



Measuring dark neutrinos at ILC

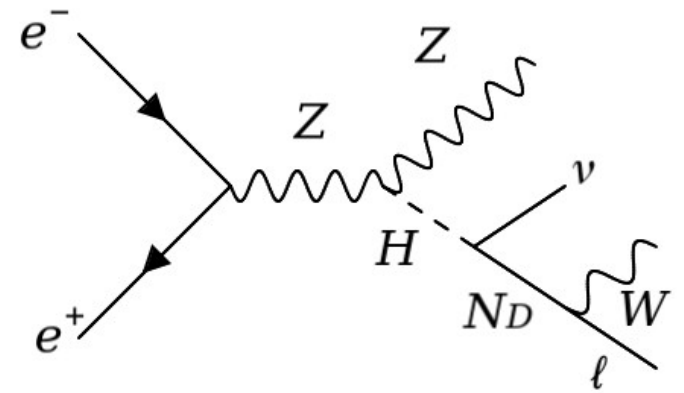
Preliminary results

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Supervised by Junping Tian



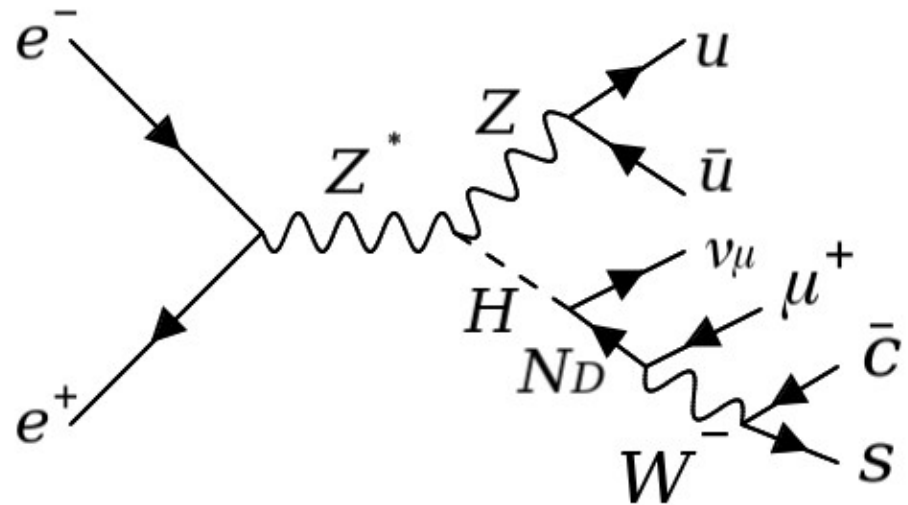
Goal

- Hypothesized dark sector model with a weak-like force
 - Can explain matter-antimatter asymmetry
 - Heavy dark neutrinos
 - My focus: $m_Z < m_{N_D} < m_H$
 - Higgs decay product
- **Goal: Investigate the sensitivity of ILC for detecting the dark neutrino**



