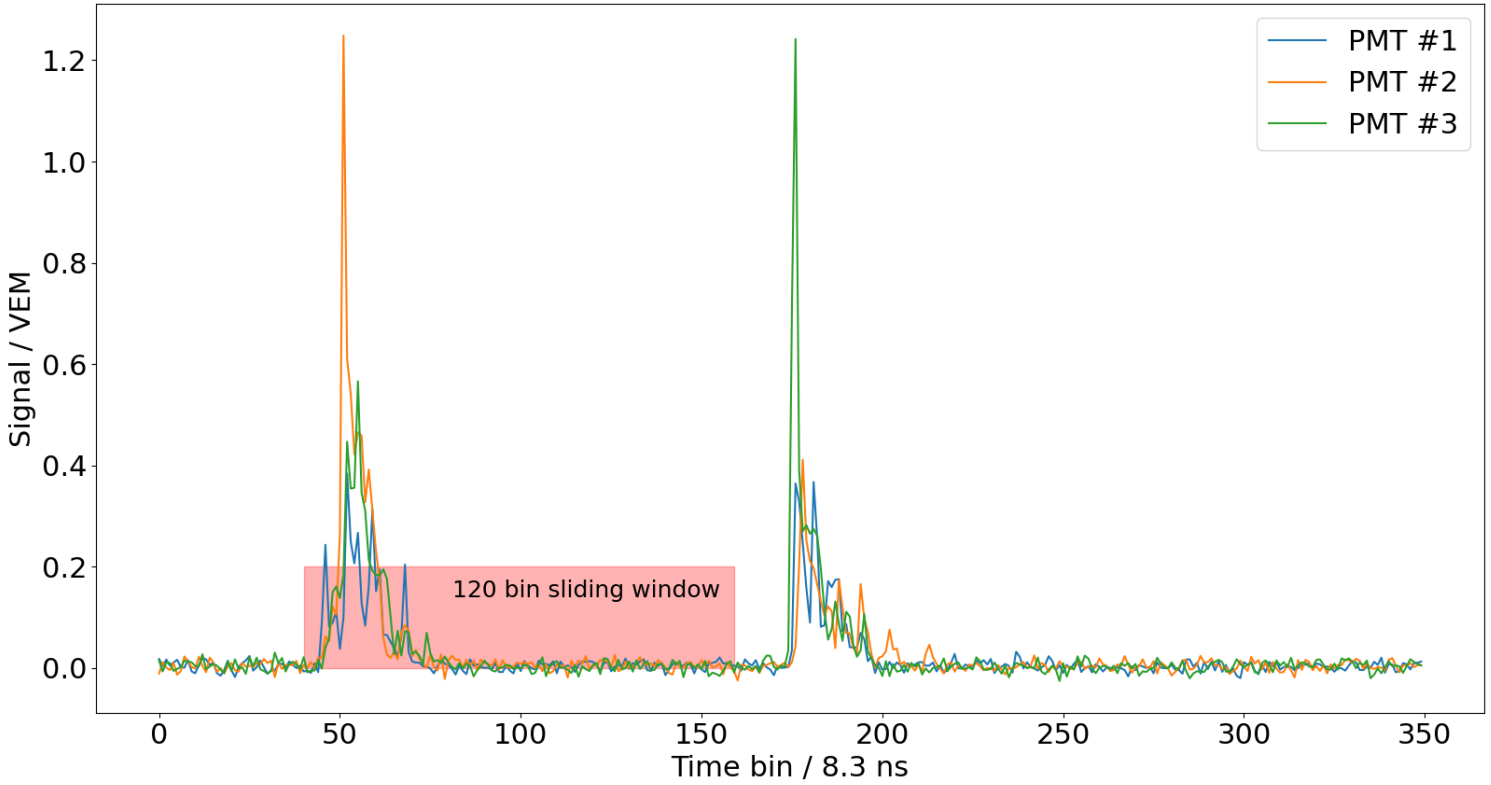
# Machine learning triggers: feasibility study

