A Neural Network z-Vertex Trigger for Belle II

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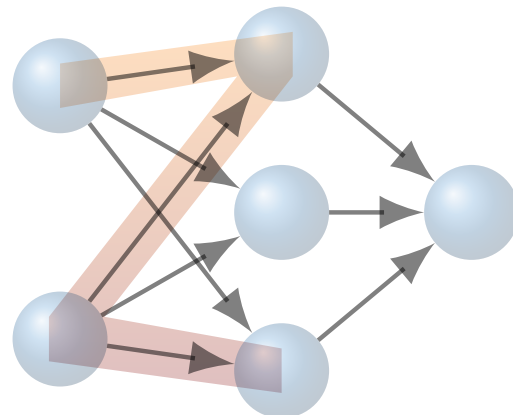


Neuro team

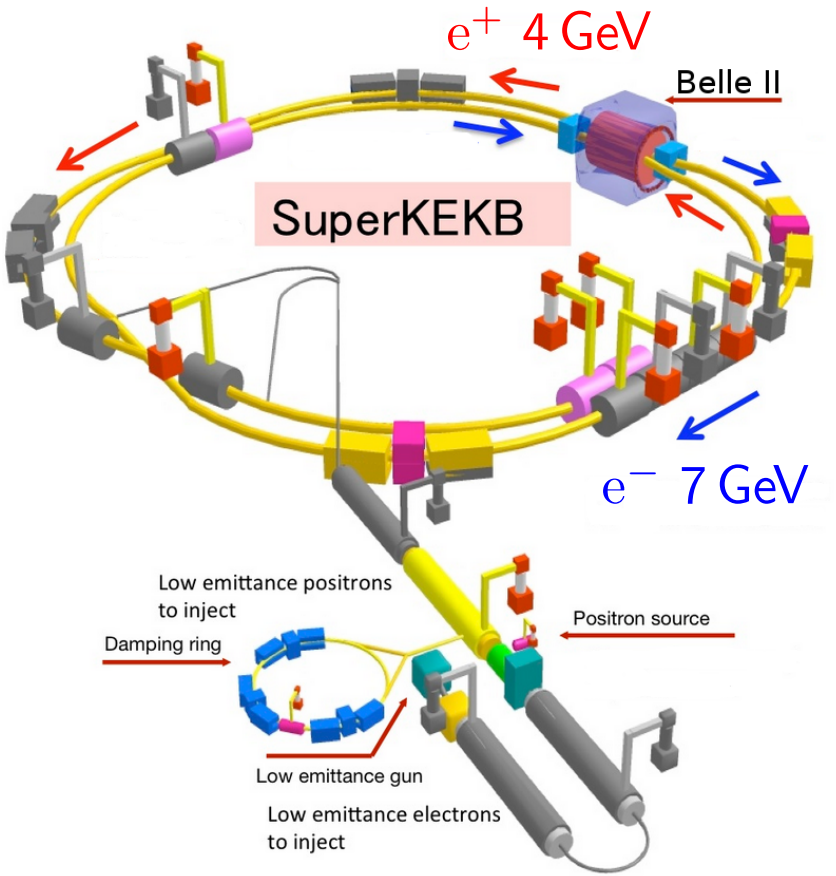
F. Abudinén (LMU), Y. Chen (TUM), M. Feindt (KIT), R. Frühwirth (HEPHY),
M. Heck (KIT), C. Kiesling (MPI), A. Knoll (TUM), S. Neuhaus (TUM),
S. Paul (TUM), T. Röder (MPI), J. Schieck (HEPHY), S. Skambraks (TUM)

