Measuring dark neutrinos at ILC
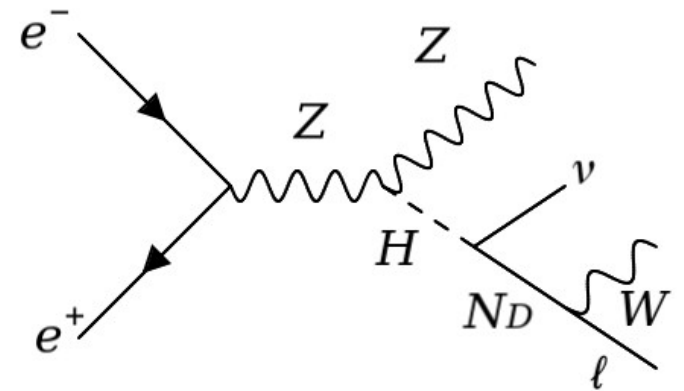## Preliminary results

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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

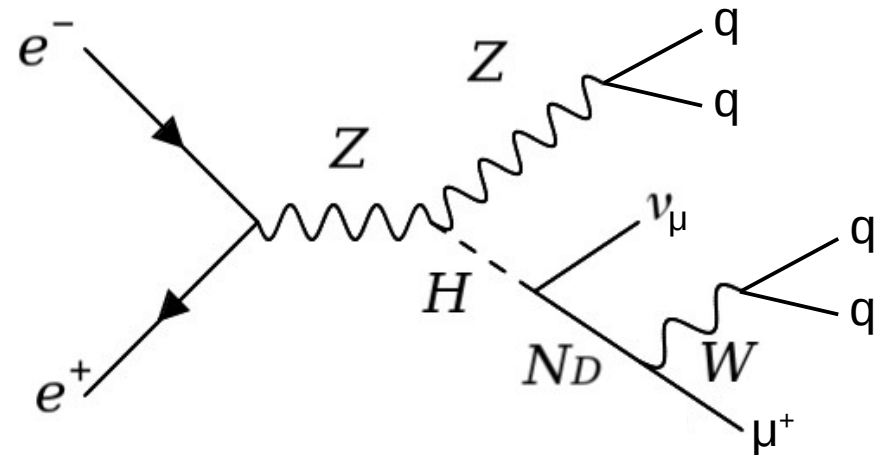- **Goal: Investigate the sensitivity of ILC for detecting the dark neutrino**

Dataset

1. Background: MC-2020 full simulation data
   - 1000 fb^{-1} each of (-0.8, +0.3), (+0.8, -0.3).
   - iLCSoft v02-02
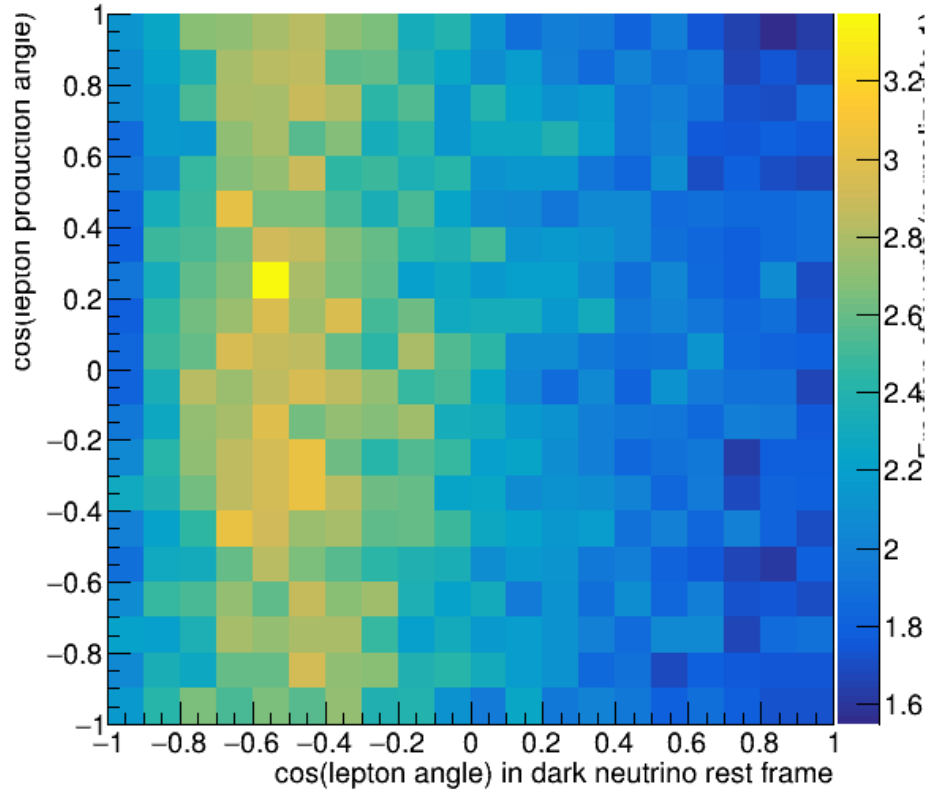   - 2f, 4f, 6f, **qqh**

