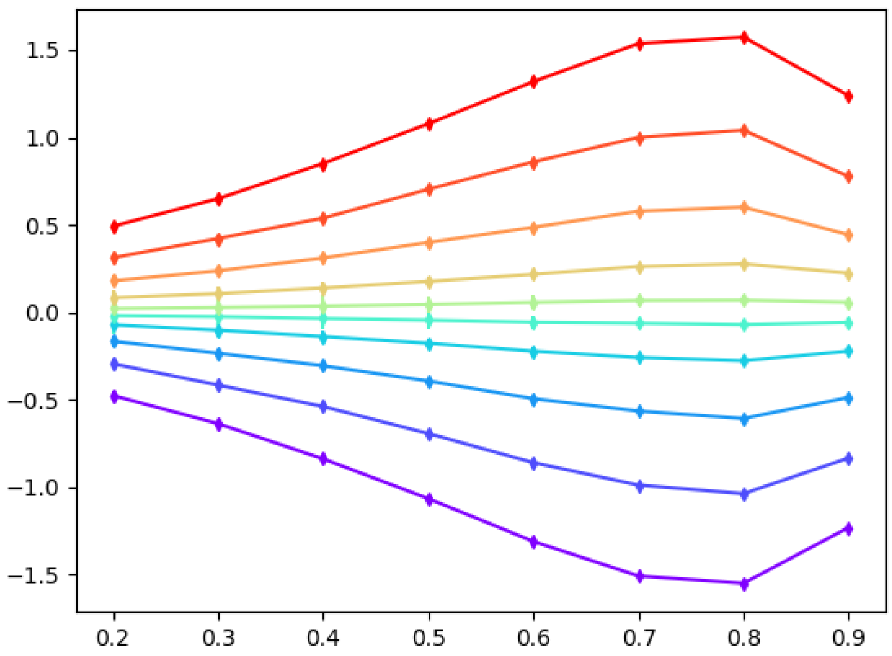
- As the cross-section varies exponentially with acceptance the optimal measurement may not be at peak A_{LR}

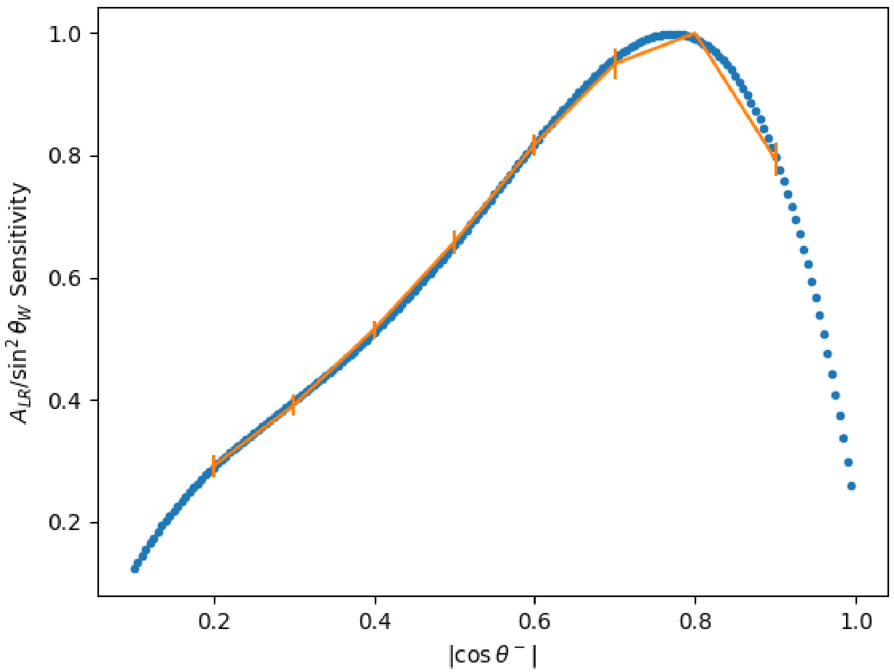


$\sin^2\theta_W$ Sensitivity

- Evaluated sensitivity in three steps

1. Normalize A_{LR} m_W sensitivity ($A_{LR}(m_W)/A_{LR}^{SM}$)
2. Weight by a statistical (from xsec and $50ab^{-1}$) and systematic uncertainty (stat=$1/\sqrt{N}$, sys=0.0029) (Left Plot)
3. Parametrize curves and fit for a max (Right Plot)





peak at $|\cos\theta| \leq 0.77$

Max ALR at $|\cos\theta| \sim 0.6$

Conclusions

- Expected statistical error is ~1-2%, Aleksevejs vs ReneSANCe differ by ~1%
- Still need to double check all calculations
- Working on writing up a paper
- Will include:
- The differences between the two theory calculations
- Projections for $\sin^2\theta_W$ sensitivity
- A study of the optimal angular selection as a function of luminosity