The Belle II experiment

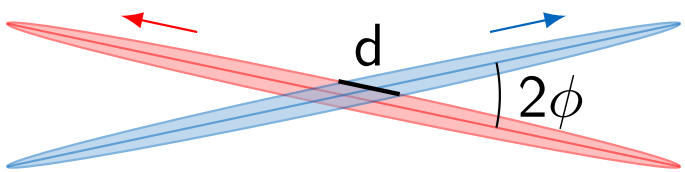
located in Tsukuba, Japan at **KEK**

高エネルギー加速器研究機構　　**K**ō **E**nerugī **K**asokuki kenkyū kikou

High Energy Accelerator Research Organization

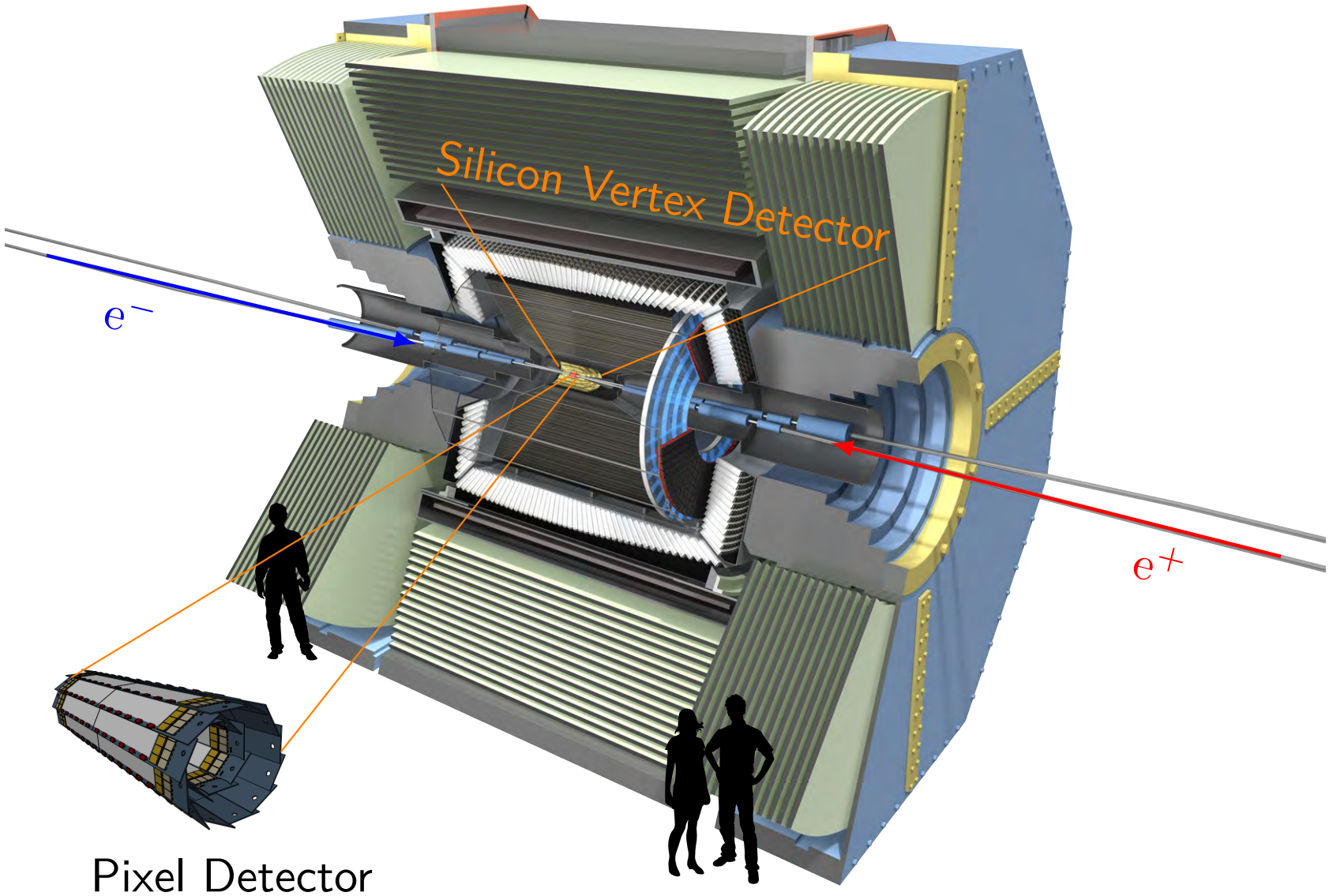


- asymmetric e^- e^+ collider
- $\Upsilon(4S)$ resonance
  ↳ $B^0\ \overline{B}^0$/ $B^+\ B^-$
- $\mathcal{L} = 8 \times 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
  (40× KEKB)