2. Signal: Full simulation data
   - m_{ND} = 100 GeV
   - Only muon channel
   - eLpR, eRpL (~200 000 events each)
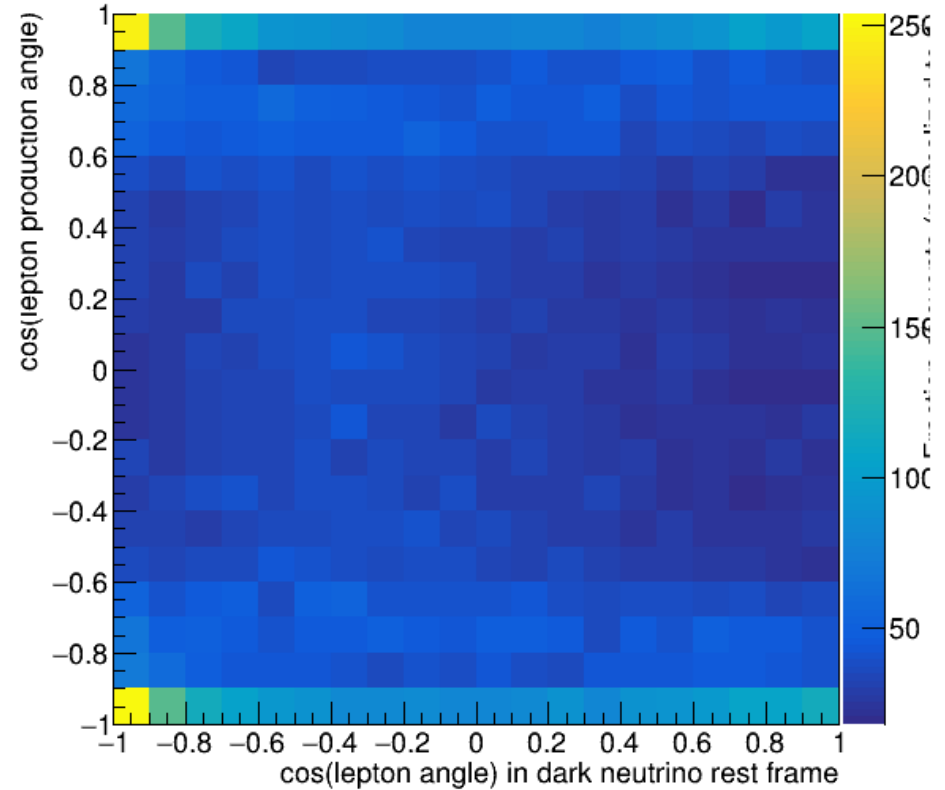   - Electron channel and more masses in the making
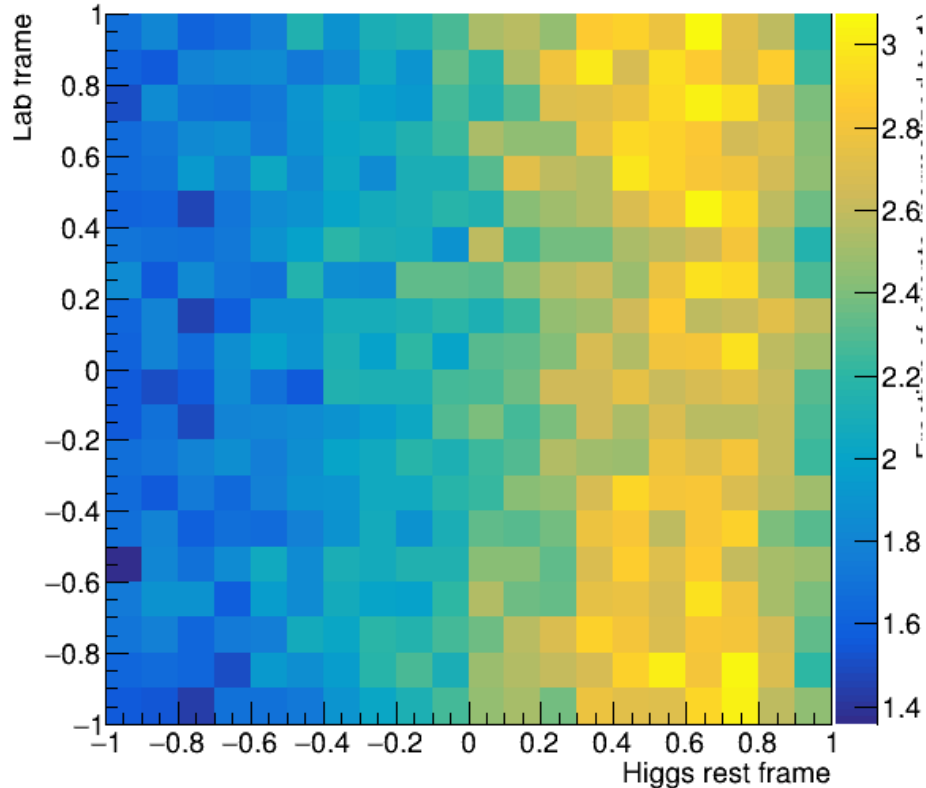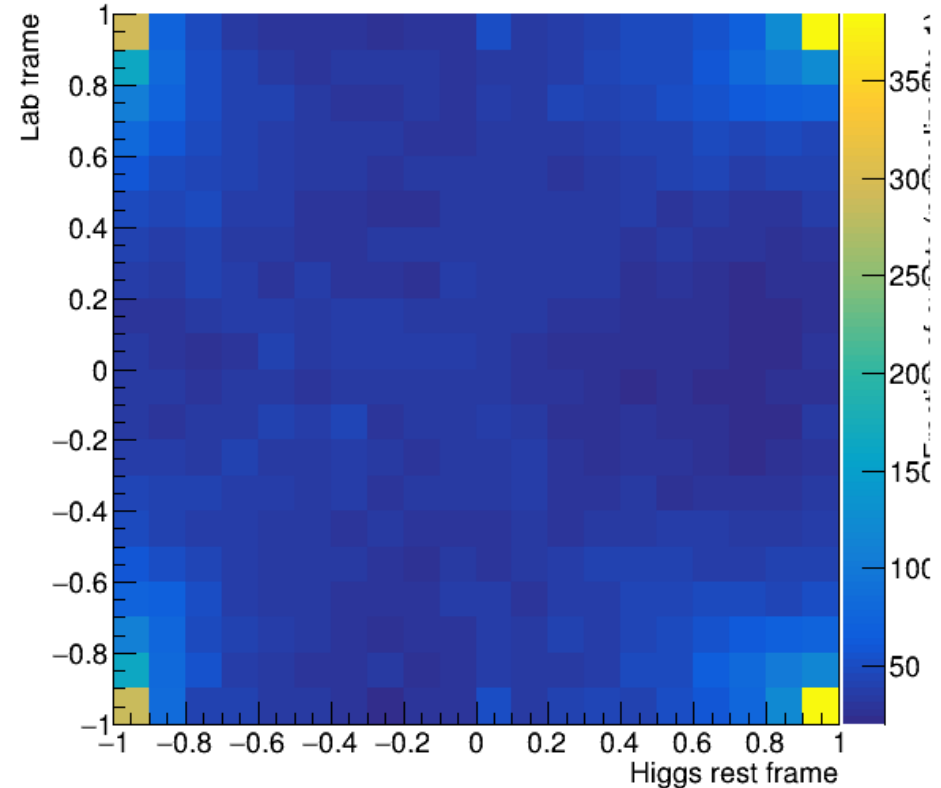
Lepton angle distribution

