Jongkuk

Flash Talk

-2025 Belle II Summer Workshop-

Yonsei University
Jongkuk Min

2025.06.27

Most interesting Session

Probability and statistics - some basics for HEP

Speaker: Alan Schwartz (University of Cincinnati)

Actually I've studied about 'Probability and statistics' before,···

But some concepts got away my 'brain'

It is a good opportunity to review some concepts

Most interesting Session

Time-dependent CP violation in B to eta' KS

Speaker: Noah Brenny (Iowa State University)

I also found Noah's session interesting.

Because I'm currently studying vertex displacement by reconstructing K_L^0 decays.

Their session gave me useful insight into improving my own analysis.

I study a decay $D^+ \to \pi^+ K_L^0 [\to \pi^+ \pi^- \pi^0 [\to \gamma\gamma]] \cdots ..$

Back up

Back up

Decay : $D^+ \to \pi^+ K_L^0,\ K_L^0 \to \pi^+\pi^-\pi^0,\ \pi^0 \to \gamma\gamma$

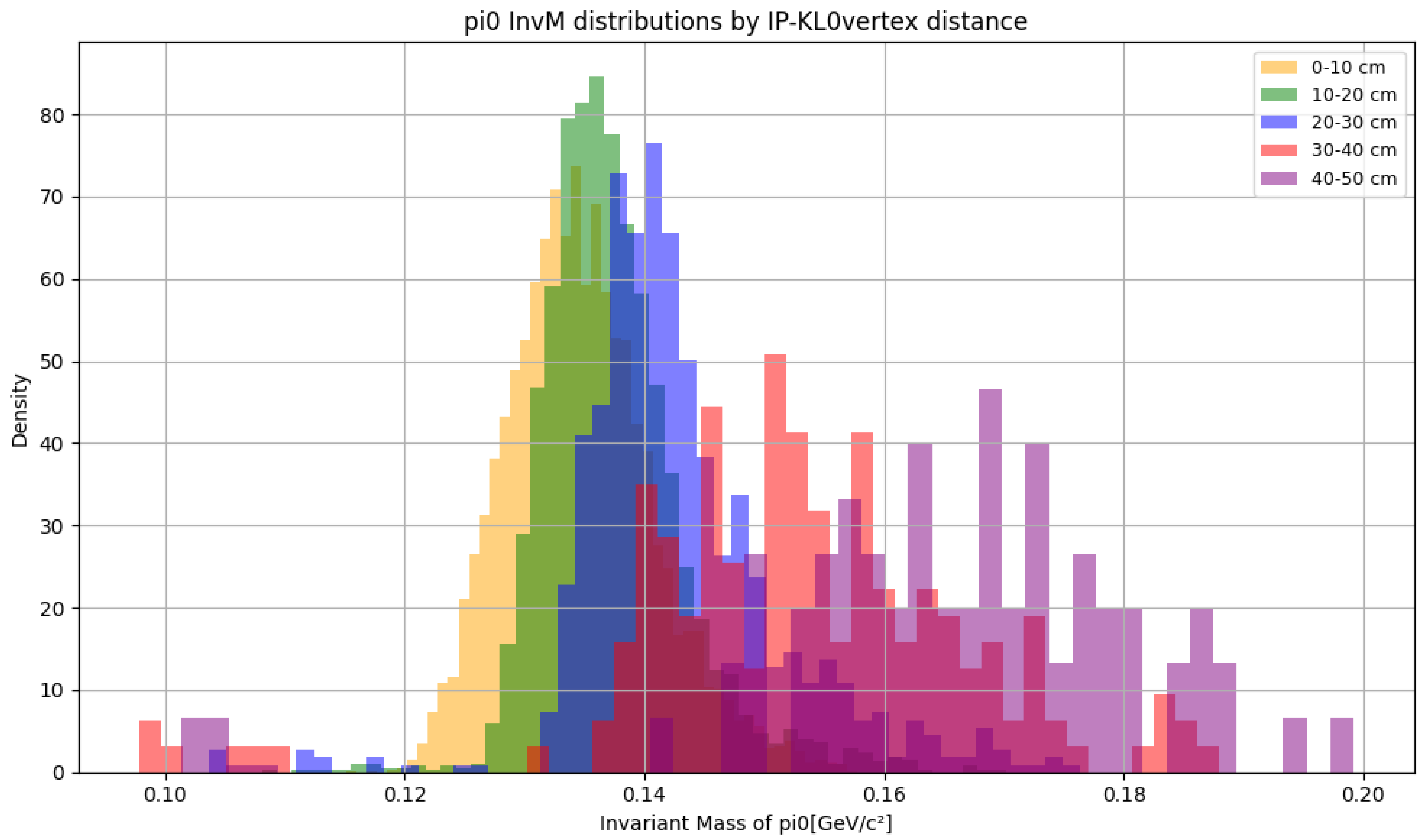
Number of Events : 20,000,000

Treefit applied with π^+, π^- ; π^0 excluded

Cut	
γ	clusterE(GeV) > 0.10
π^+	pionID > 0.1
π^0	0.12 < InvM(GeV) < 0.15
K_L^0	0.4 < InvM < 0.6
D^+	1.0 < InvM < 2.0 & isSignal == 1