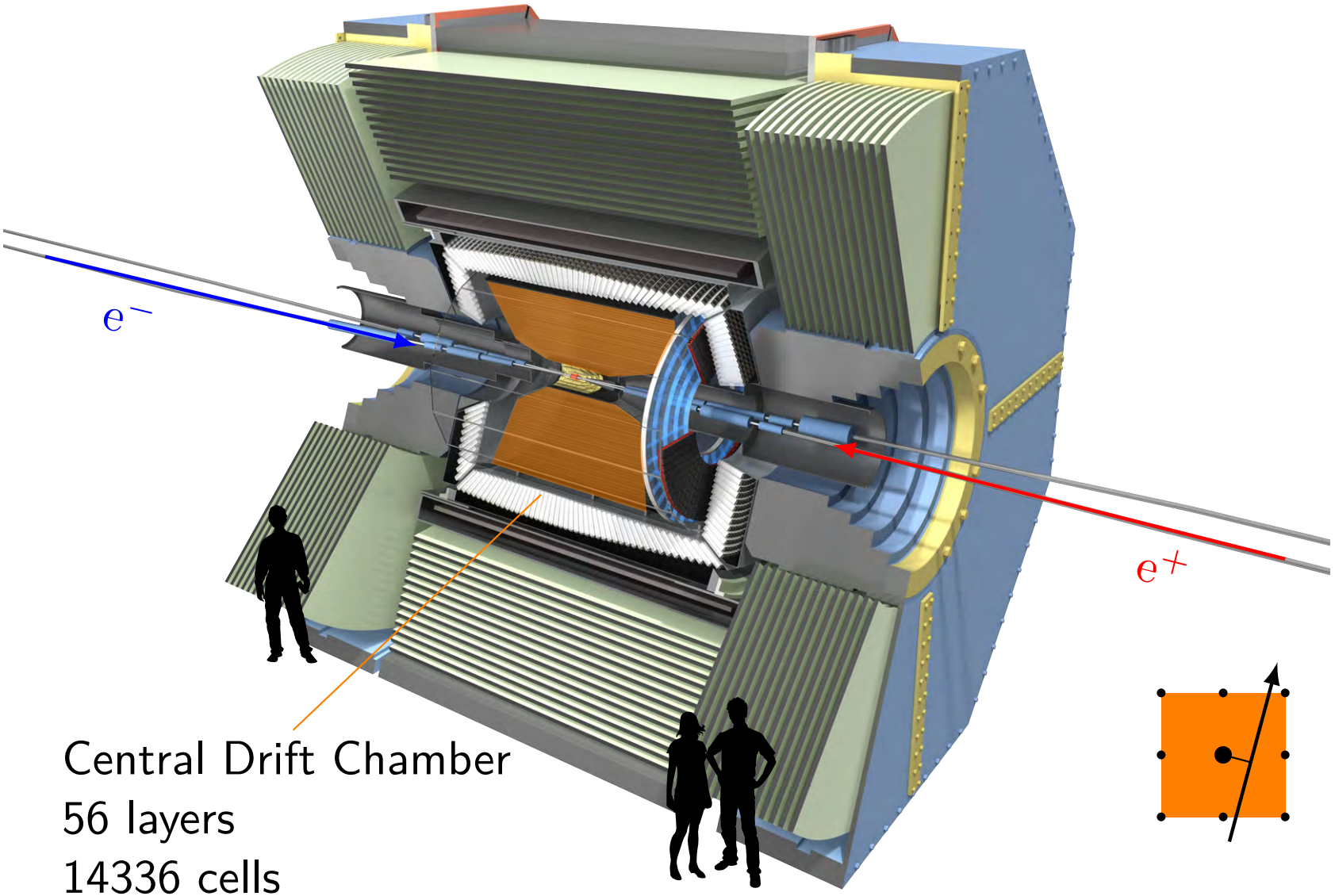


Nano-Beam scheme

The Belle II detector

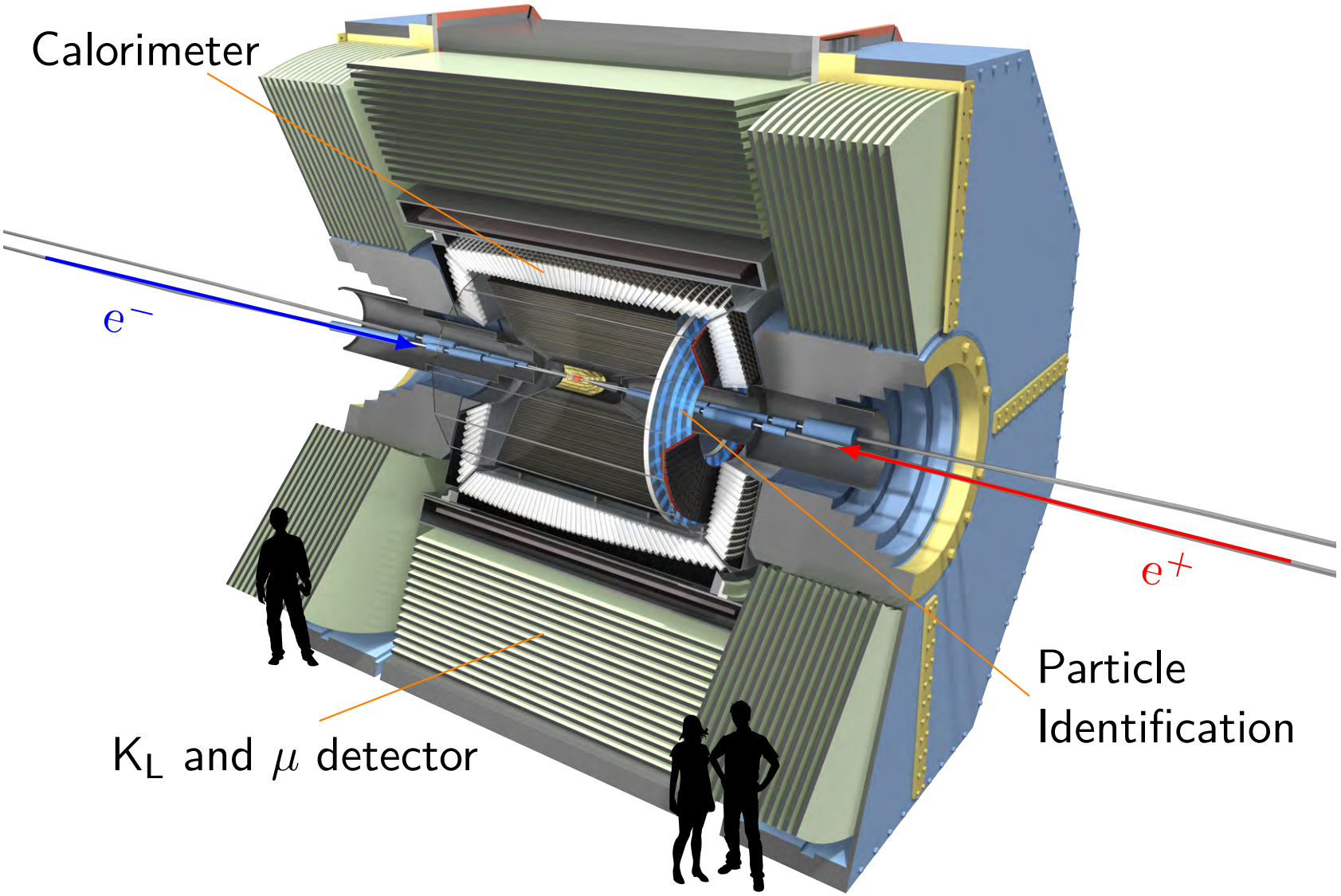


The Belle II detector

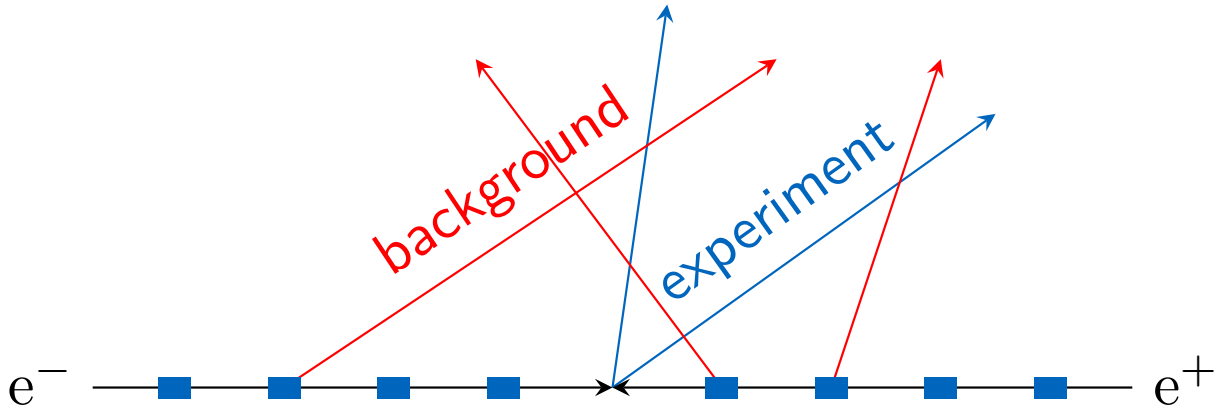


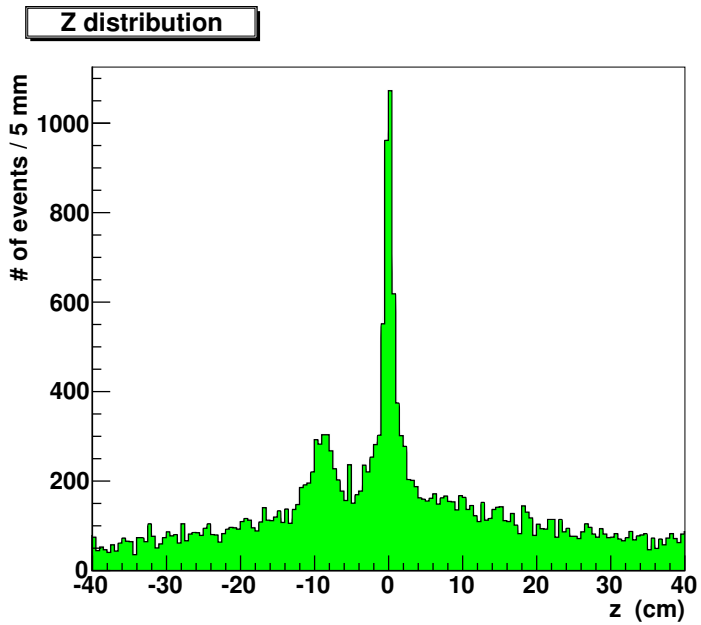
Central Drift Chamber
56 layers
14336 cells

