Precise measurement of two-fermion final states in 250 GeV ILC for BSM

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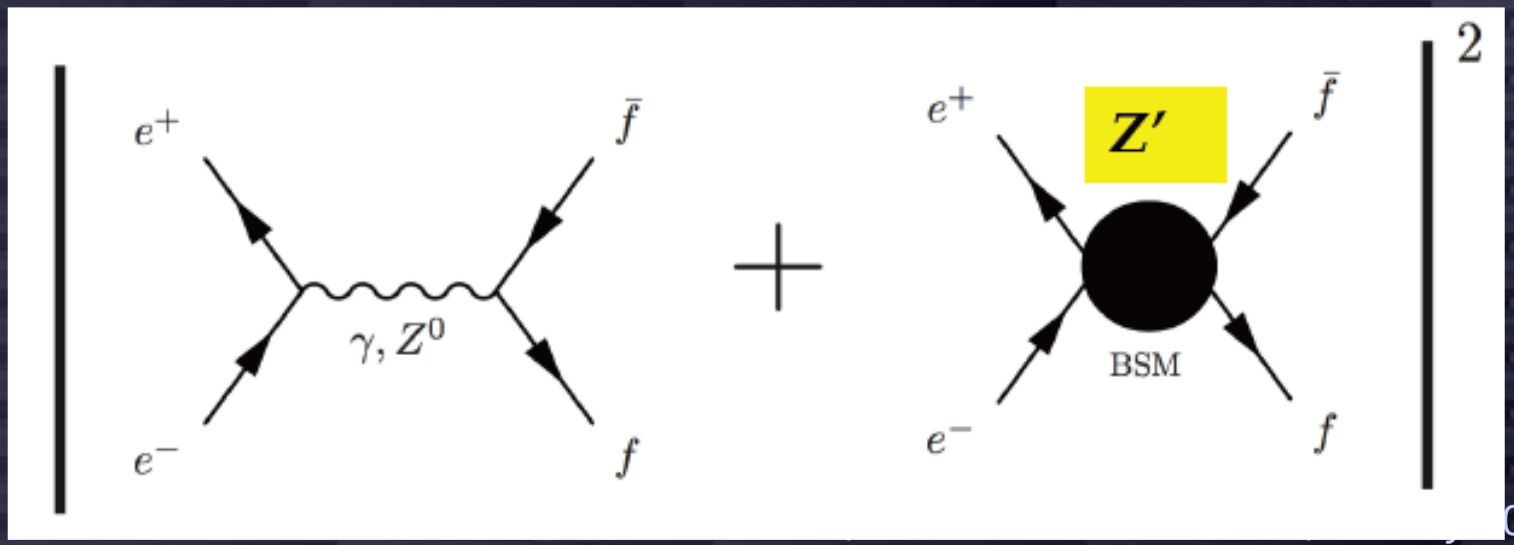
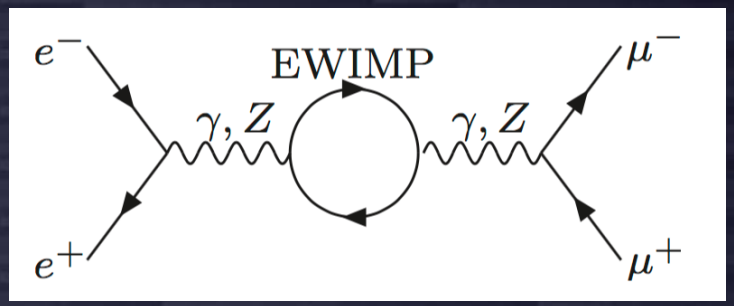
2-fermion final states in LC

- Simple electroweak process
  - Precise QED calculation
  - High cross section
  - → O(0.1%) cross section measurement possible
  - Differential cross section (production angle)
  - → Sensitive to BSM models (and separation)