Signal MC - Variation of reconstructed π^0 invariant mass with distance between IP and 3π vertex

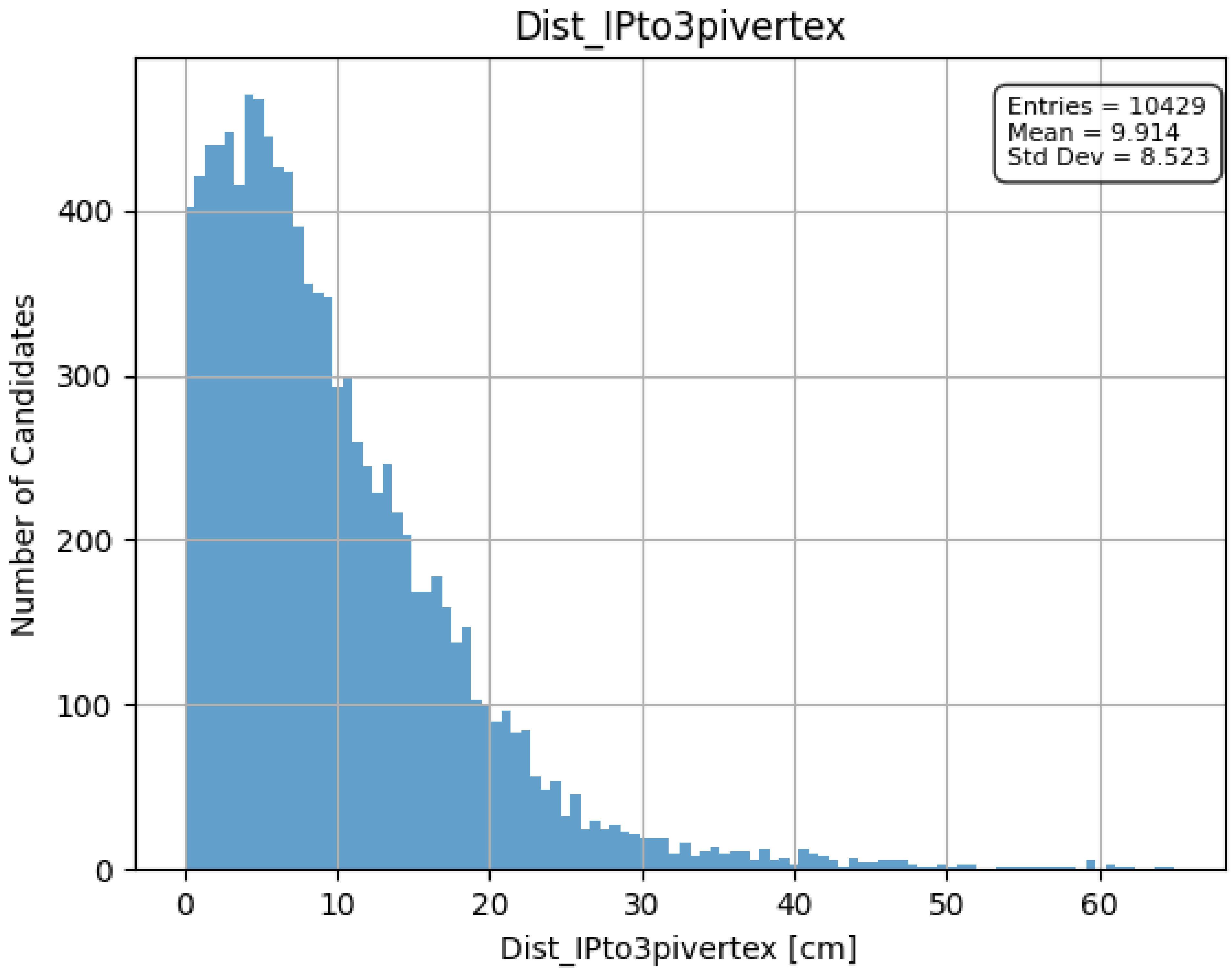
$$D^+ \to \pi^+ K_L^0[\to \pi^+\pi^-\pi^0[\to \gamma\gamma]]$$



Normalization

- $density = \frac{counts}{\sum(counts) \times bin\,width}$
- $\sum(density \times bin\,width) = 1$