The Belle II detector



Goal: z-vertex track trigger for Belle II



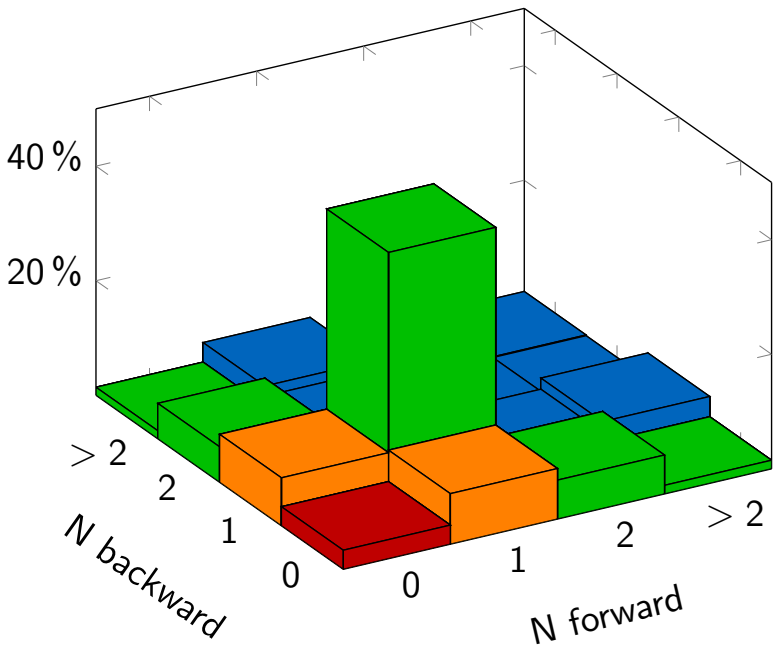


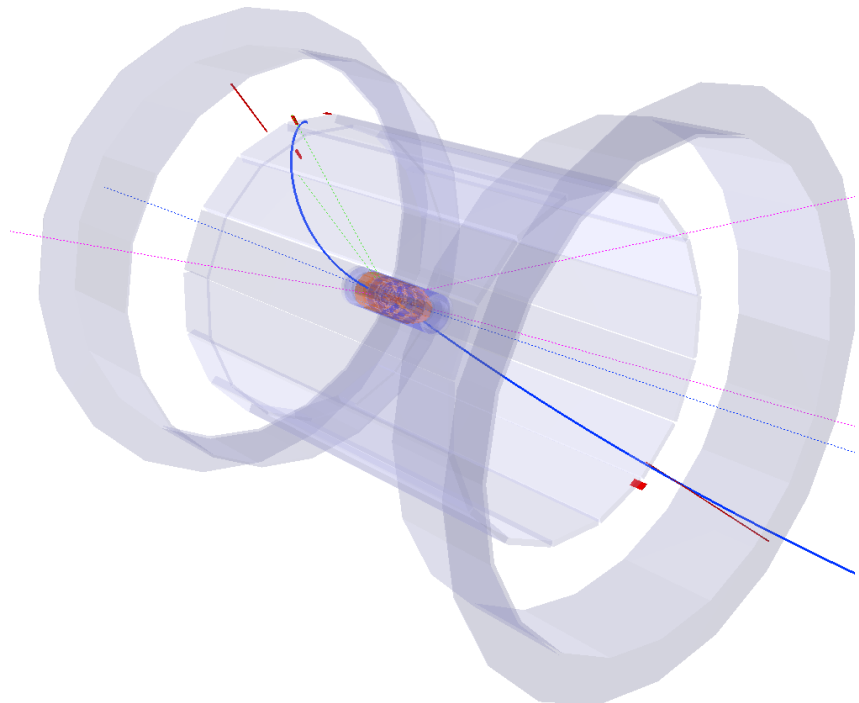
z-vertex distribution in Belle

- reject tracks from $z \neq 0\,\text{cm}$ at 1st trigger level
- suppress machine background
- z-vertex resolution $< 2\,\text{cm}$
- time window $< 1\,\mu\text{s}$ (pipelined)

Benefit of a z-vertex track trigger

without z-vertex: ≥ 3 tracks, both forward and backward (CMS)