BSM models

- Z' models
  - SSM
  - ALR (Alternative Left-Right model)
  - E_6 models (motivated from string theory)
  - Gauge Higgs Unification (Hosotani model)
- General WIMP search
  - Determined by spin of EWIMP



Conditions

Standard H-20 like scenario in 250 GeV

Total Luminosity	$(e^-_L e^+_R)$	$(e^-_R e^+_L)$
2000 fb^{-1}	900 fb^{-1}	900 fb^{-1}

Polarization: 80% (e^-), 30% (e^+)
ILD full simulation (DBD sample)

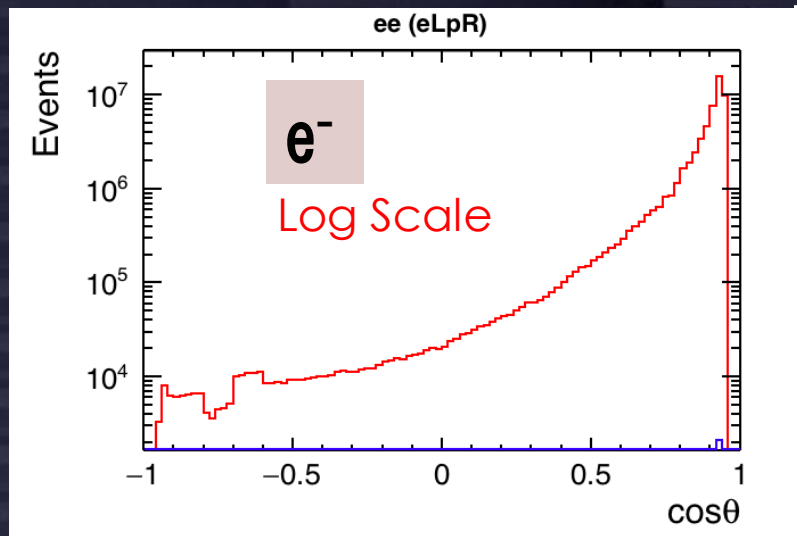
Leptonic final states

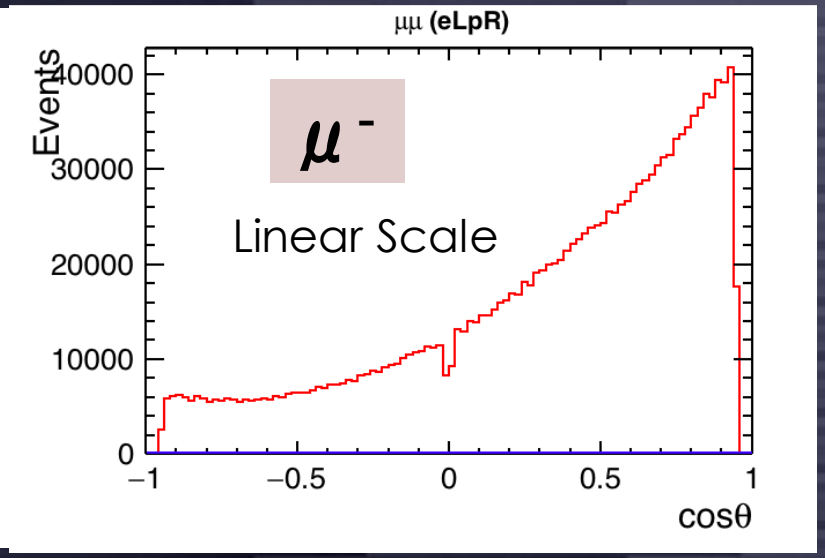
signal	Background
$e^-e^+ \to e^-e^+$	• 2f - $\mu^-\mu^+$ $\tau^-\tau^+$ • 4f - Leptonic
$e^-e^+ \to \mu^-\mu^+$	• 2f – e^-e^+ $\tau^-\tau^+$ • 4f - Leptonic
$e^-e^+ \to \tau^-\tau^+$	• 2f - e^-e^+, $\mu^-\mu^+$ • 4f - Leptonic • 2f-qq