Backup



Dist_IPto3pivertex
Entries = 10429
Mean = 9.914
Std Dev = 8.523
Number of Candidates
400
300
200
100
0
0
10
20
30
40
50
60
Dist_IPto3pivertex [cm]

Logan

Secret MVA Competition Project

Logan Benninghoff

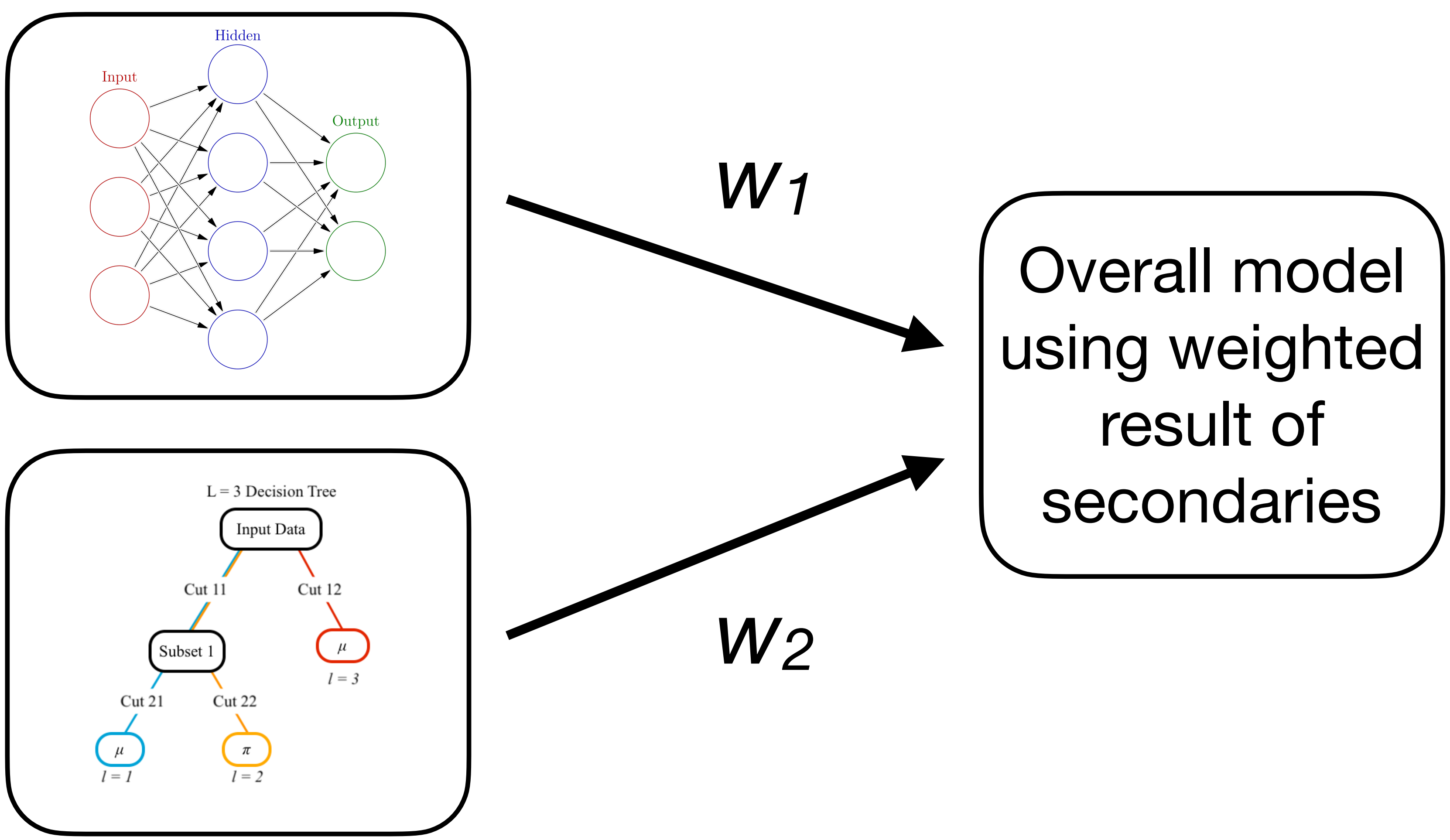
THE UNIVERSITY of MISSISSIPPI

Belle II

Secret Project (not submitted)

- Couldn't submit, installed software package dependencies caused problems.

- In testing, apparent optimal model was,



Quick Notes

- This is a similar procedure to what underlies GBDTs, they are weighted outputs of multiple DTs.
- Weakness is likely processing speed, but if the goal is just accuracy, keep this structure in mind.
- Ex. ~ One model performs well for distinguishing beam background photons, other model performs well for fake photons. Combine the results from both in a weighted model.