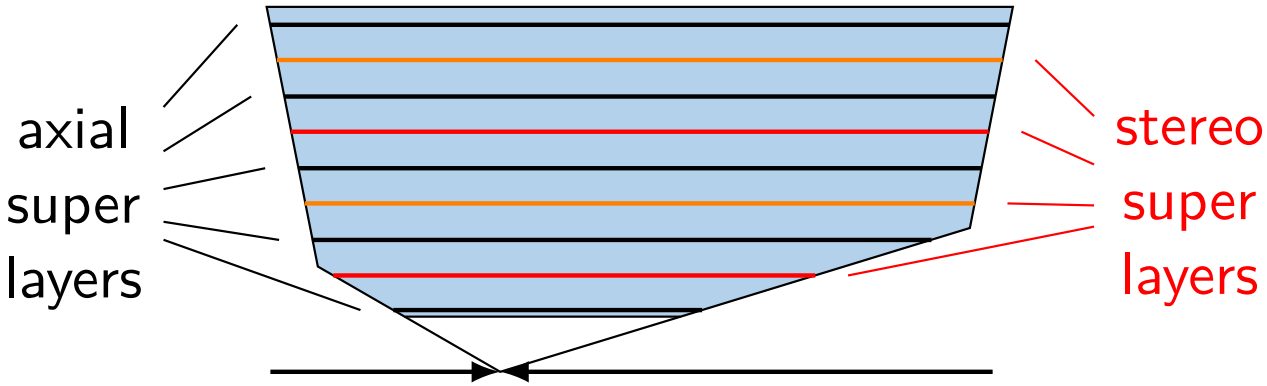


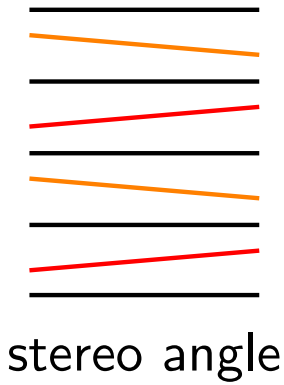
$$e^- e^+ \rightarrow \tau^- \tau^+$$

efficiency increase by factor 3.92

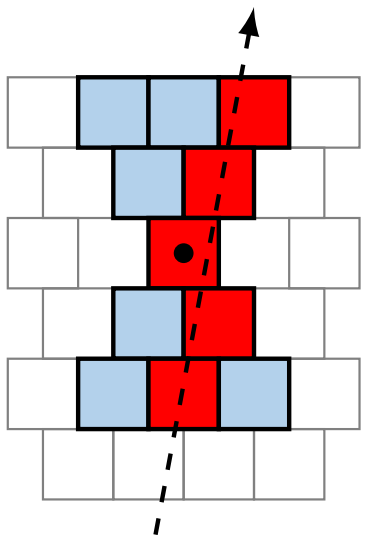
$\rightarrow$ 79.5 % efficiency

Input for the neural network z-vertex trigger

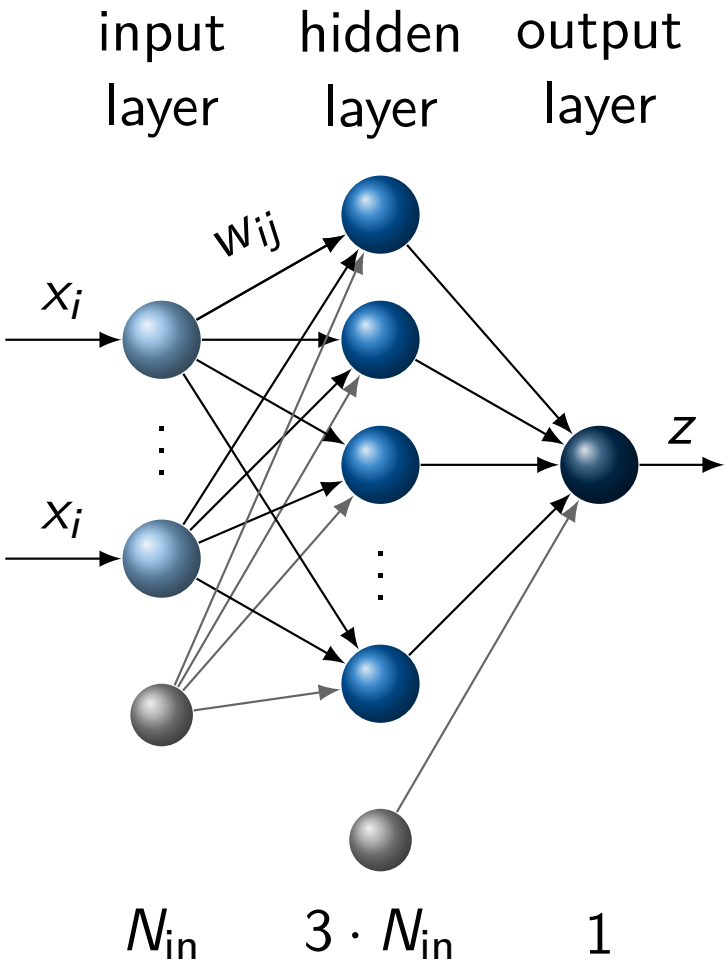




- only CDC (no vertex detector)
- 56 layers combined to 9 super layers
- 2336 track segments (TS) in 9 layers
- position and drift time of central wires
- 2D track estimates



The Multi Layer Perceptron (MLP)



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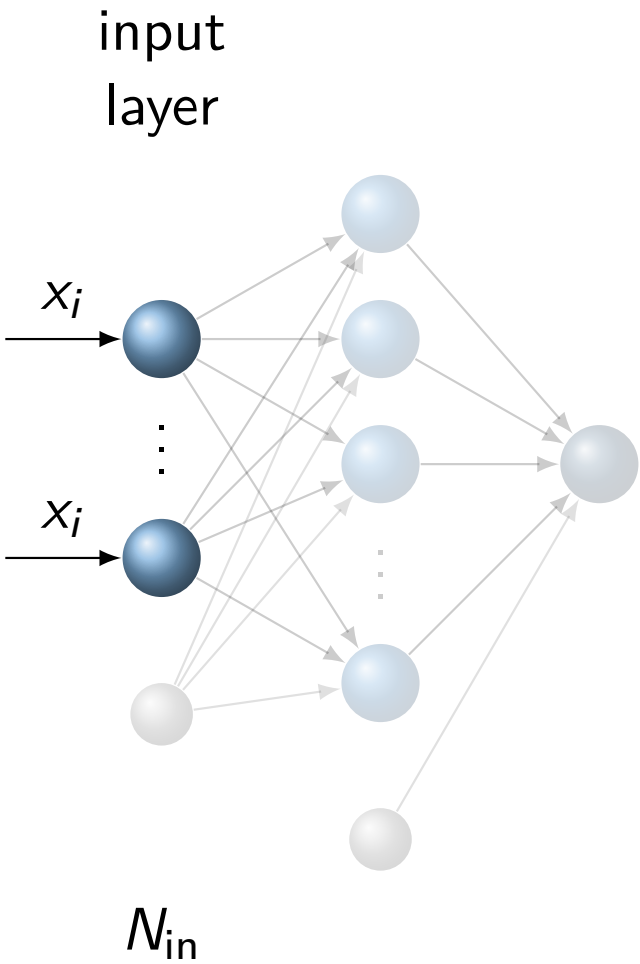
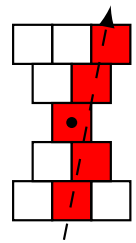


- input: TS information
  - number of TS
  - drift time of central wire



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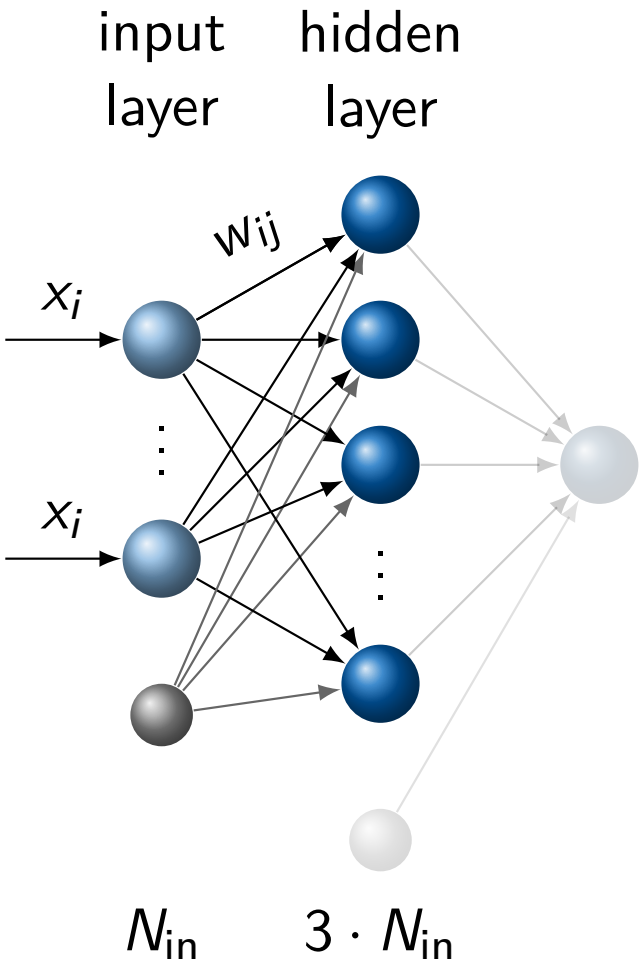
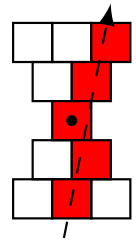


- input: TS information
  - number of TS
  - drift time of central wire
- one neuron:
  $y_j = \tanh\left(\sum_i w_{ij} x_i + b_j\right)$



