

Selective background Monte Carlo simulation at Belle II

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"Origin and Structure of the Universe"

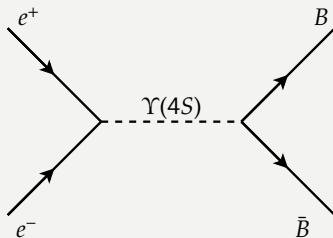
February 2019



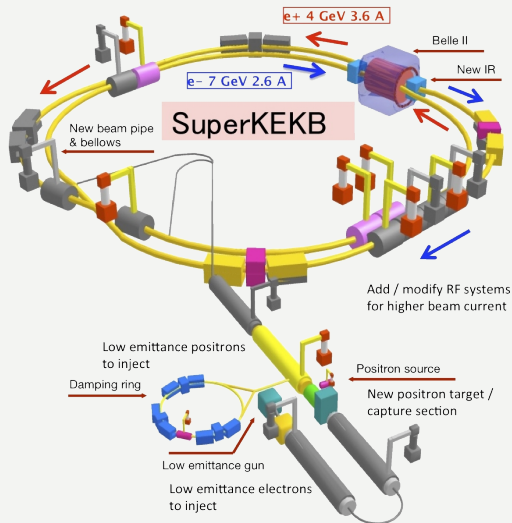
Bundesministerium
für Bildung
und Forschung

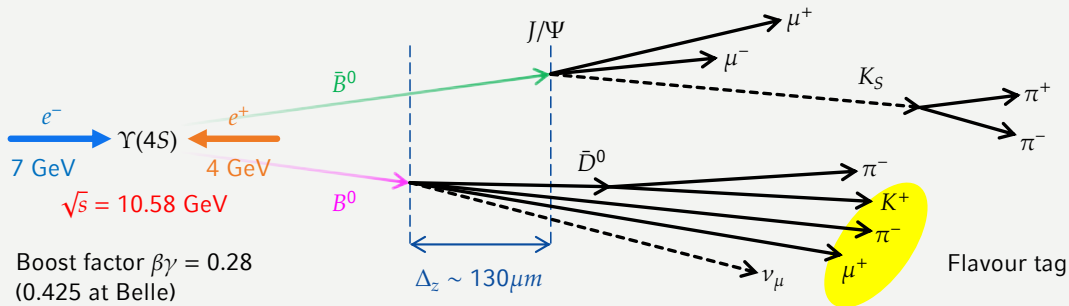


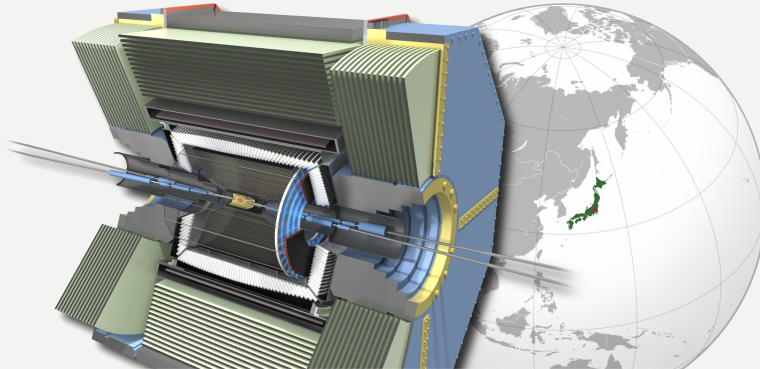
- Asymmetric e^+e^- experiment
- Mainly at $\Upsilon(4S)$ resonance (10.58 GeV)



Focus on B, charm and τ physics





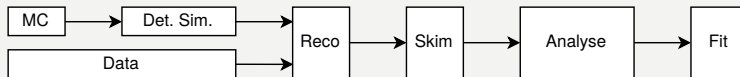


	KEKB/Belle	SuperKEKB/Belle II
Operation	1999–2010	2019–
Peak luminosity	$2.11 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	$8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
Integrated luminosity	1 ab^{-1} (772 million $B\bar{B}$ pairs)	50 ab^{-1}



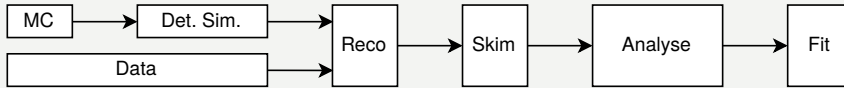
Problem Belle II expecting 50 ab^{-1} of data (Belle: 1 ab^{-1})
Want MC $\approx 10 \times$ data
Event simulation is time consuming
Most background events discarded trivially