signal

background

Dark neutrino angle distribution

# Machine learning

- Boosted decision tree (TMVA)
- **100** trees, **4** nodes at most, optimize gini index
- Updated input parameters:
  - Production angles of lepton, neutrino, Z, dark neutrino
  - Dark neutirno angle in Higgs rest frame
  - Lepton angle in dark neutrino rest frame
  - With and without corrected dark neutrino mass

- B-tagging and c-tagging did not result in a meaningful improvement

Significance output of BDT

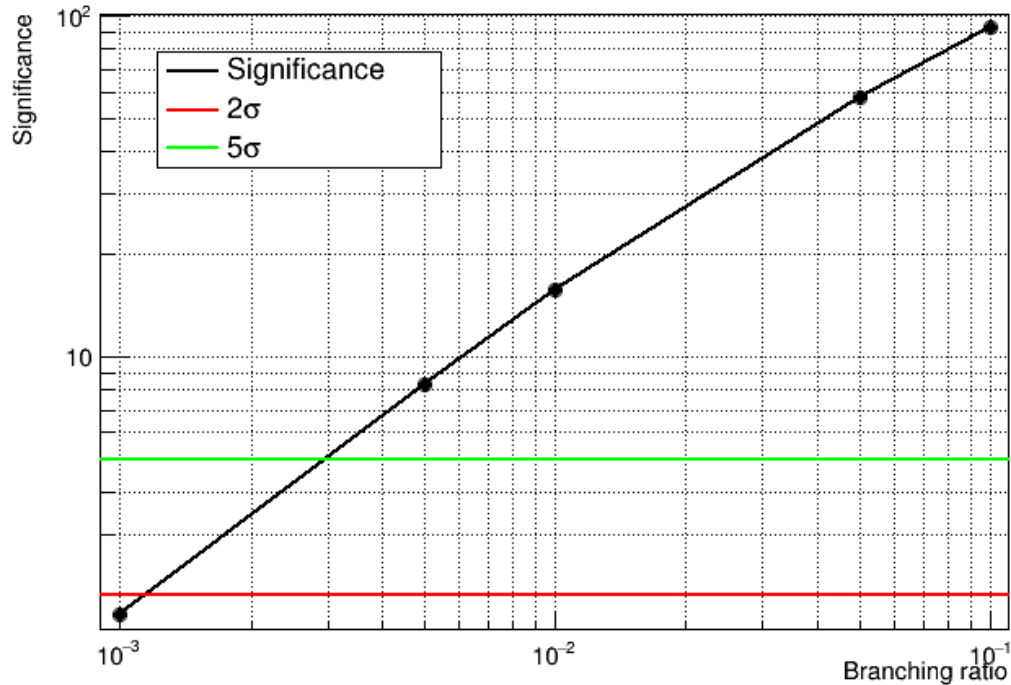Significance curve with beam polarization elpr
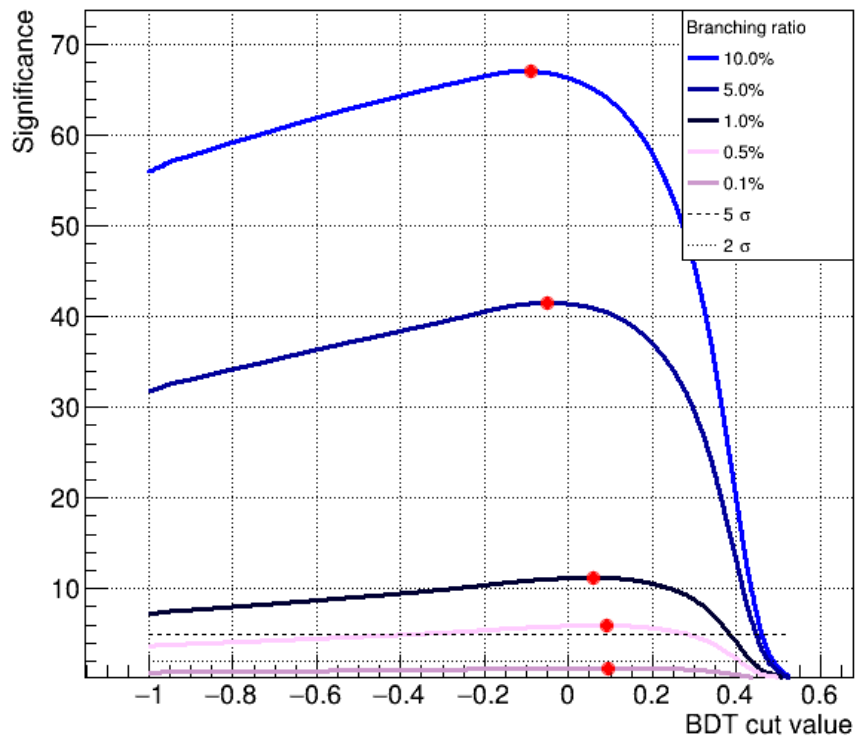
Significance curve with beam polarization erpl
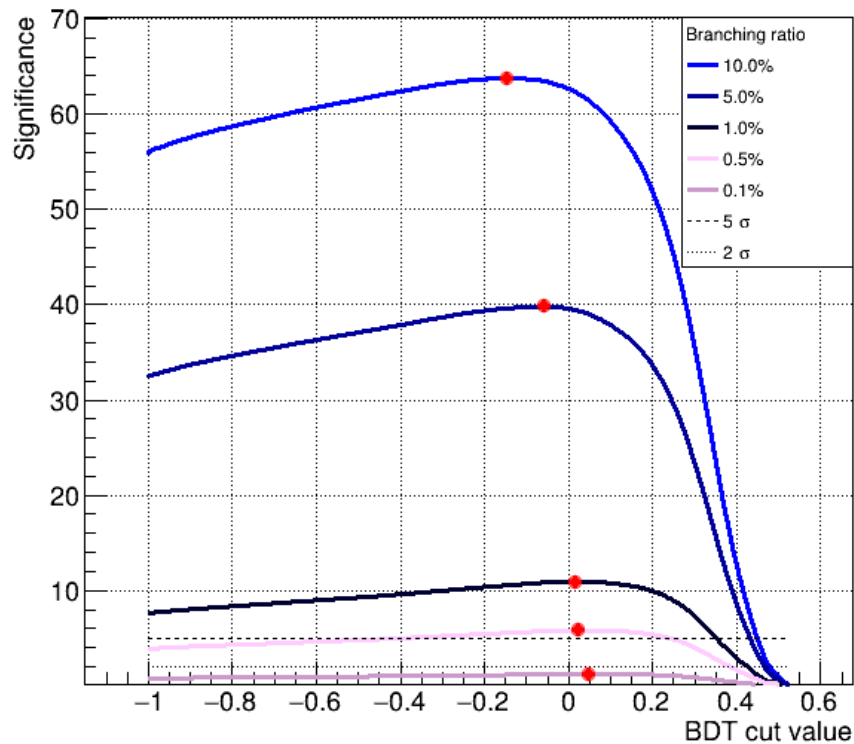
Total significance for different BRs