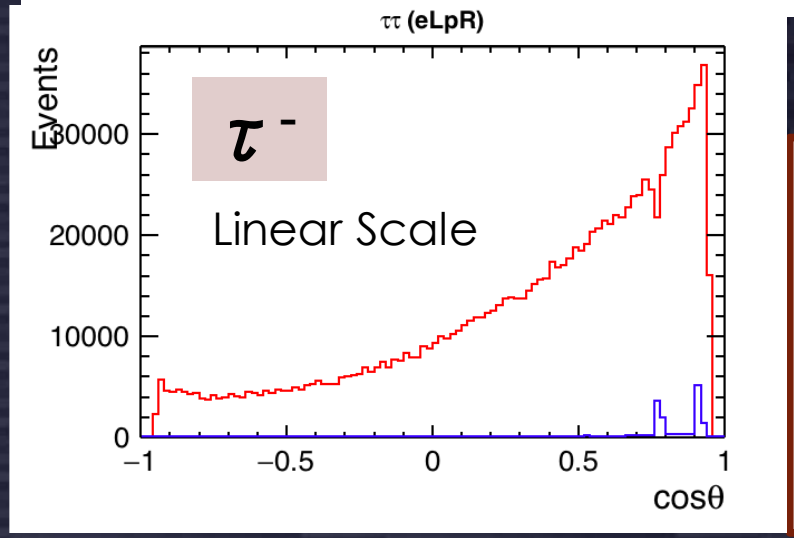
Hadronic final states

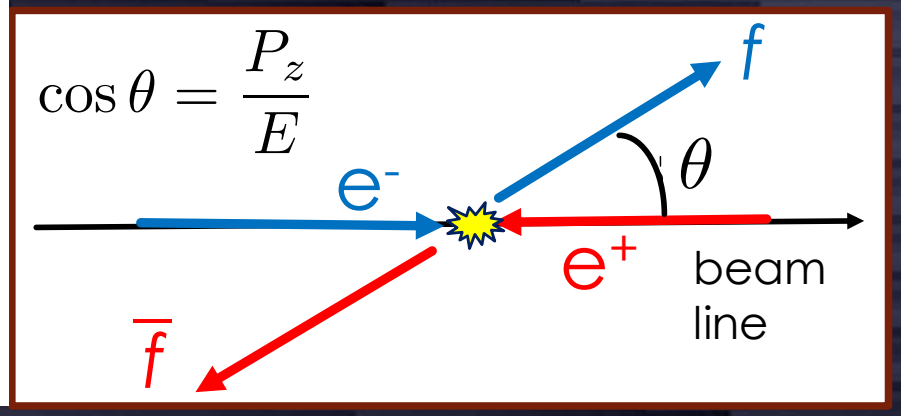
signal	Background
$e^-e^+ \to bb$	• 2f – *qq (q = u, d, s, c)* • 4f – hadronic ,semiLeptonic
$e^-e^+ \to cc$	• 2f – *qq (q = u, d, s, b)* • 4f - hadronic ,semiLeptonic