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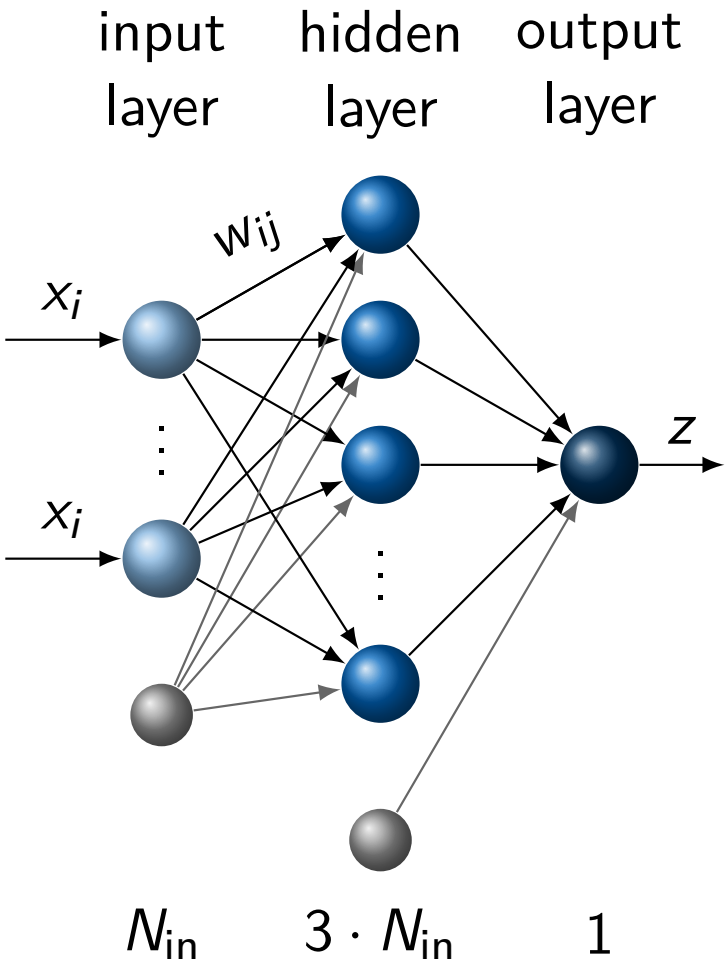
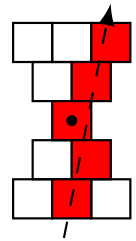
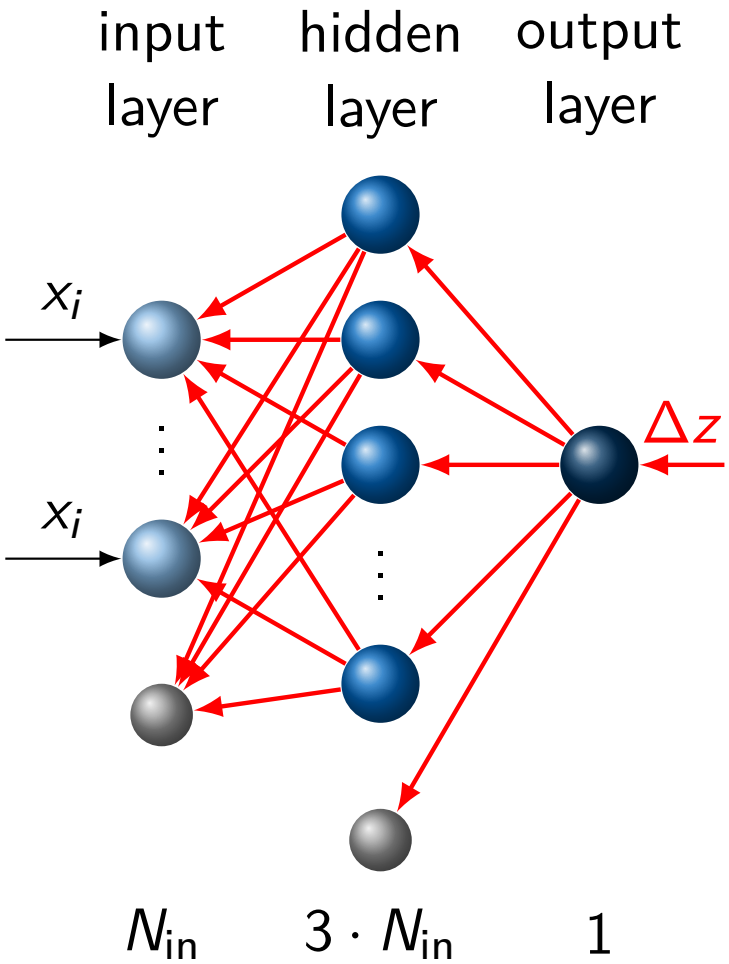


- input: TS information
  - number of TS
  - drift time of central wire



- one neuron:
  $y_j = \tanh\left(\sum_i w_{ij} x_i + b_j\right)$
- output trained to approximate scaled z-vertex

The Multi Layer Perceptron (MLP)



- input: TS information
  - number of TS
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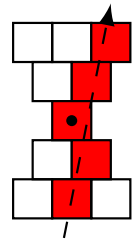
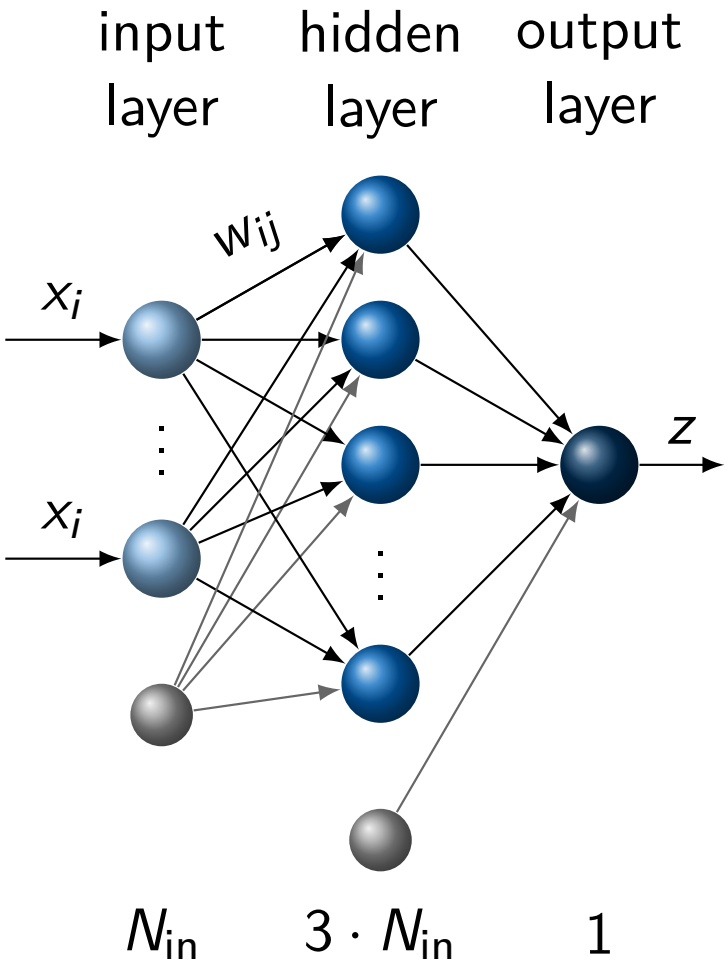
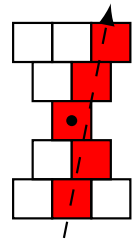


- one neuron:
  $y_j = \tanh\left(\sum_i w_{ij} x_i + b_j\right)$
- output trained to approximate scaled z-vertex
- training with rprop algorithm (back propagation)