## KA / BsAs Meeting - Friday, 01.07.22

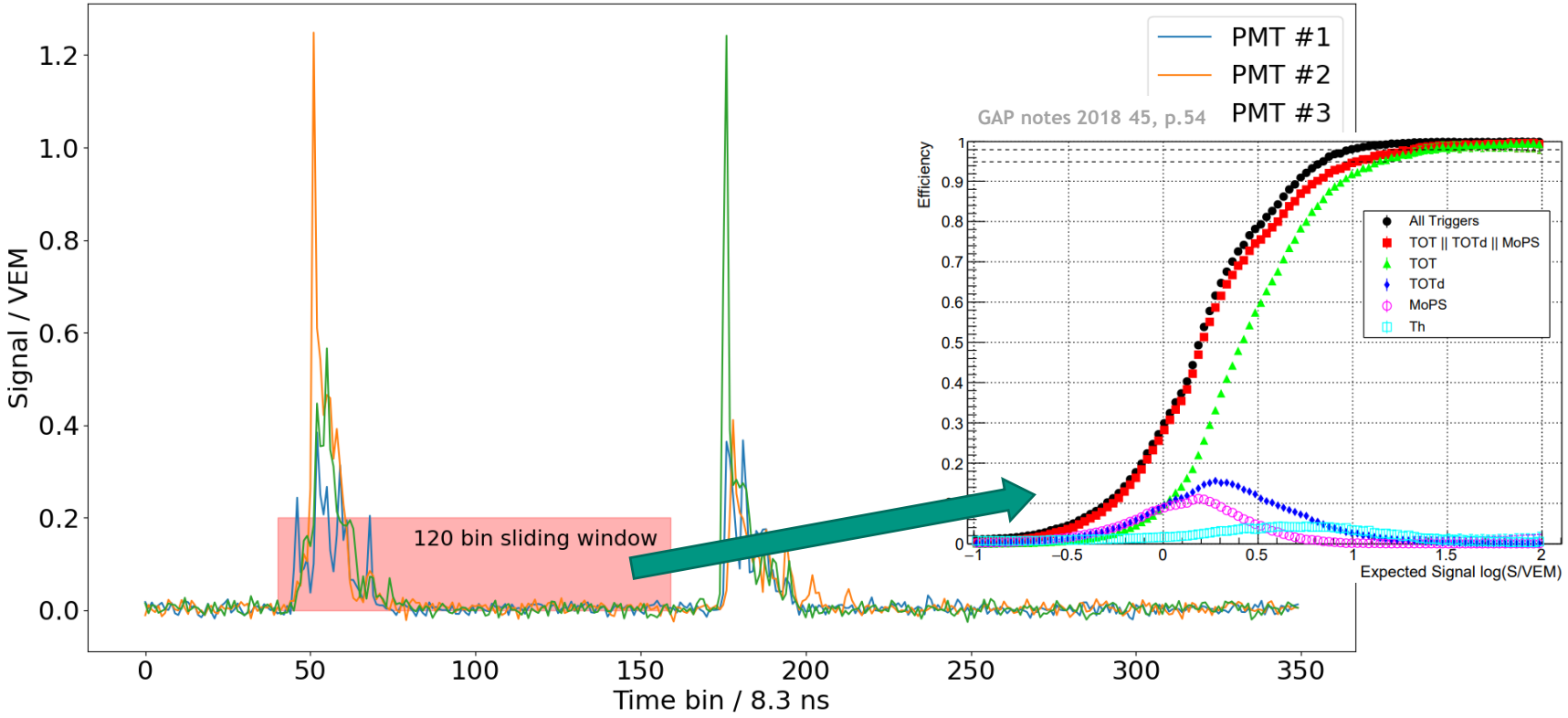
# The situation

- **Current triggers (Th, ToT, etc.) rely on absolute signal strengths**
  - **Threshold (Th): coincident signal of 1.75 (T1) or 3.2 (T2) VEM in all PMTs**
  - **Time-over-threshold (ToT): number of bins above threshold within any window of 120 bins for > one PMTs**
  - **ToT-deconvoluted (ToTd): Same as ToT, but on deconvoluted signal**
  - **Multiplicity-of-Positive-Steps (MoPS): number of raising FADC values within 120 bins for > one PMT**

# The situation



# The situation



# The goal

- Current station-level triggers (Th, ToT, etc.) have inefficiencies
- Test whether neural networks (NNs) are more capable
  - Improve low-signal response while keeping a high background rejection
  - In theory sensitive to whatever we want…
  - … just need to provide appropriate training data

# The data - signals

- Protons with log E $16 - 19.5$ eV (QGSJET-II.04) ~40k Showers
- Use custom trigger module to catch all particles that hit station
  - Lower station level trigger thresholds for ToT, Th, etc. ➡ T2
  - Force T3 (Event trigger) if any T2 is present ➡ Event readout
- Caveat to this approach: no baseline, stray muons, no noise