Leptonic channels



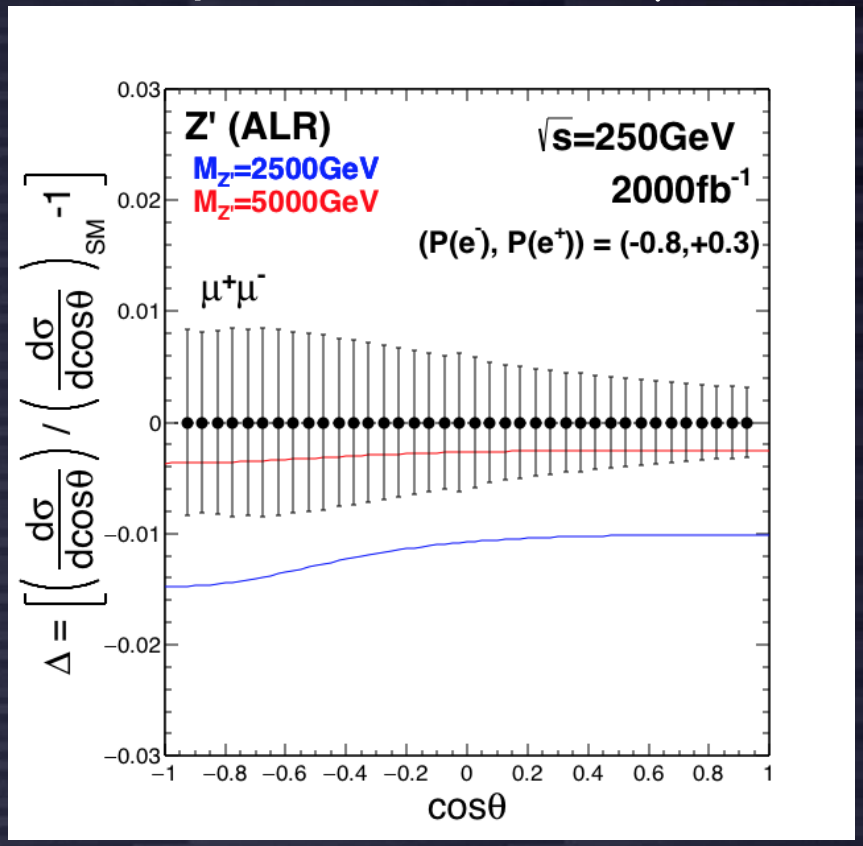






Leptonic channels – BSM sensitivity

Example: ALR Z' with μ channel



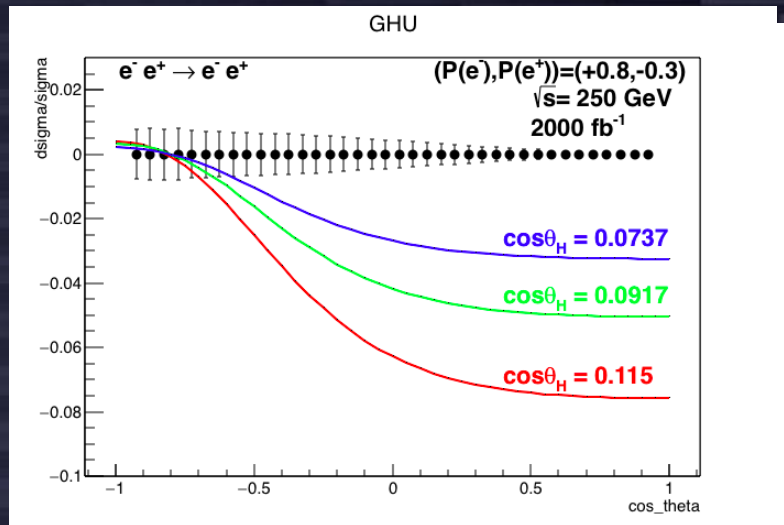
$$\chi^2(\mathrm{BSM}) = \sum_i \left\{ \left(\frac{\delta\sigma_i(\mathrm{BSM})}{\sigma_i(\mathrm{SM})} \Big/ \frac{S_i}{\sqrt{S_i + N_i}} \right)^2 + 1 \right\}$$