Without dark neutrino mass

Significance for different values of BR(H →νN)•BR(N →lW)

With dark neutrino mass

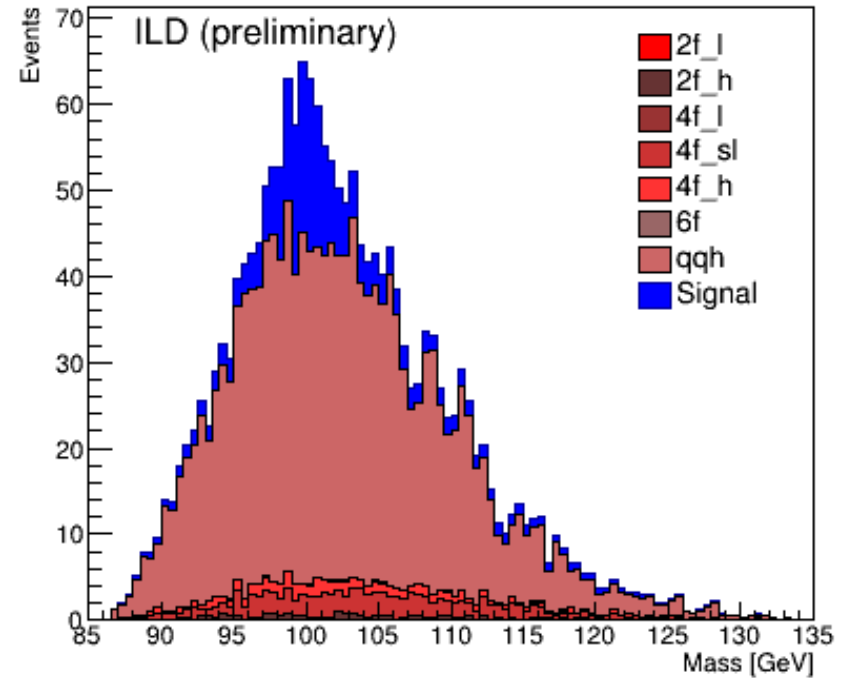Significance for different values of BR(H →νN)•BR(N →lW)
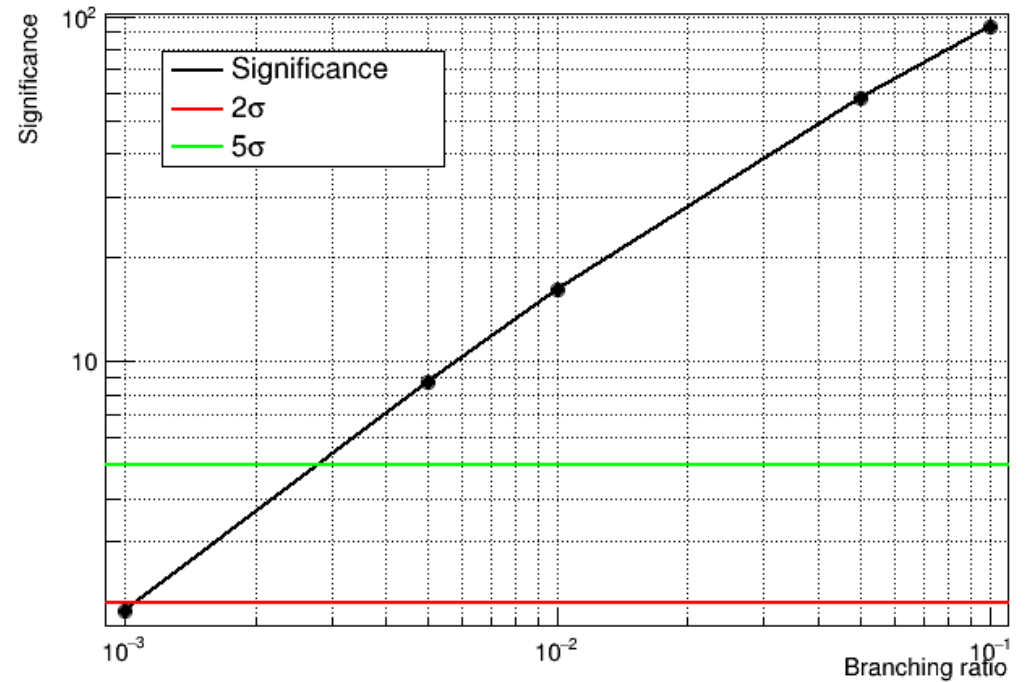
Dark neutrino mass (BR = 0.5%)