Noah

Flash Talk

Noah Brenny

Summary

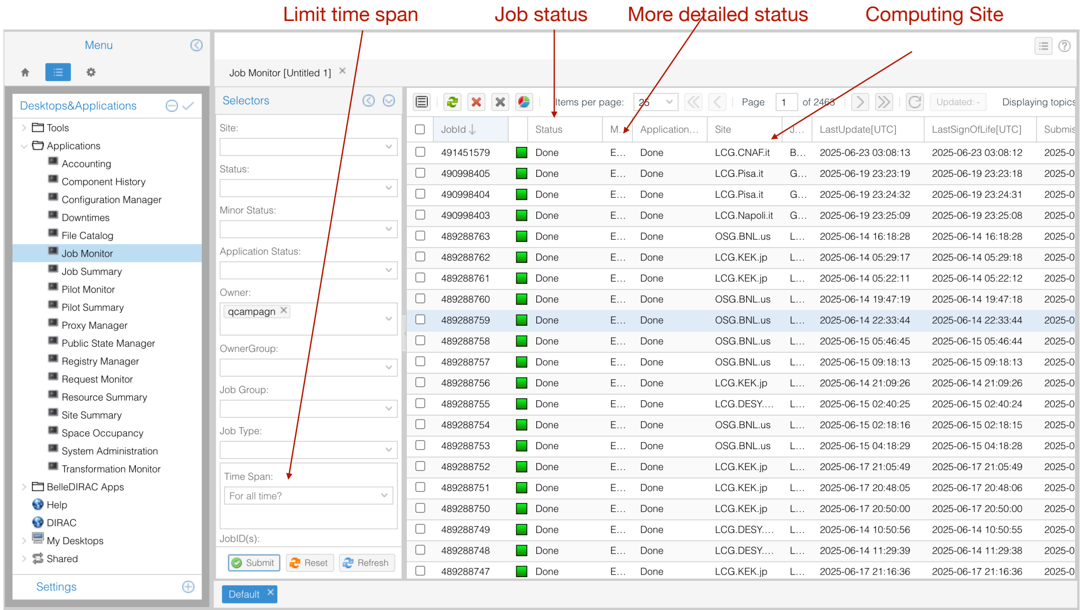
	Pro	Con
isSignal	Easy, Clean	Limited Acceptance
mcPDG	Easy, Clean	Related to specific reconstructed particle object
mcErrors	Informative, shows were matching goes wrong	Does not show physics process generated
genUpsilon4S	Custom access to generated processes	Slightly complex extraction / analysis
GenMCTagTool	Easy access to generated processes	Only links to first occurrence of particle of interest, limited to first order decay
TopoAna	Clean customizable access to information on generated processes, clean pdf output for analysis of signal and sample composition	Requires a little understanding of TopoAna, can be problematic with messy events, requires more variables and computation, not linked to basf2
Custom module	Custom access to generated processes	Requires a little understanding of the backend of how things are stored / access, prone to error

Reconstructed truth

Event truth

https://dirac.cc.kek.jp:8443/DIRAC/

Monitoring jobs - WebApp



MC truth matching (T. Crane)

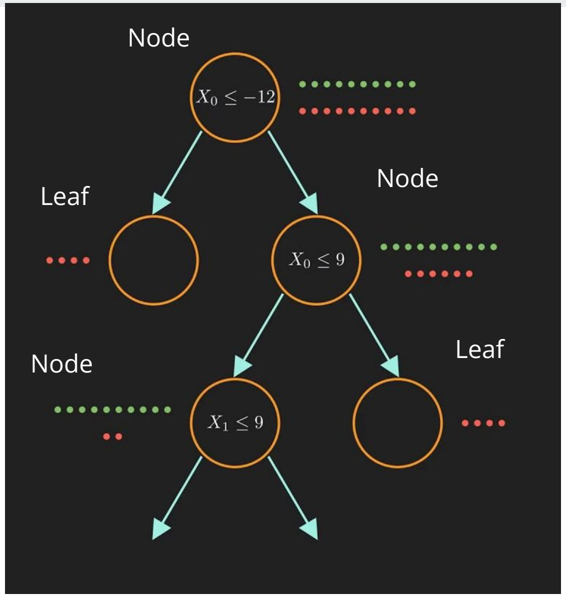
- There are a lot of tools that perform truth matching
- Best choice depends on analysis

gbasf2 hands-on (Q. Campagna)

- Can use WebApp for interacting with gbasf2 jobs
- Computing needs more developers

How decisions are made?