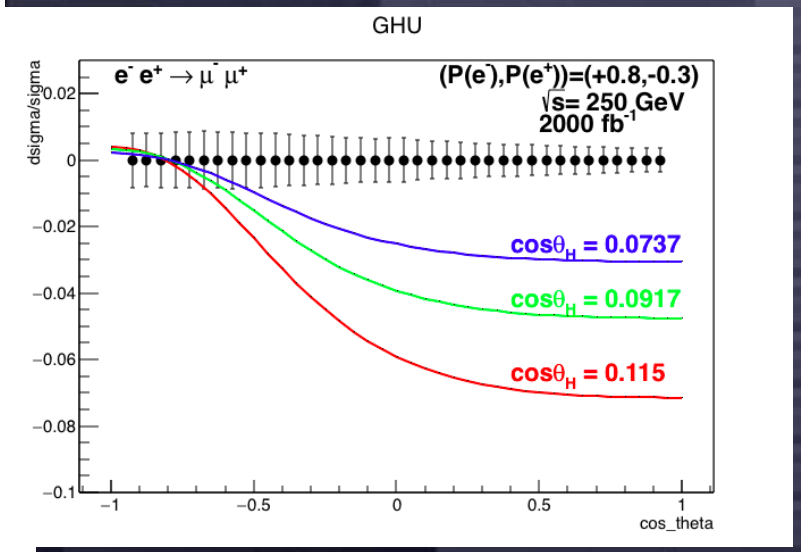
deviation from BSM

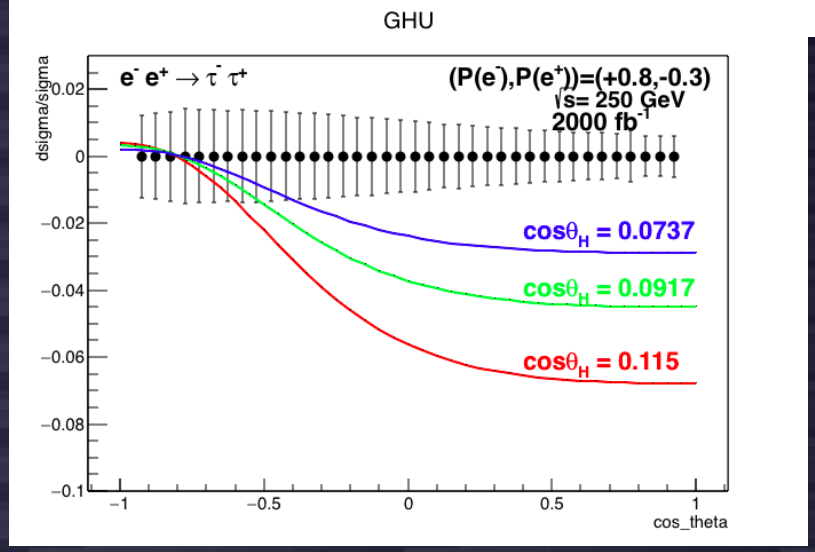
only SM

BSM model	mass reach (3 sigma)
SSM	2.8 TeV
ALR	4.0 TeV
χ	2.9 TeV
ψ	1.4 TeV
η	1.8 TeV