The Multi Layer Perceptron (MLP)



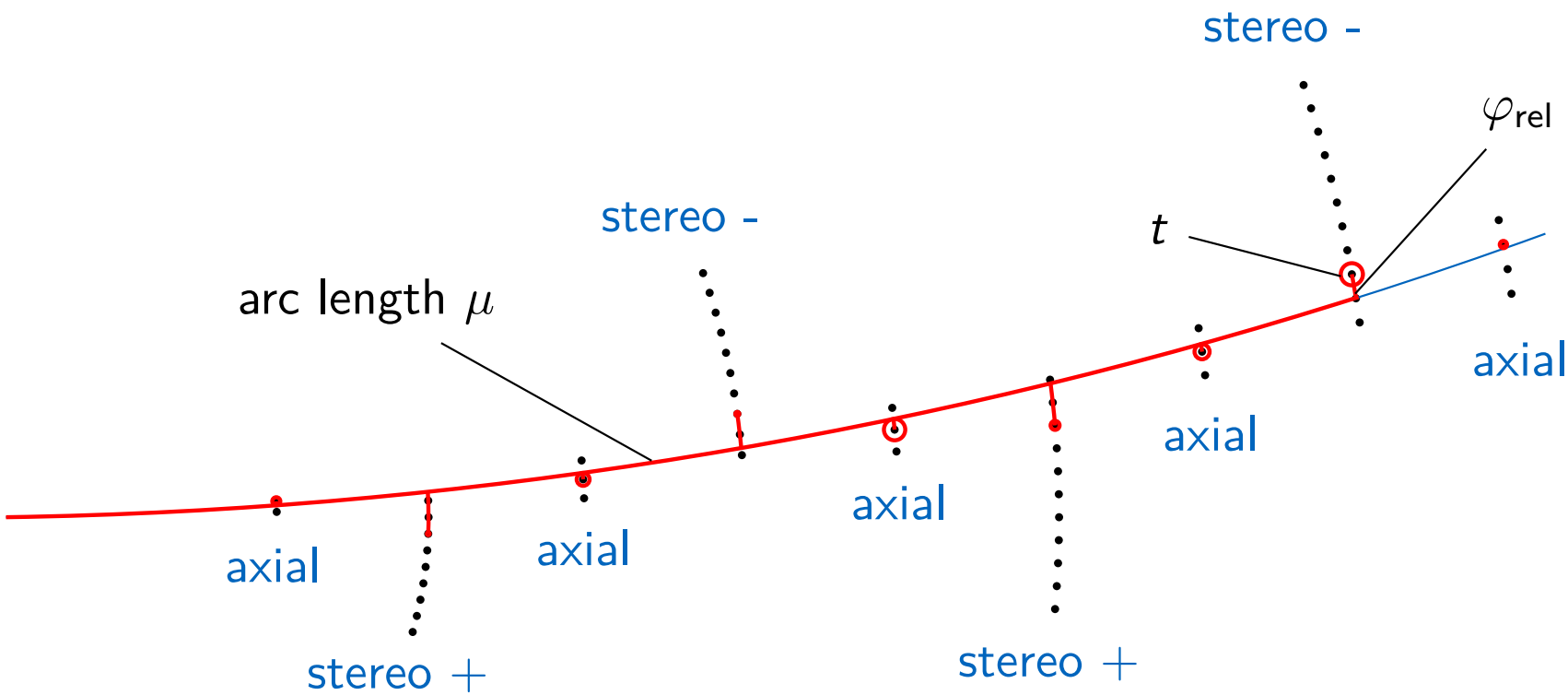
- input: TS information
  - number of TS
  - drift time of central wire



- one neuron:
  $y_j = \tanh\left(\sum_i w_{ij} x_i + b_j\right)$
- output trained to approximate scaled z-vertex
- training with rprop algorithm (back propagation)
- short deterministic runtime

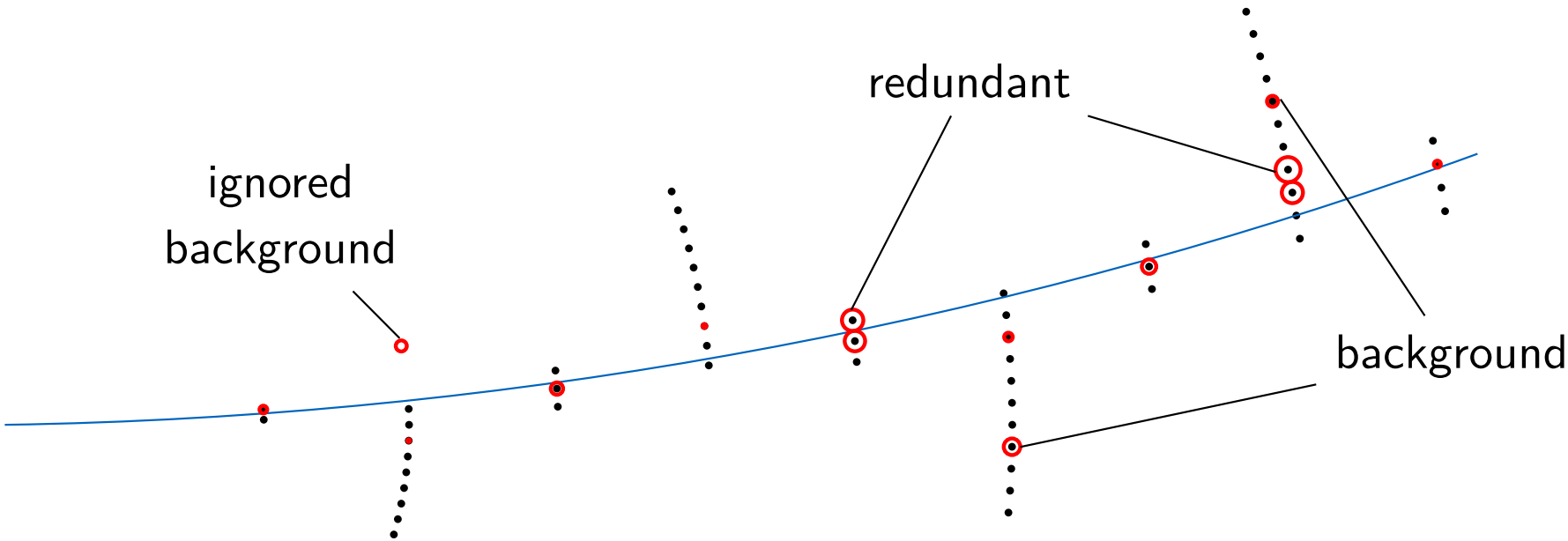
Input representation for neural network

use track estimates provided by 2D finder
3 inputs per layer, values: $(t, \varphi_{\text{rel}}, \mu)$, default: (0, 0, 0)