- The decision is made by minimizing the Gini Impurity or entropy of the subset
  - Gini = $\sum_i (p_i)(1-p_i) = 1 - \sum_i (p_i)^2$
  - Entropy = $-\sum_i (p_i)\log(p_i)$
  - Others…
- All possible splits are considered and optimal cut is selected



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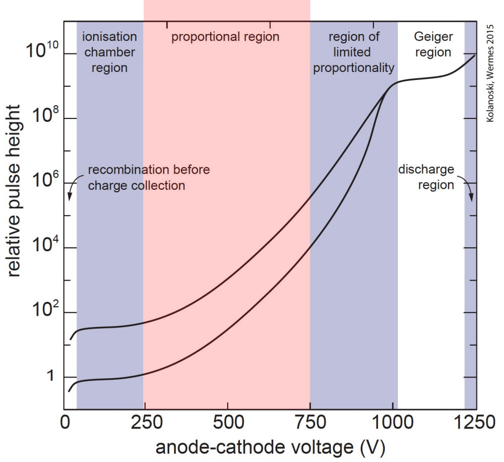
Q: How can we keep the avalanching process under control?

A: Quenching gasses work here too!
- "Cools" electrons (steals KE)
- Absorb UV photons that cause secondary showers
  - These can cause *runaway* avalanches

It's kind of magic! The same kinds of additives that gave us *high drift velocity and low diffusion* also keep the avalanches under control!
- Keeps signals in proportional region
- Limits space-charge effects
- Prevents runaway avalanches

We want to be here!



Q: There's a **big downside** to using hydrocarbons in this environment. Any clue what it is?

ML/AI tools (T. Lam)

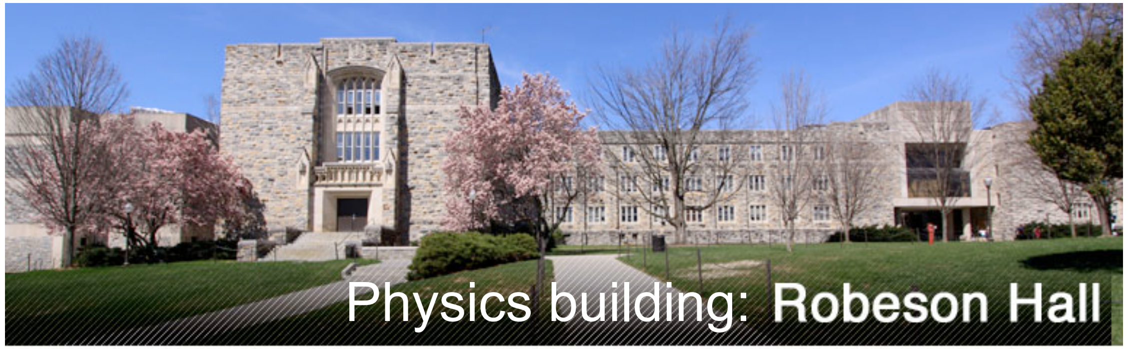
- Decision trees decide by minimizing entropy or similar function

CDC (P. Lewis)

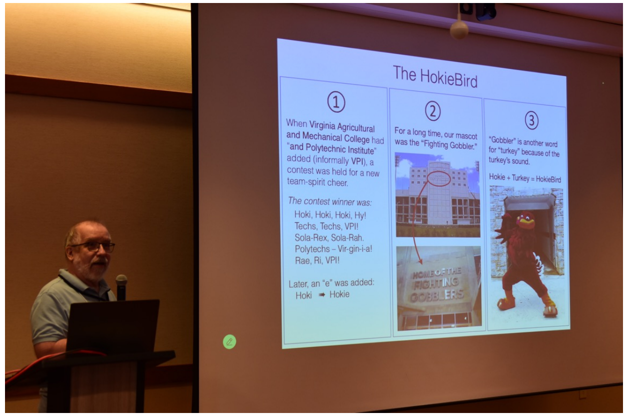
- Quenching gas:
  - Gives high drift velocity and low diffusion
  - Keeps avalanches under control

- VT is very nice
  - Buildings
  - People
- Thank you, Tommy, Kindo-san, Leo, and Katrina!

Hokie Stone



Welcome (L. Piilonen)



Seunghak

Belle II Summer Workshop
(Flash talk)

Yonsei University

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June 27th, 2025

Some interesting lectures for me …

- Belle II Detector related lectures

Ex)

4:00 PM

CDC — 45m — Cascades

Speaker: Peter Lewis (BELLE (BELLE II Experiment))

Belle II workshop 20...

- ML related lectures

Ex)

3:30 PM

ML/AI tools in Belle II analyses — 20m — Cascades

Speakers: Boyang Zhang (University of Hawaii [Belle II]), Tommy Lam (Virginia Tech (BELLE II Experiment))

ML Hands-on sessi...

- Statistical method related lectures

Ex)

1:00 PM

Probability and statistics - some basics for HEP — 30m — Cascades

Speaker: Alan Schwartz (University of Cincinnati)

ProbStatistics.pdf

How can they help my research?