Dark neutrino corrected mass | Beam (-0.8, 0.3)
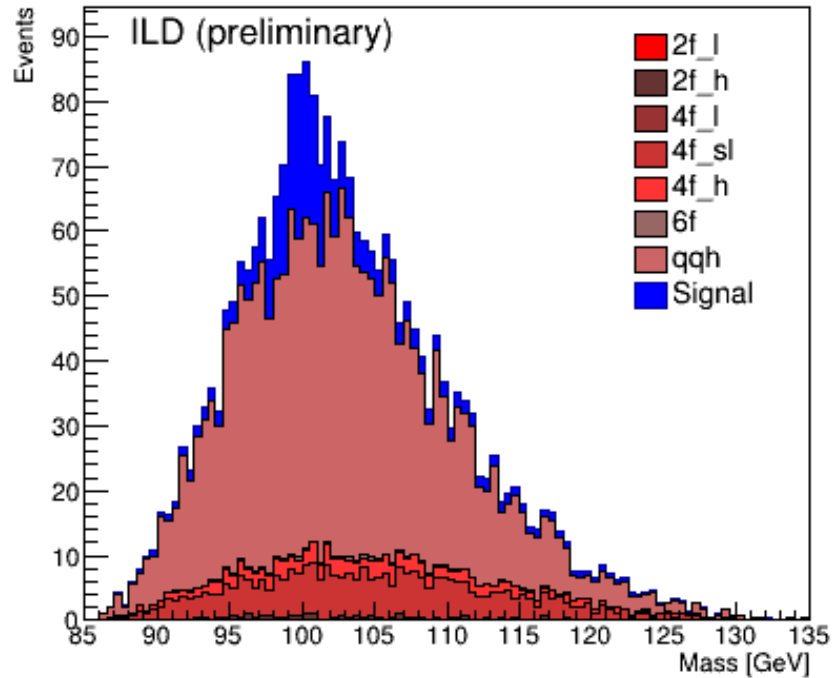
Dark neutrino corrected mass | Beam (0.8, -0.3)