Stage	HEP-SPEC06 s/event
Framework overhead	0.79
Event generation	0.11
Detector simulation	47.23
Event reconstruction	26.77



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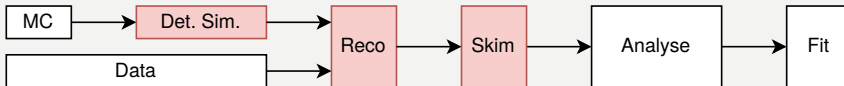
Task Come up with a way to only simulate useful (background) events



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Dataset Generic MC simulations and their corresponding skims

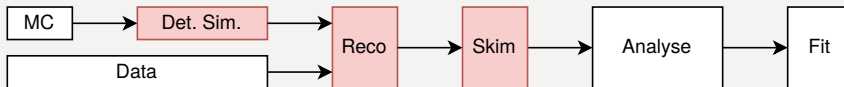


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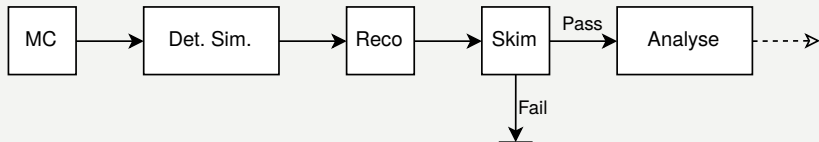
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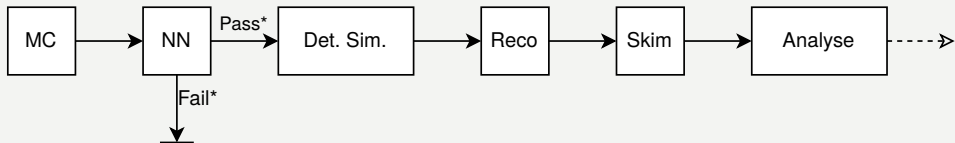
Solution Use neural networks to predict (classify) event usefulness before performing full simulation



Want to predict (labels):



with generalised prediction module:



Train on two FEI skim channels:

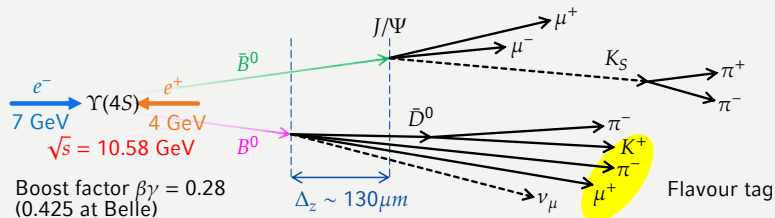
- ▶ FEI Had. B^0 : 8.5 M events
- ▶ FEI Had. B^+ : 4 M events

10% reserved for validation.

Test events simulated independently.

Table: FEI skim event retention rates.

Channel	Had B^+	Had B^0
$B^0\bar{B}^0$	5.62%	4.25%
B^+B^-	8.35%	3.82%
$u\bar{u}$	6.86%	3.78%
$d\bar{d}$	7.20%	3.39%
$c\bar{c}$	12.0%	5.73%
$s\bar{s}$	6.13%	2.95%



Decay strings:

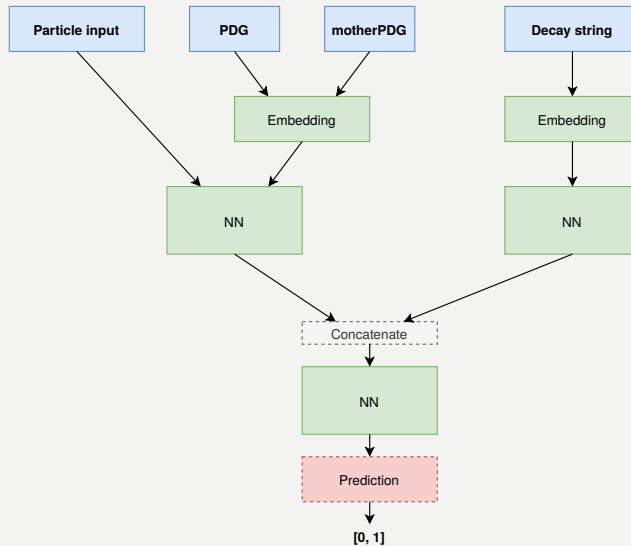
$$\bar{B}^0 \rightarrow J/\psi(\rightarrow \mu^+ \mu^- K_S^0(\rightarrow \pi^+ \pi^-))$$