- I was having a hard time dealing with some peaking backgrounds in my generic MC samples
- I hope making use of machine learning techniques(RFC, XGBoost, etc) that I learned from the lectures would be helpful.

- I was having a hard time understanding some statistical methods used in hep-ex
- I hope reading some references from the lecture would help me.

- I was having a hard time understanding Belle II detector mechanisms
- All lectures related to detectors in Belle II from this workshop gave me some kind of insight.

Thank You!

Backup slides

Research topic

Introduction

My current research topic is:

"Searching for Majorana neutrinos in lepton number violation decay modes with charm hadrons"

$(X_c^+ \rightarrow h^- \ell^+ \ell^{(\prime)+})$ X: Charm hadron $(D^+, D_s^+, \Lambda_c^+)$, h: π^-, K^-, p^-, $\ell : e,^+ \mu^+$)

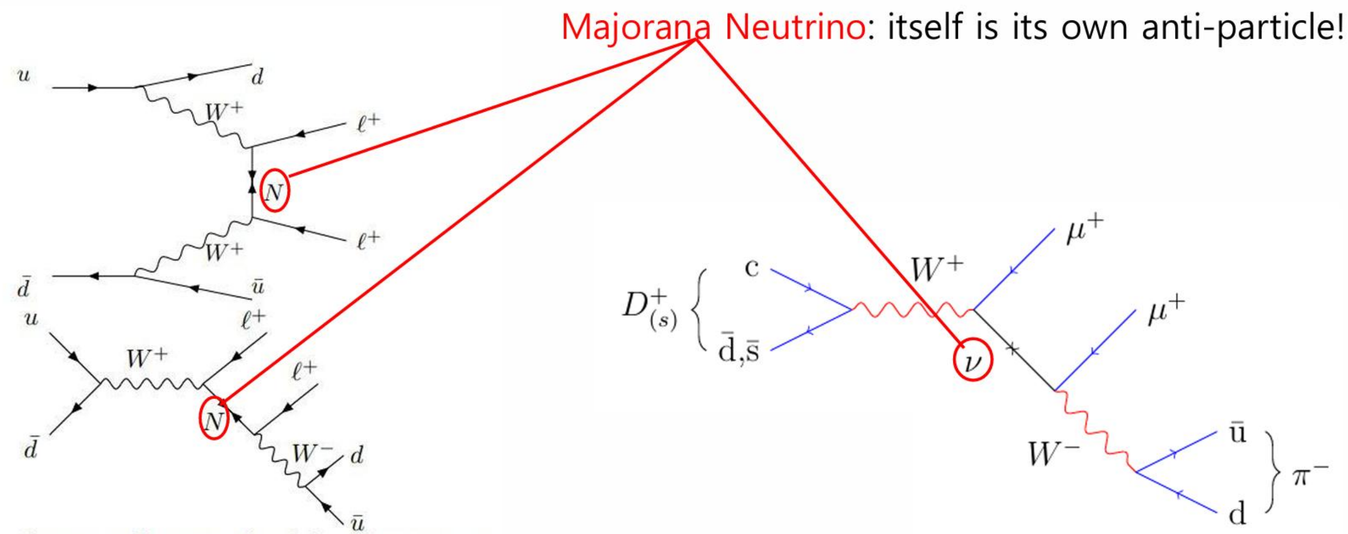

FIG. 1: Feynman diagrams for $\Delta L = 2$ processes induced by a Majorana neutrino N in $q\bar{q}'$ collisions.