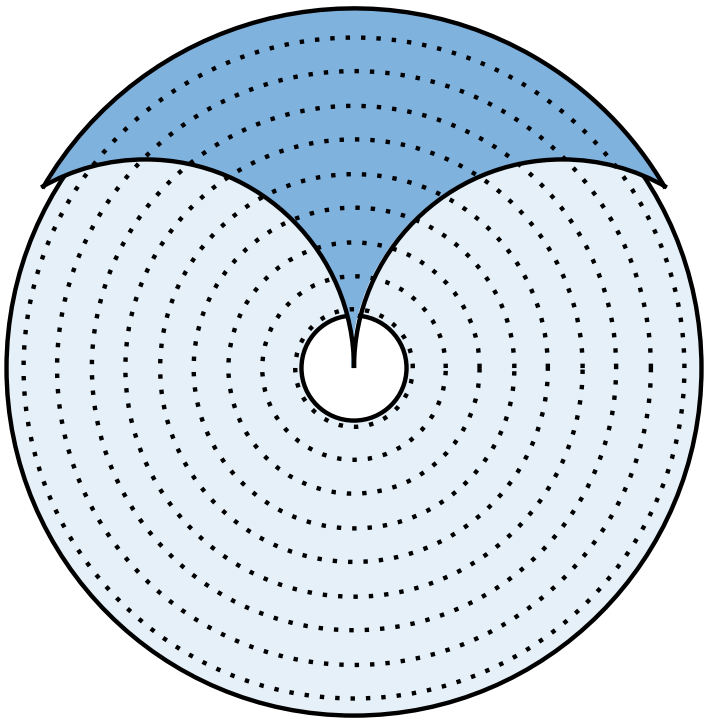
Input representation for neural network

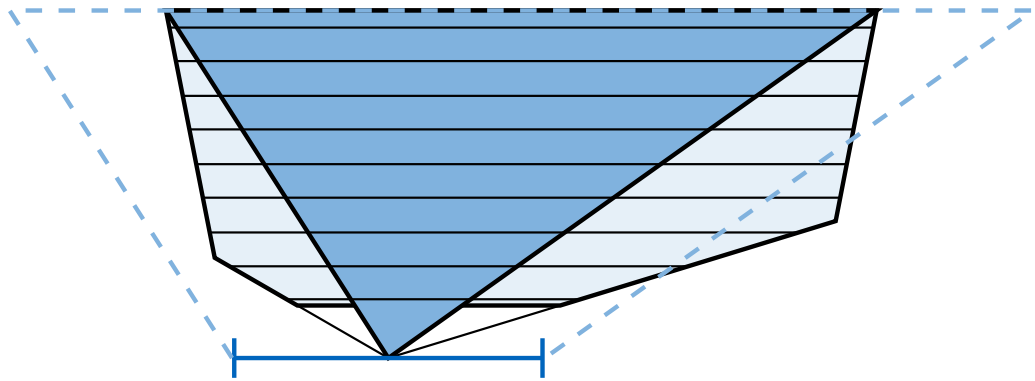
several hits in SL: use only fastest hit
problematic for background



Training data

single tracks (uniform distribution in φ, θ, z, p_T^{-1})
plan: retrain with real data (offline vertex as target)

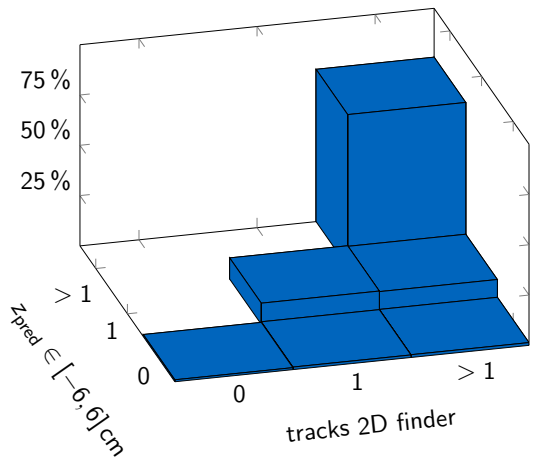




$\varphi \in [0°, 360°]$,
$\theta \in [35°, 123°]$,
$p_T \in [0.3, 5]\,\text{GeV}$,
$z \in [-50, 50]\,\text{cm}$

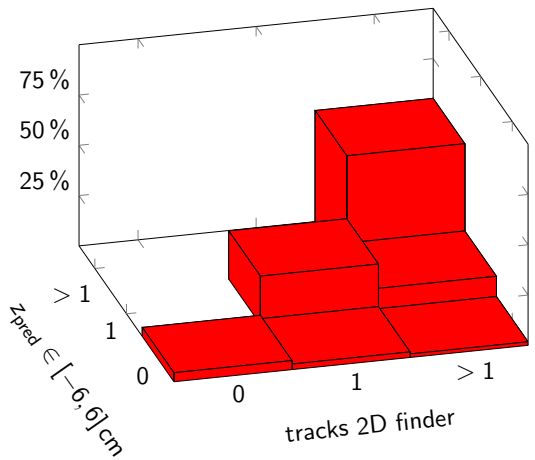
$e^- e^+ \to \tau^- \tau^+$ efficiency

only events with 2 tracks in acceptance region taken into account



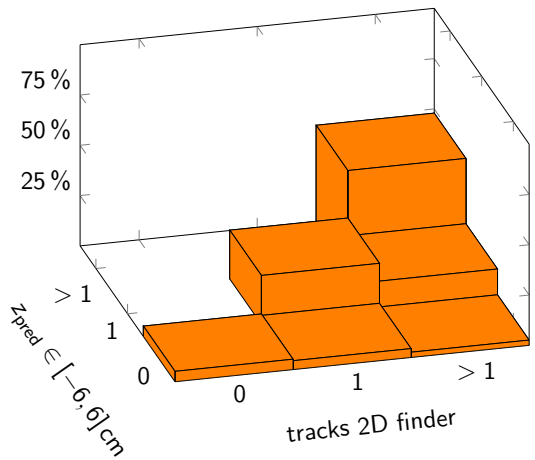
linear drift

MLP efficiency 86 %



nonlinear drift

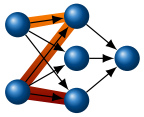
MLP efficiency 84 %



nonlinear, background

MLP efficiency 80 %

$$\text{efficiency: } \frac{N(z_{\text{MLP}} \in [-6, 6]\,\text{cm})}{N(\text{2D tracks})}$$



Conclusion

L1 z-vertex trigger for Belle II with $\mathcal{O}(\text{cm})$ resolution

- MLP with 2D information as input and z-vertex as output
- z resolution $\approx 2\,\text{cm}$ to $3\,\text{cm}$ (worse for low p_T)
- noise robust

Next steps

- hardware implementation for cosmic test in October 2015
- preprocessing to improve resolution
- final integration in Belle II $\approx$ 2017

latest resolution plots