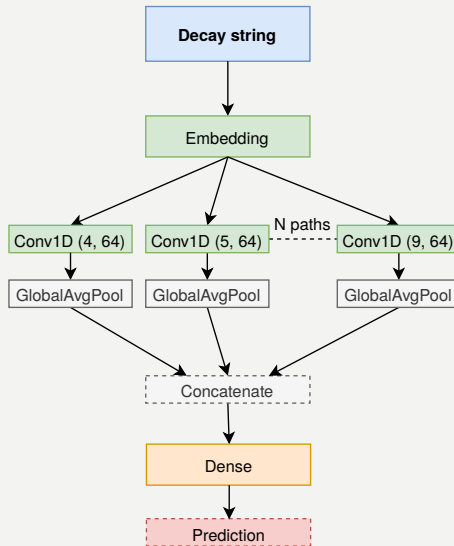
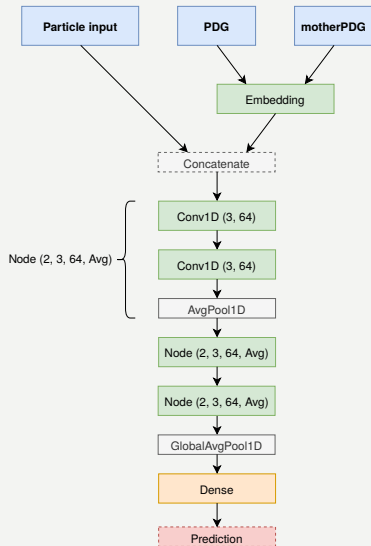
becomes:

$$-511 \left(\begin{array}{c} 443 \\ -13 \end{array} \right) \left(\begin{array}{cc} 13 & 310 \\ 211 & -211 \end{array} \right) \right)$$

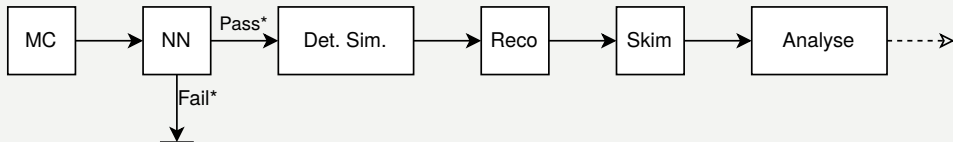
MCParticles

1	300553 (Upsilon(4S))	E: 1.100e+01	m: 1.058e+01	p:(...)	v:(...)
2	521 (B+)	E: 5.511e+00	m: 5.279e+00	p:(...)	v:(...)
4	-421 (anti-D0)	E: 1.939e+00	m: 1.865e+00	p:(...)	v:(...)
10	310 (K_S0)	E: 5.913e-01	m: 4.976e-01	p:(...)	v:(...)
20	211 (pi+)	E: 2.379e-01	m: 1.396e-01	p:(...)	v:(...)
21	-211 (pi-)	E: 3.534e-01	m: 1.396e-01	p:(...)	v:(...)
11	211 (pi+)	E: 3.484e-01	m: 1.396e-01	p:(...)	v:(...)
12	-211 (pi-)	E: 7.756e-01	m: 1.396e-01	p:(...)	v:(...)
5	413 (D*+)	E: 2.453e+00	m: 2.010e+00	p:(...)	v:(...)
14	411 (D+)	E: 2.239e+00	m: 1.870e+00	p:(...)	v:(...)
28	-321 (K-)	E: 8.801e-01	m: 4.937e-01	p:(...)	v:(...)
29	211 (pi+)	E: 5.853e-01	m: 1.396e-01	p:(...)	v:(...)
30	211 (pi+)	E: 7.737e-01	m: 1.396e-01	p:(...)	v:(...)
15	22 (gamma)	E: 2.138e-01	m: 0.000e+00	p:(...)	v:(...)
6	313 (K*0)	E: 1.111e+00	m: 8.617e-01	p:(...)	v:(...)
16	321 (K+)	E: 8.508e-01	m: 4.937e-01	p:(...)	v:(...)
17	-211 (pi-)	E: 2.683e-01	m: 1.396e-01	p:(...)	v:(...)
3	-521 (B-)	E: 5.493e+00	m: 5.279e+00	p:(...)	v:(...)
7	43 (Xu0)	E: 2.052e+00	m: 8.646e-01	p:(...)	v:(...)
18	211 (pi+)	E: 4.797e-01	m: 1.396e-01	p:(...)	v:(...)
19	-211 (pi-)	E: 1.572e+00	m: 1.396e-01	p:(...)	v:(...)
8	11 (e-)	E: 1.621e+00	m: 5.110e-04	p:(...)	v:(...)
9	-12 (anti-nu_e)	E: 1.820e+00	m: 0.000e+00	p:(...)	v:(...)