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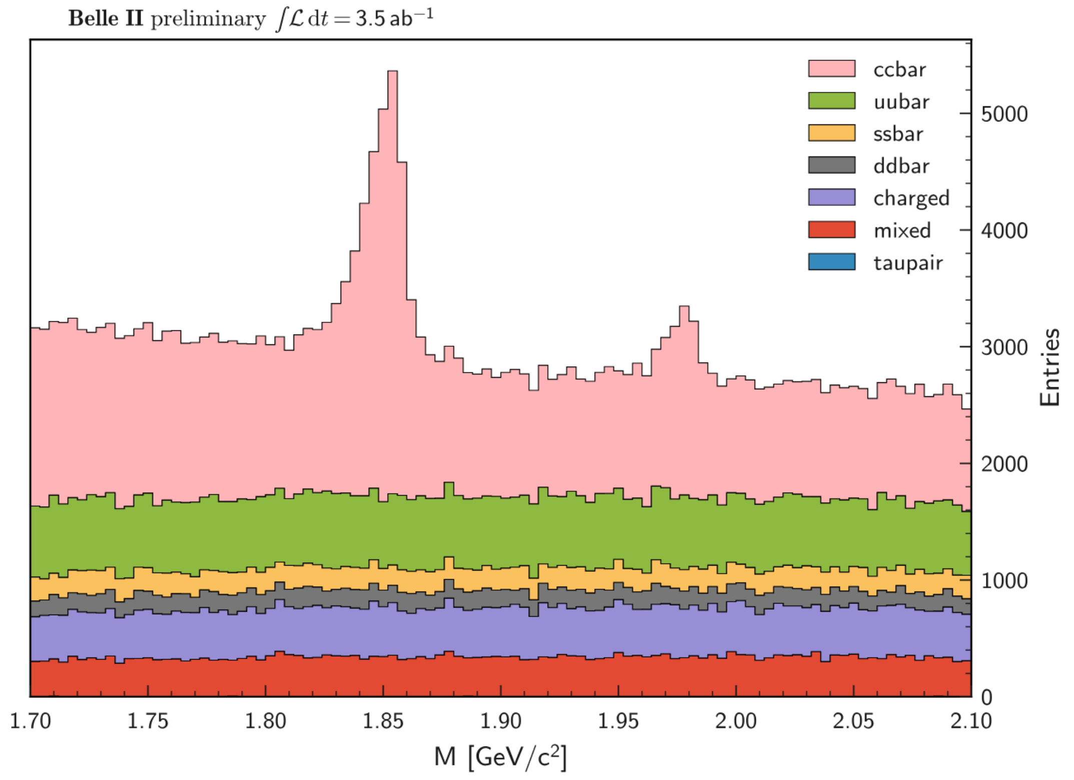
[0901.3589] The Search for Heavy Majorana Neutrinos

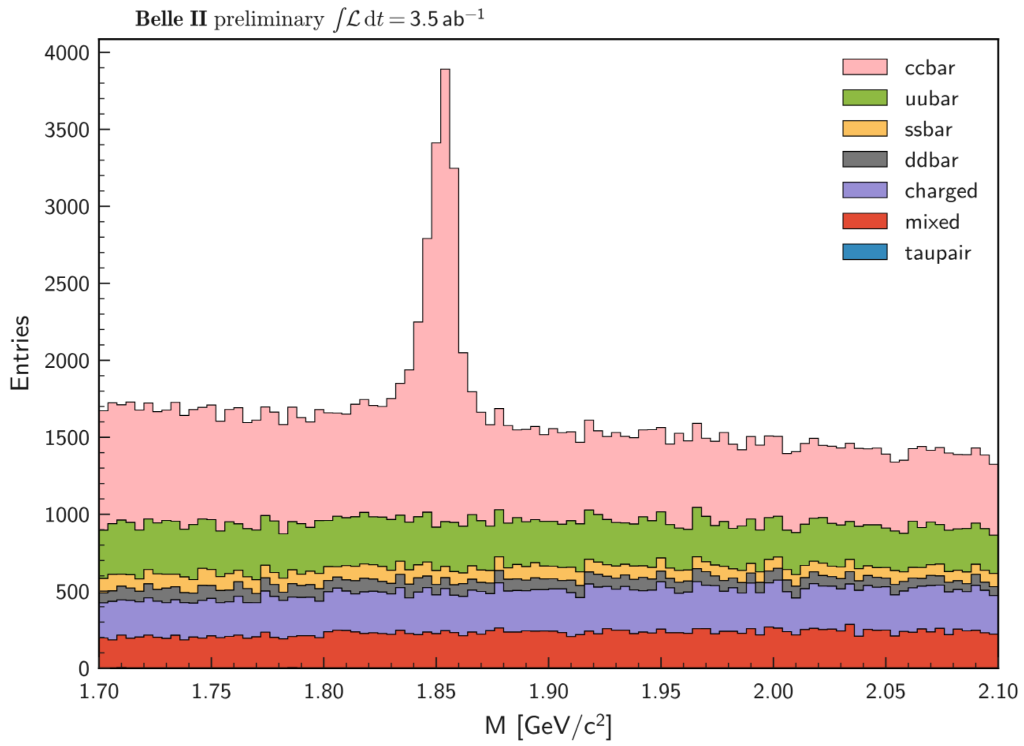
1107.4465(https://arxiv.org/pdf/1107.4465)

Peaking Background

$D_{(s)}^{+} \rightarrow K^{-}\mu^{+}\mu^{+}$ signal decay mode with initial cuts has two peaking bkgs
(MC16ri run1 generic MC data)



After giving momentum cuts to two leptons, I removed peaking bkg near D_s+ and signal efficiency decreased a bit



(I feel very sorry that I just brought most of the backup slides from my old presentation screenshots because I'm too lazy.. Please forgive me as I received the late email ☹)

Topoana

Table 9: Cascade decay branches of D^+.