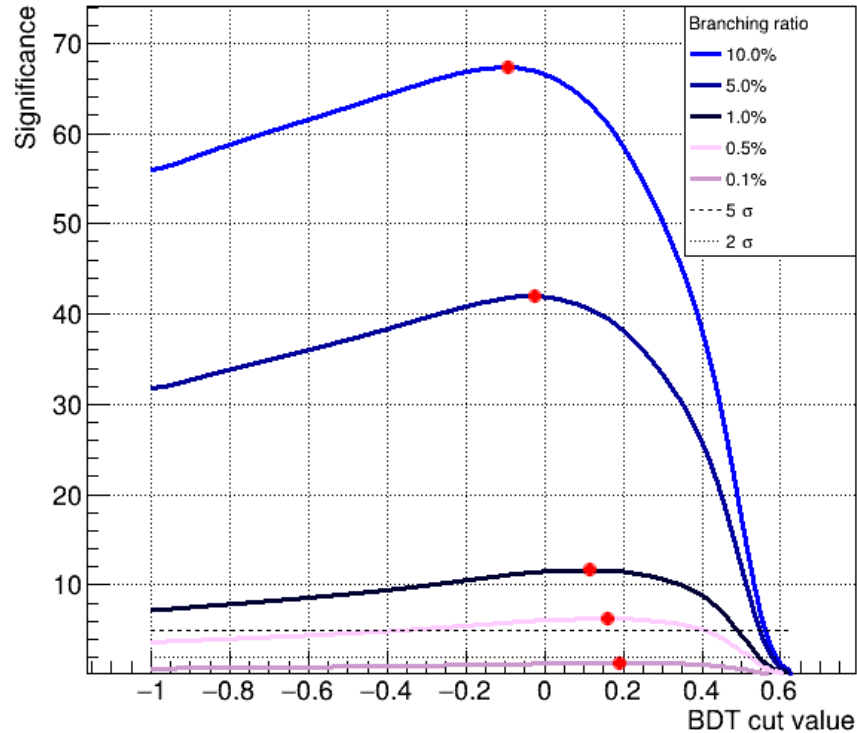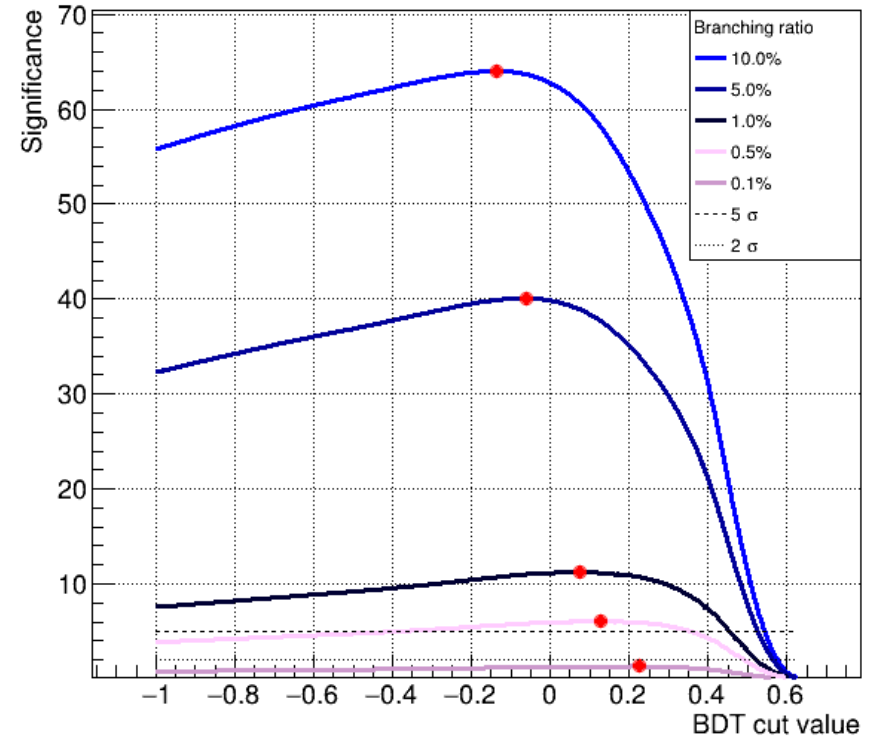# Future work