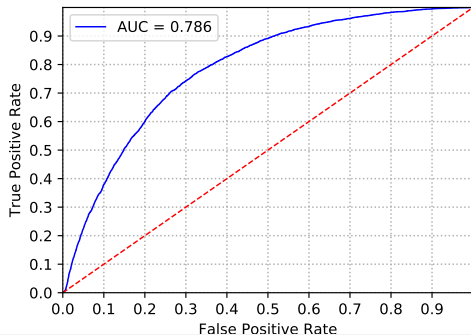




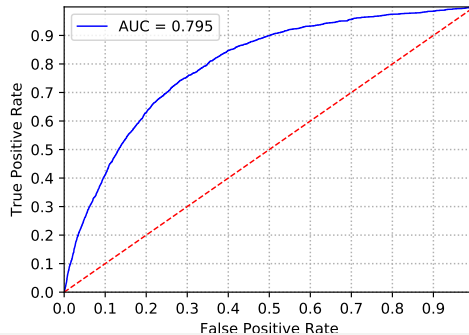
- ▶ Simulate 100,000 events of each sample
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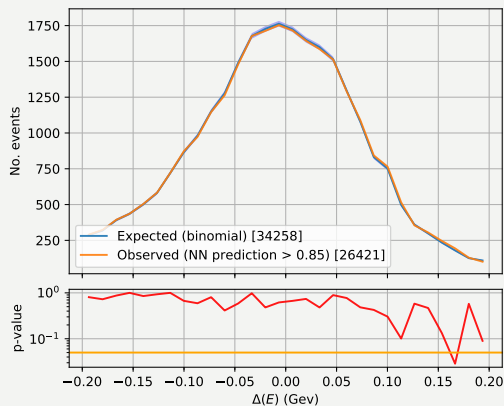
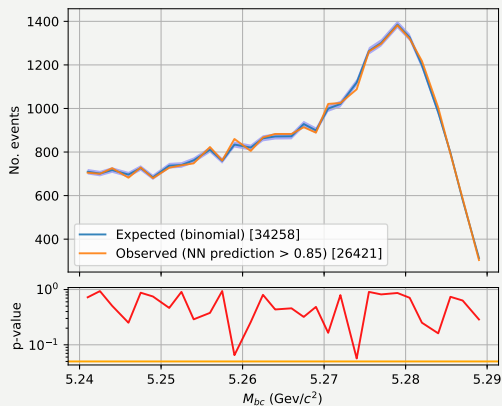


(a) Charged FEI B^+

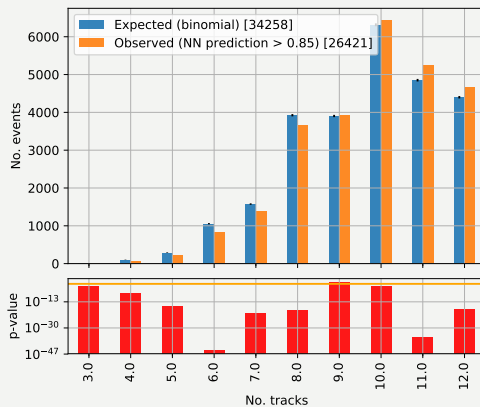
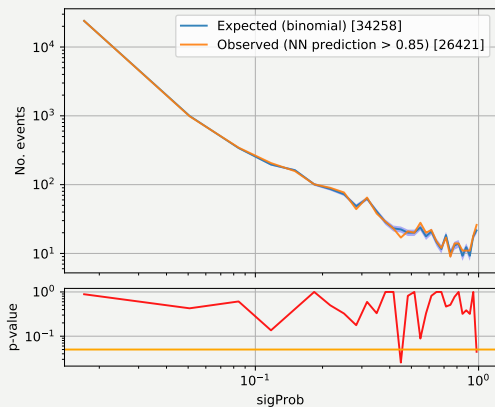