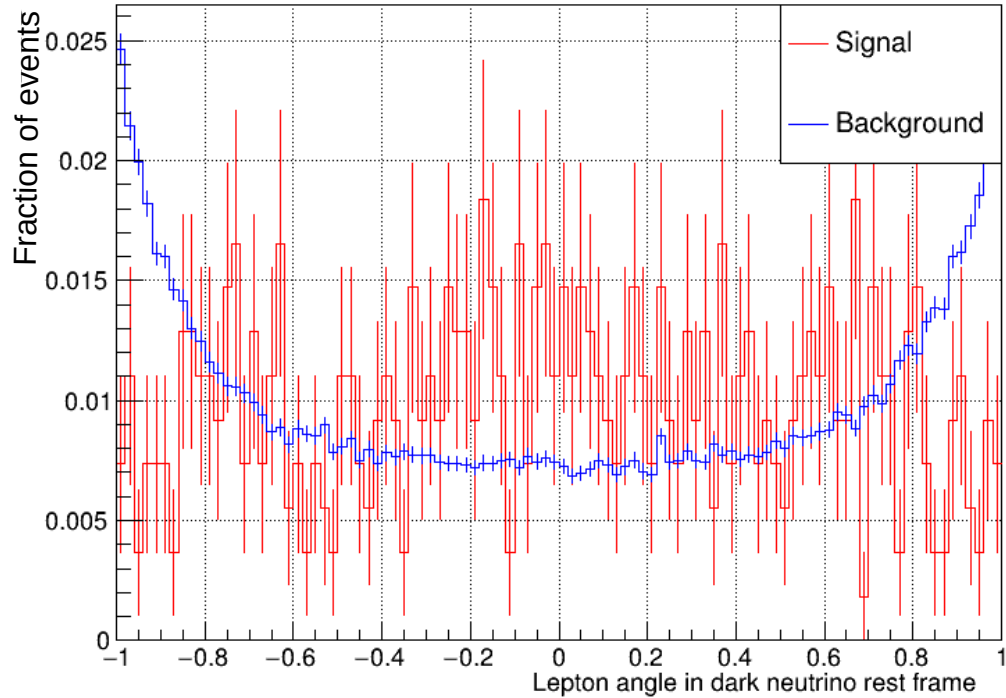
Dataset

1. Background: MC-2020 full simulation data
 - 1000 fb⁻¹ of (-0.8, +0.3), iLCSoft v02-02
 - 2f, 4f, 6f, qqh_ww (no MC truth preselection)
2. Signal: Full simulation data
 - Only one decay mode
 - 979 events
 - eLpR
 - More events are in the making