Leptonic channels – GHU sensitivity

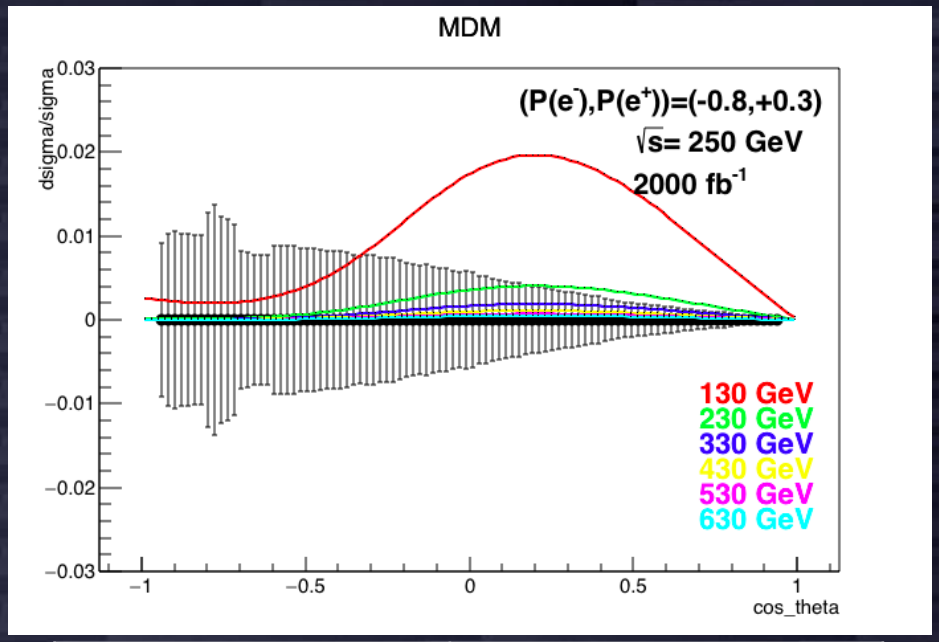






Clear separation for any favorable θ_H

Leptonic channels - EWIMP



	mass reach (3σ)
Higgsino	150 GeV
MDM	330 GeV
Wino	190 GeV

Mass reach of direct search: slightly less than 125 GeV

Higher mass reach is observed with 2l final states.
(but not so satisfactory)

Further improvement should be investigated

Hadronic channels - difficulties

2x more statistics, but…

- Jet charge identification
  - Secondary tracks
  - Should increase efficiency
  - (This study is not optimized)
- Charge assignment
  - Assign positive and negative jets
  - We can use charge of two jets
- Treatment of angular smearing
- Theoretical calculation

Charge assignment

Jet1	Jet2	条件 1	+	0	−	条件 2	+	0	−
2	2	B	57042	30046	29545	A	14822	7459	7765
2	2	A	63328	24894	28411	B	10369	7459	7066
2	1	B	76748	60794	44257	A	24591	21520	14683
2	1	A	83417	55611	42771	B	18590	21520	15501
2	0	B	19239	67602	9065	A	29456	19469	18677
2	0	A	42781	29199	23926	B	6000	19469	3730
1	1	B	28157	31528	17870	C	15262	4985	11281
1	0	B	35064	39606	23072	C	18700	6355	14551
1	0	C	46805	15357	35580	B	5299	6355	3703
0	0	C	18113	5532	13611	-			

Jet1	Jet2	条件 3	+	0	−	efficiancy	purity
2	2	C	3538	1231	2690	64.65%	65.34%
2	2	C	3538	1231	2690	66.22%	66.93%
2	1	C	10310	3542	7668	61.41%	62.63%
2	1	C	10310	3542	7668	61.78%	63.01%
2	0	C	9045	3217	7207	60.20%	62.29%
2	0	C	9045	3217	7207	60.29%	62.39%
1	1	-				55.98%	59.83%
1	0	-				55.01%	58.83%
1	0	-				53.31%	57.01%
0	0	-				48.62%	57.10%