rowNo	cascade decay branch of D^+	iCascDcyBrP	nCase	nCcCase	nAllCase	nCCase
1	$D^+ \to \pi^+\pi^+K^-$	4	53393	53935	107328	107328
2	$D^+ \to \mu^+\nu_\mu\bar{K}^*, \bar{K}^* \to \pi^+K^-$	22	39212	40155	79367	186695
3	$D^+ \to \mu^+\nu_\mu\bar{K}^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	41	15927	15686	31613	218308
4	$D^+ \to \mu^+\nu_\mu\bar{K}^0, \bar{K}^0 \to K_L^0$	32	13614	13389	27003	245311
5	$D^+ \to \pi^0\pi^+\bar{K}^*, \bar{K}^* \to \pi^+K^-$	34	11625	11702	23327	268638
6	$D^+ \to \pi^0\pi^+K_S^0, K_S^0 \to \pi^+\pi^-$	26	11445	11427	22872	291510
7	$D^+ \to \pi^0K_L^0\pi^+$	33	10711	10636	21347	312857
8	$D^+ \to \pi^+\pi^+K^-\gamma^F$	2	8917	9075	17992	330849
9	$D^+ \to e^+\nu_e\bar{K}^*, \bar{K}^* \to \pi^+K^-$	14	7729	7590	15319	346168
10	$D^+ \to \pi^+K^+K^-$	7	4901	4883	9784	355952
11	$D^+ \to \mu^+\nu_\mu\bar{K}^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^0\pi^0$	112	4425	4468	8893	364845
12	$D^+ \to e^+\nu_e\bar{K}^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	28	4054	4056	8110	372955
13	$D^+ \to e^+\nu_e\bar{K}^0, \bar{K}^0 \to K_L^0$	48	4006	3931	7937	380892
14	$D^+ \to \pi^0\pi^+K_S^0, K_S^0 \to \pi^0\pi^0$	37	3466	3459	6925	387817
15	$D^+ \to \pi^0\pi^+\pi^+\pi^-$	53	3278	3300	6578	394395
16	$D^+ \to \rho^+\bar{K}^*, \rho^+ \to \pi^0\pi^+, \bar{K}^* \to \pi^+K^-$	10	3274	3134	6408	400803
17	$D^+ \to e^+\nu_e\bar{K}^*\gamma^F, \bar{K}^* \to \pi^+K^-$	12	3036	3182	6218	407021
18	$D^+ \to \mu^+\nu_\mu\bar{K}^*, \bar{K}^* \to \pi^+K^-\gamma^F$	0	2985	3044	6029	413050
19	$D^+ \to \mu^+\nu_\mu\bar{K}^*\gamma^F, \bar{K}^* \to \pi^+K^-$	51	2855	2924	5779	418829
20	$D^+ \to \pi^+\rho^+K^-, \rho^+ \to \pi^0\pi^+$	16	2890	2811	5701	424530
21	$D^+ \to \pi^+K_S^0, K_S^0 \to \pi^+\pi^-$	11	2854	2846	5700	430230
22	$D^+ \to \pi^0\pi^+K^+K^-$	94	2658	2454	5112	435342
23	$D^+ \to \mu^+\nu_\mu\pi^+K^-$	44	2415	2551	4966	440308
24	$D^+ \to K_L^0\pi^+$	61	2532	2329	4861	445169
25	$D^+ \to \mu^+\nu_\mu\bar{K}^*, \bar{K}^* \to \pi^0\bar{K}^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	47	2266	2306	4572	449741
26	$D^+ \to \pi^+\bar{K}_1^{\prime 0}, \bar{K}_1^{\prime 0} \to \pi^+K^{*-}, K^{*-} \to \pi^0K^-$	69	2095	2129	4224	453965
27	$D^+ \to \mu^+\nu_\mu\bar{K}^*, \bar{K}^* \to \pi^0\bar{K}^0, \bar{K}^0 \to K_L^0$	85	2087	2105	4192	458157
28	$D^+ \to \pi^+\bar{K}_1^{\prime 0}, \bar{K}_1^{\prime 0} \to \pi^0\bar{K}^*, \bar{K}^* \to \pi^+K^-$	160	2030	2097	4127	462284
29	$D^+ \to \pi^+\pi^+\pi^-\eta, \eta \to \gamma\gamma$	56	2042	1995	4037	466321
30	$D^+ \to \pi^0\pi^+\pi^+\pi^-\eta, \eta \to \gamma\gamma$	130	1931	1979	3910	470231
31	$D^+ \to K_L^0a_1^+, a_1^+ \to \rho^0\pi^+, \rho^0 \to \pi^+\pi^-$	18	1893	1830	3723	473954
32	$D^+ \to e^+\nu_e\bar{K}^0\gamma^F, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	9	1791	1875	3666	477620
33	$D^+ \to e^+\nu_e\bar{K}^0\gamma^F, \bar{K}^0 \to K_L^0$	70	1681	1724	3405	481025