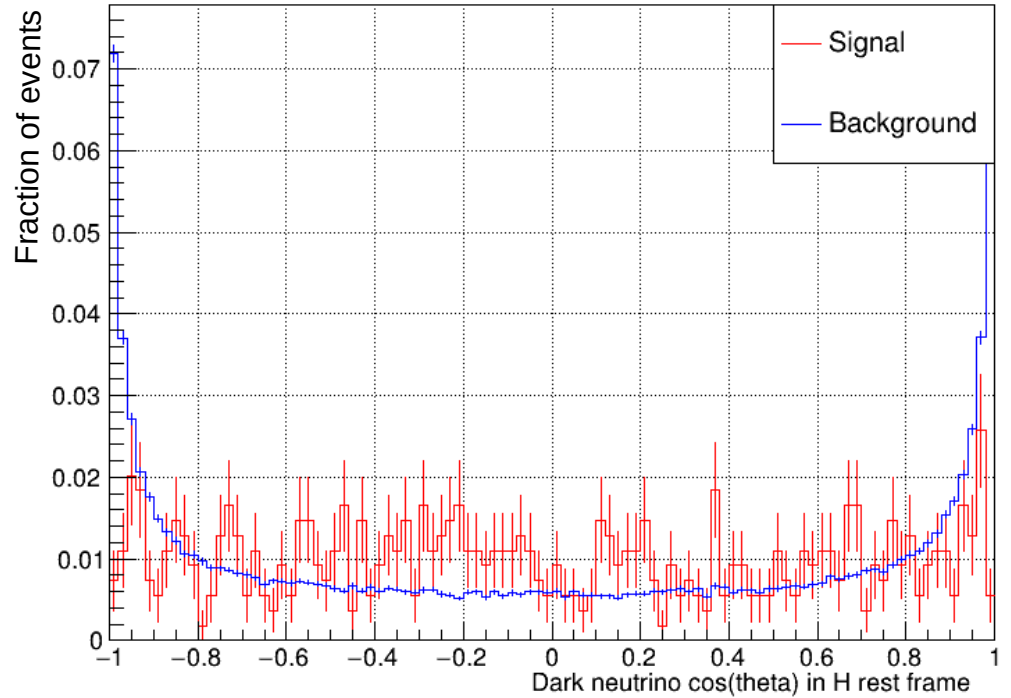


Distributions

Signal vs background of Lepton angle in dark neutrino rest frame

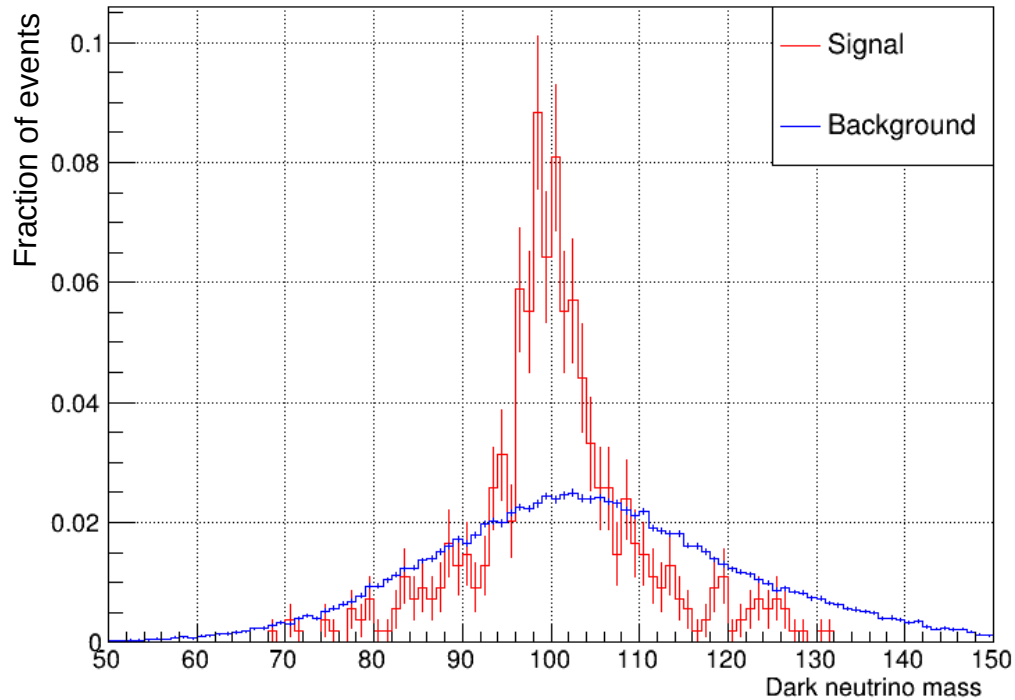


Signal vs background of Dark neutrino $\cos(\theta)$ in H rest frame

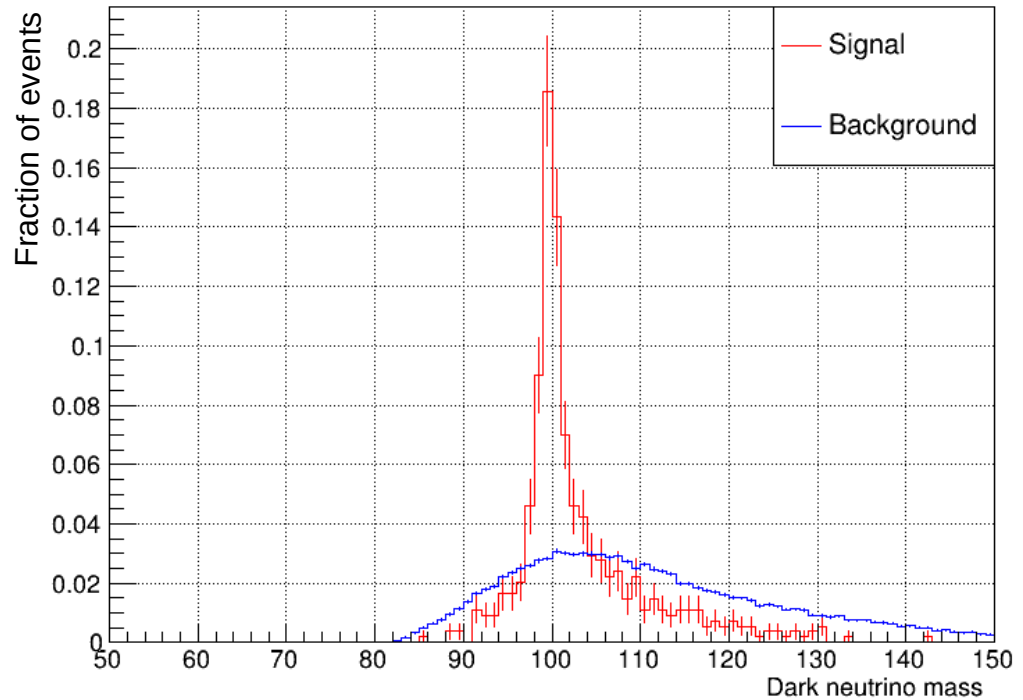


Mass distributions

m_{N_D}



$m_{N_D} - m_W + m_{W_0}$



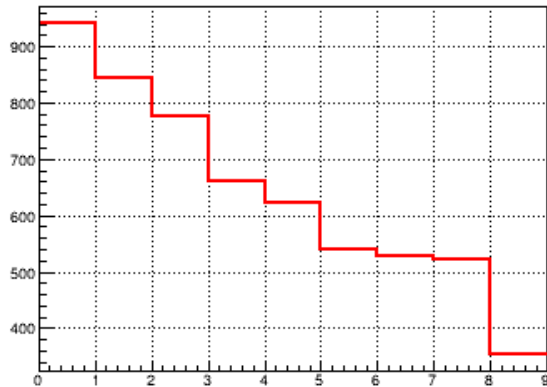
Machine learning

- Boosted decision tree (TMVA)
- **50** trees, **3** nodes at most, optimize **gini index**
- Weighted events. **Reweighted** to have equal number of dark neutrino and background events
- Additional input parameters:
 - Lepton $\cos(\theta)$ in dark neutrino rest frame
 - Dark neutrino $\cos(\theta)$ in Higgs rest frame
 - Corrected dark neutrino mass