- More dark neutrino samples
  - Electron channel
  - Other dark neutrino masses

Significance output of BDT – with mass

Dark neutrino mass (BR = 0.5%)
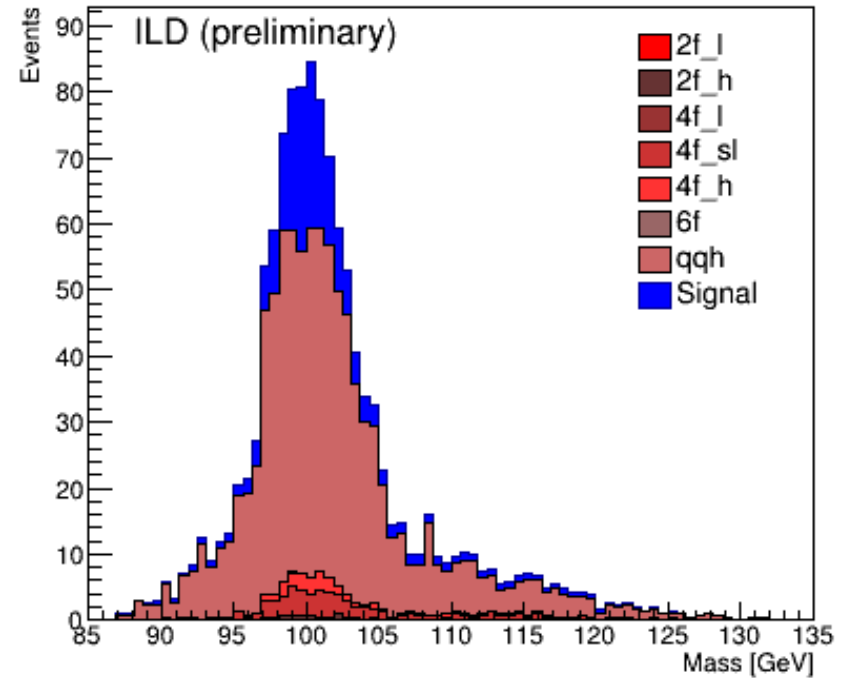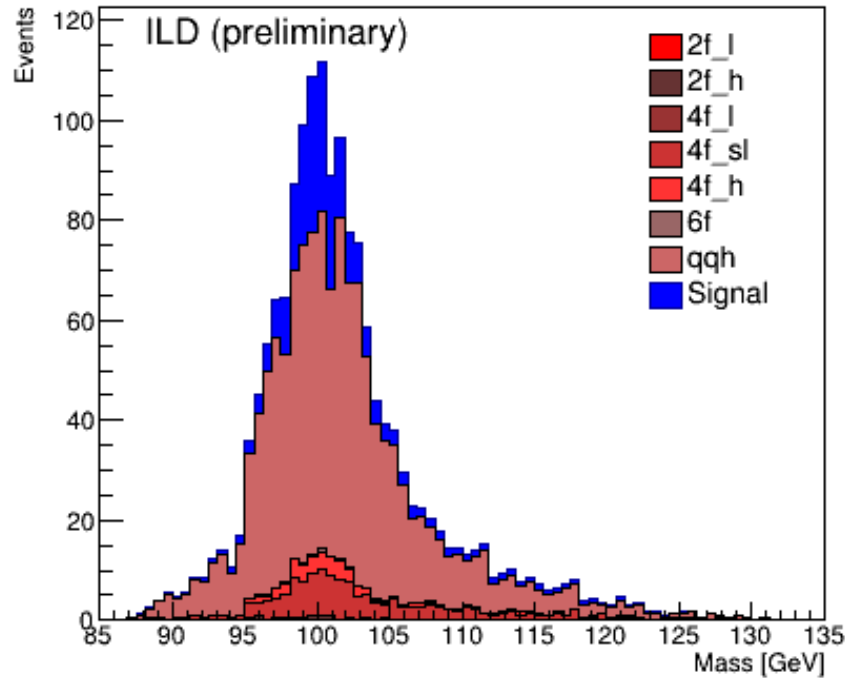
Cut table – 1% BR

(-0.8, +0.3)	Total signal	Total background	Significance	2f_l	2f_h	4f_l	4f_sl	4f_h	6f	qqh
No cuts	1397	136859842	0.12	12982897	77324421	10379315	19163106	16800470	1278	208355
Pre-selection	1215	30132034	0.22	7366002	1606336	7651845	13260215	220833	872	25932
elep/50. + emis/90. < 1.	1085	1565721	0.87	75113	265900	857303	209602	147613	705	9485
0.8 < mvalep	902	882872	0.96	54525	41290	623639	138607	18676	585	5550
(180. < mvis) && (mvis < 225.)	845	391342	1.35	34476	21865	237881	82092	9918	383	4728
0.007 < y34	726	27311	4.34	160	2109	406	13519	6778	346	3993
2 < min_n	711	16305	5.45	4	1223	7	4376	6541	314	3841
(10. < mis.P()) && (mis.P() < 50.)	702	8703	7.24	2	564	4	2207	2449	102	3376
MVA cut	521	1457	11.72	0	14	0	180	52	7	0

(+0.8, -0.3)	Total signal	Total background	Significance	2f_l	2f_h	4f_l	4f_sl	4f_h	6f	qqh
No cuts	954	66651497	0.12	10314870	45672588	6114301	2839022	1570051	260	140405
Pre-selection	830	12565351	0.23	5696748	979693	4109167	1739683	22431	194	17434
elep/60. + emis/100. < 1.	799	1526118	0.65	99987	189804	1016886	193442	17855	167	7978
0.6 < mvalep	769	1212198	0.70	88826	62401	890288	159199	5357	156	5971
(160. < mvis) && (mvis < 220.)	755	564514	1.00	63936	33233	359843	99486	2819	96	5100
0.004 < y34	708	38358	3.58	565	6575	2378	21820	2369	93	4558
4 < min_n	621	9269	6.24	0	1775	0	1881	1910	71	3631
(10. < mis.P()) && (mis.P() < 50.)	613	5895	7.59	0	879	0	1049	902	23	3042
MVA cut	484	1359	11.28	0	20	0	93	45	2	0