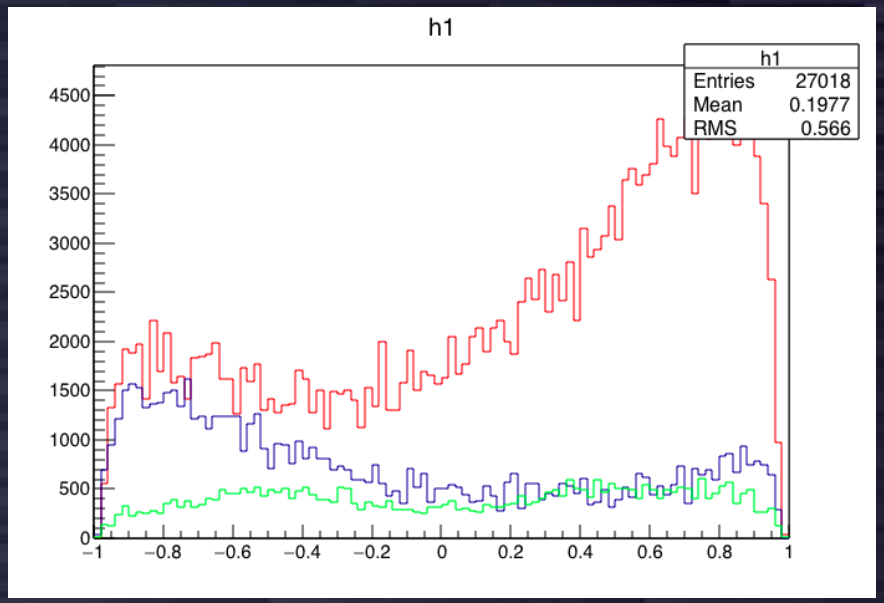
Performance by number of rec. vtx

- 2-jet clustering (LCFIPlus)
- B-tagging (LCFIPlus)
- No vertex recovery (yet)
- Select “positive” and “negative” jets
  - A. Charge sum of tracks of 2nd & 3rd vtx
  - B. Charge sum of tracks of 2nd vtx only
  - C. Charge sum of all tracks
- ~60% efficiency obtained