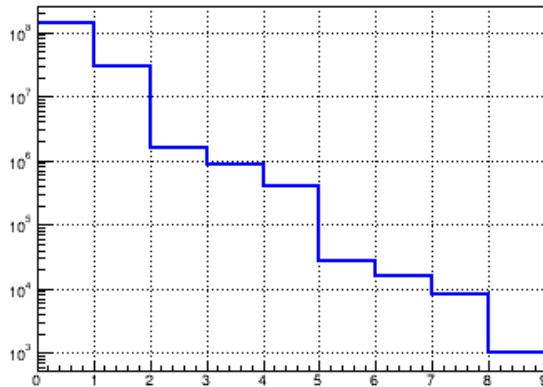
Cut table – eLpR beam – 1% BR

	Total signal	Total background	Significance	2f_l	2f_h	4f_l	4f_sl	4f_h	6f	qqh_ww
No cuts	941	136696075	0.08	12982897	77324421	10379315	19163106	16800470	1278	44588
Pre-selection	843	30123331	0.15	7366002	1606336	7651845	13260215	220833	872	17229
elep/50. + emis/90. < 1.	777	1562208	0.62	75113	265900	857303	209602	147613	705	5971
0.8 < mvalep	661	881954	0.70	54525	41290	623639	138607	18676	585	4632
(180. < mvis) && (mvis < 225.)	624	390727	1.00	34476	21865	237881	82092	9918	383	4114
0.007 < y34	541	26873	3.27	160	2109	406	13519	6778	346	3555
2 < min_n	528	15908	4.12	4	1223	7	4376	6541	314	3444
(10. < mis.P()) && (mis.P() < 50.)	523	8455	5.52	2	564	4	2207	2449	102	3128
MVA cut	353	1030	9.49	0	8	0	103	32	5	882