(b) Mixed FEI B^0

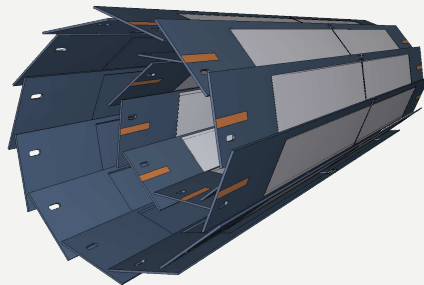
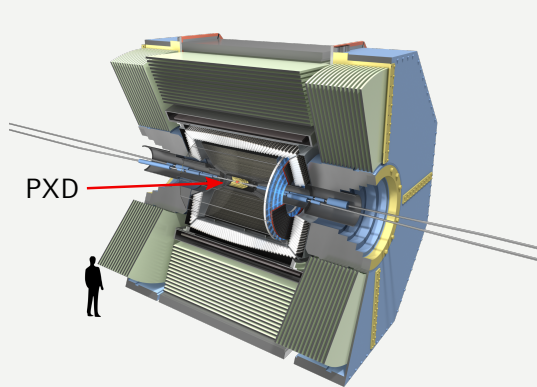
Compare kinematics before/after applying NN threshold:



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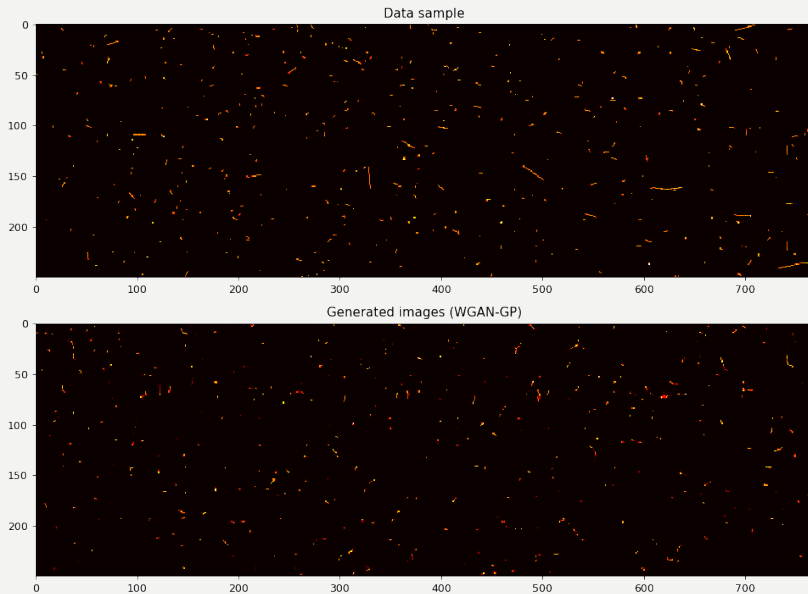
- ▶ Adversarial / loss penalty to discourage bias.
- ▶ Investigating usage in ATLAS simulation (bachelor student)
- ▶ Presenting results at ACAT

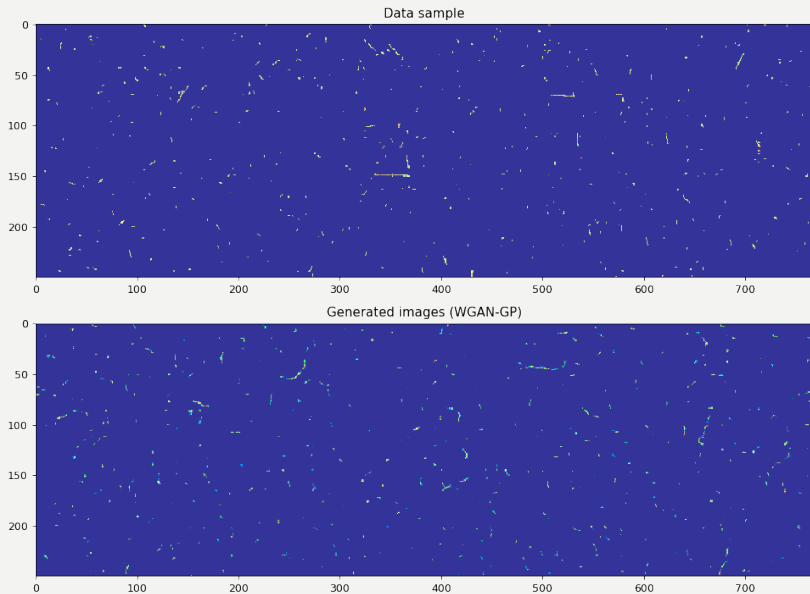


Inner ring: 8 ladders (3.1M pixels)

Inner ring: 12 ladders (4.6M pixels)

Goal: Simulate backgrounds with GAN





Thank you

First attempt:
Secondary NN $\rightarrow$ use to reweight events.