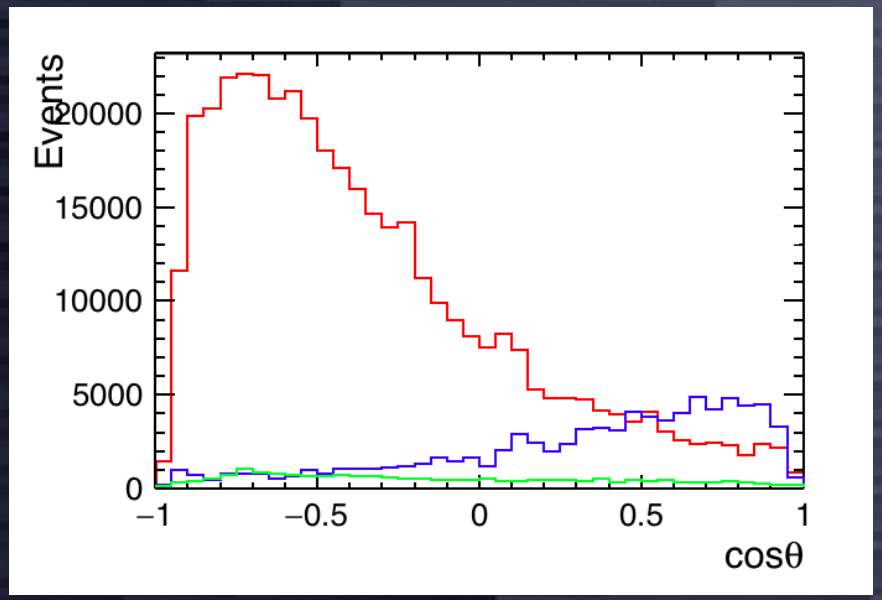
Angular distribution

eRpL

b

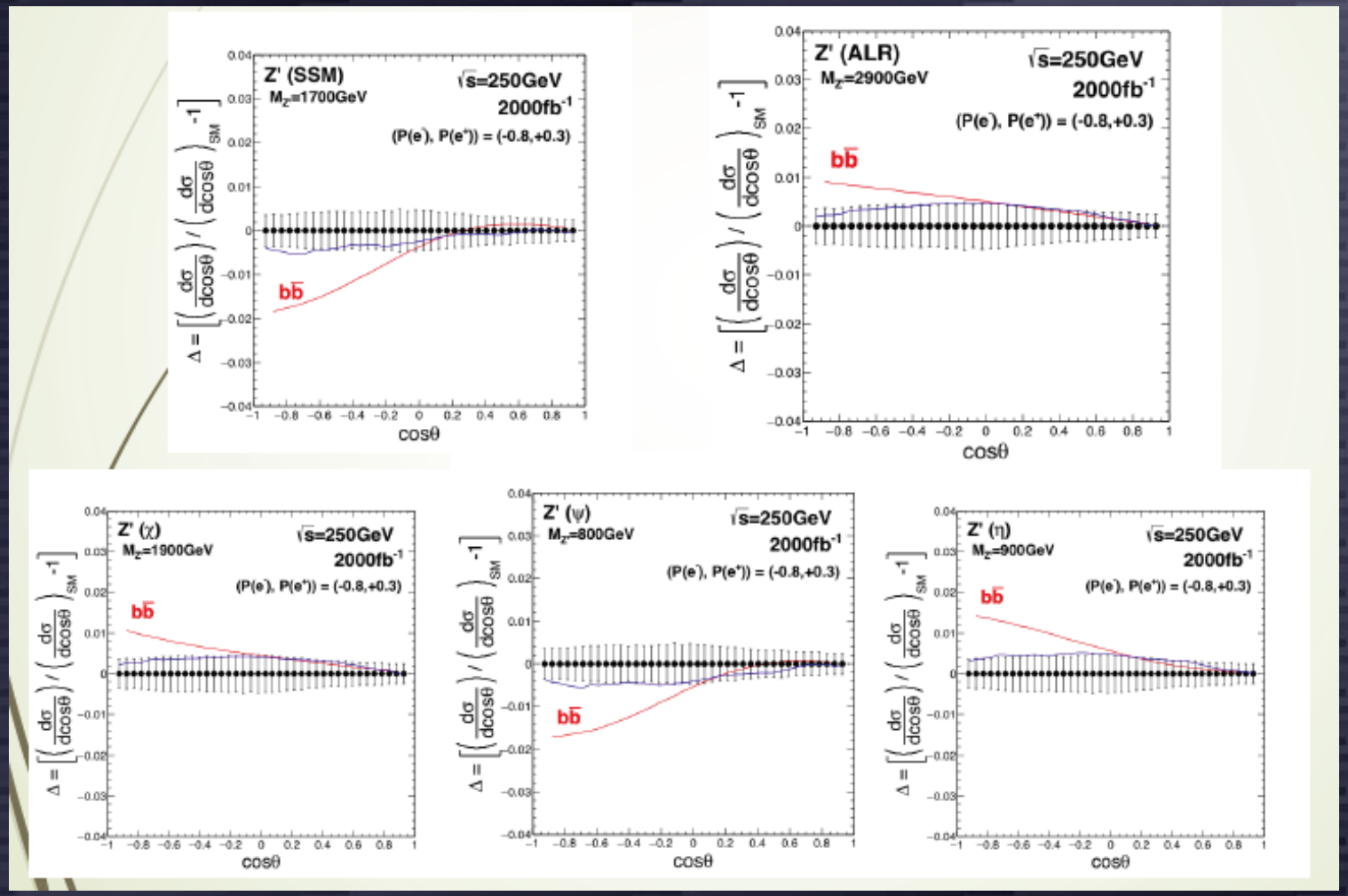


cbar



Red: true, blue: wrong sign, green: bkg.

bb for Z' search



Red: true assignment, blue: current assignment

Big degradation due to mis-assignment → need to improve

Results on Z'

BSM model	mass reach (lepton)	(b)	(c)
SSM	2.8 TeV	2.7 TeV	2.7 TeV
ALR	4.0 TeV	2.7 TeV	2.8 TeV
χ	2.9 TeV	2.0 TeV	1.4 TeV
ψ	1.4 TeV	1.5 TeV	1.4 TeV
η	1.8 TeV	1.2 TeV	1.4 TeV

No significant gain from leptons

Summary & todo

- Z' mass reach on SSM, ALR → several TeV
  - Should be slightly improved, but not 10 TeV
- GHU Z': Full coverage of favorable region
  - $\theta_H > 0.05$
  - Model identification is the next step
- General WIMP: slightly larger than direct
- Todo
  - Vertex track recovery
  - Revisiting method to calculate deviation
  - Will resume study with new students

	mass reach (3σ)
Higgsino	150 GeV
MDM	330 GeV
Wino	190 GeV