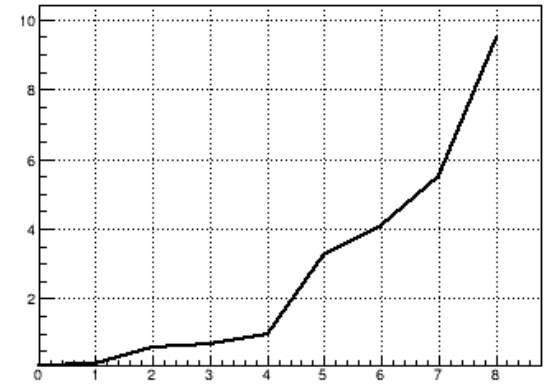
Number of signal events after each cut



Number of background events after each cut

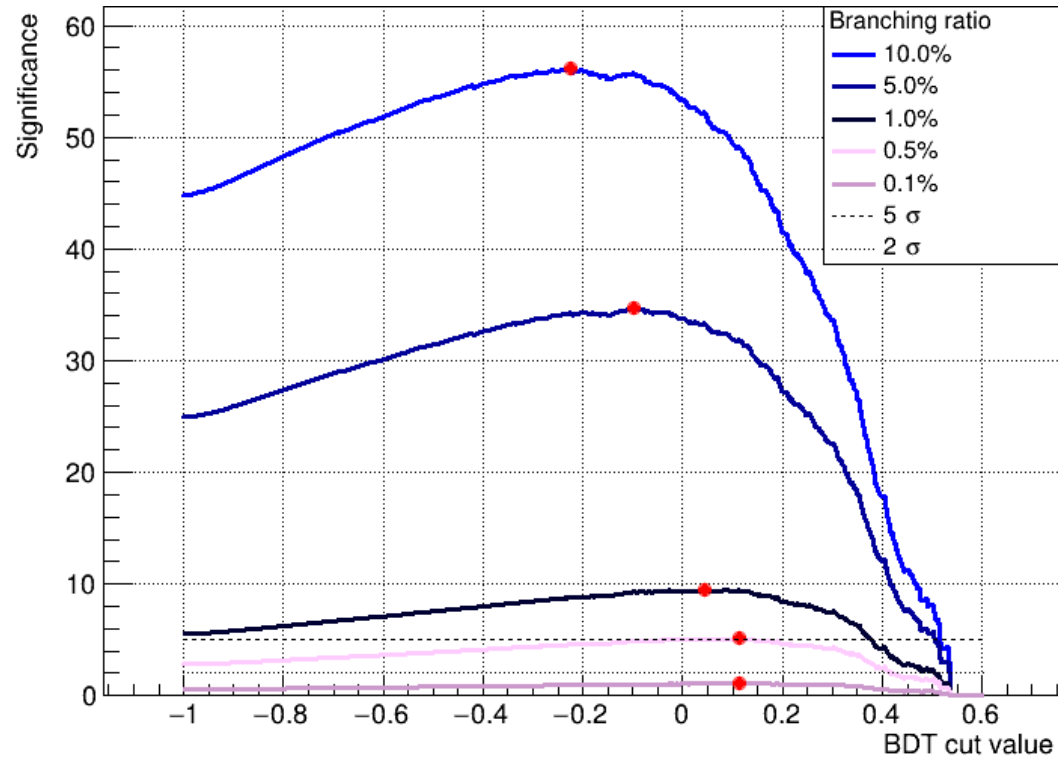


Significance



Preliminary Significance

- eRpL samples not included
→ In reality the significance is higher
- Uses m_{ND} as input to MVA
→ "cheating"
- BR of at least **0.5%** can be detected with **5σ**
- BR of **0.1%** can likely be excluded with **2σ**



Future work

- More dark neutrino samples
 - More decay modes
 - More events
 - eRpL samples
- Inclusive Higgs decay as background
- Investigate potential bug with angles

Mass distribution after all cuts

Signal vs background of Adjusted dark neutrino mass