# The data - backgrounds

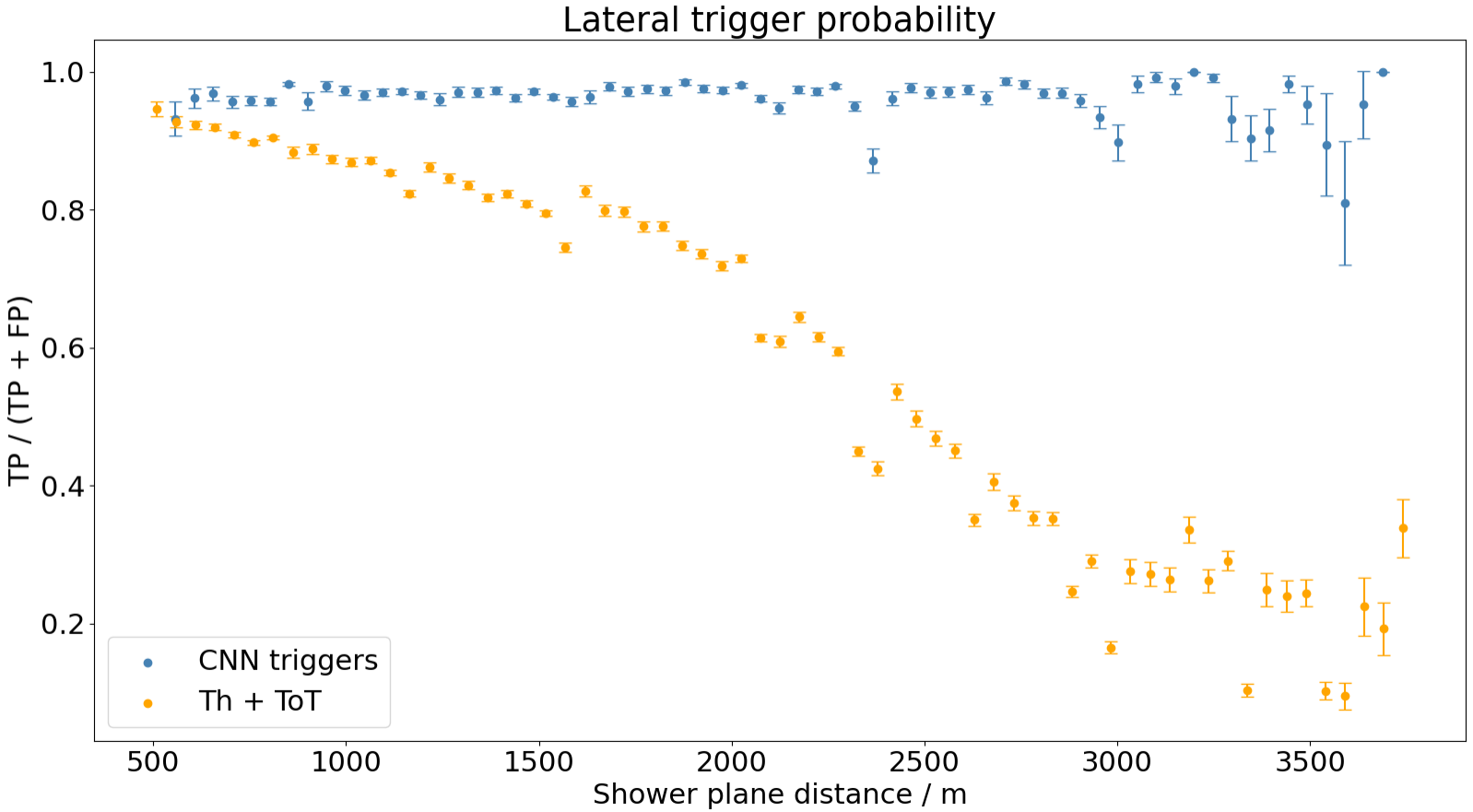
- For now very simple, no accidentally injected particles (yet)
  - Baseline uniformly distributed within $[-2, 2]$ ADC
  - Gaussian noise with $\sigma = 2$ ADC
  - Baseline length $20\,000$ bins $\triangleq 166\ \mu s$ ➡ **can do with way less!**
- Place signal at random position on top of background noise

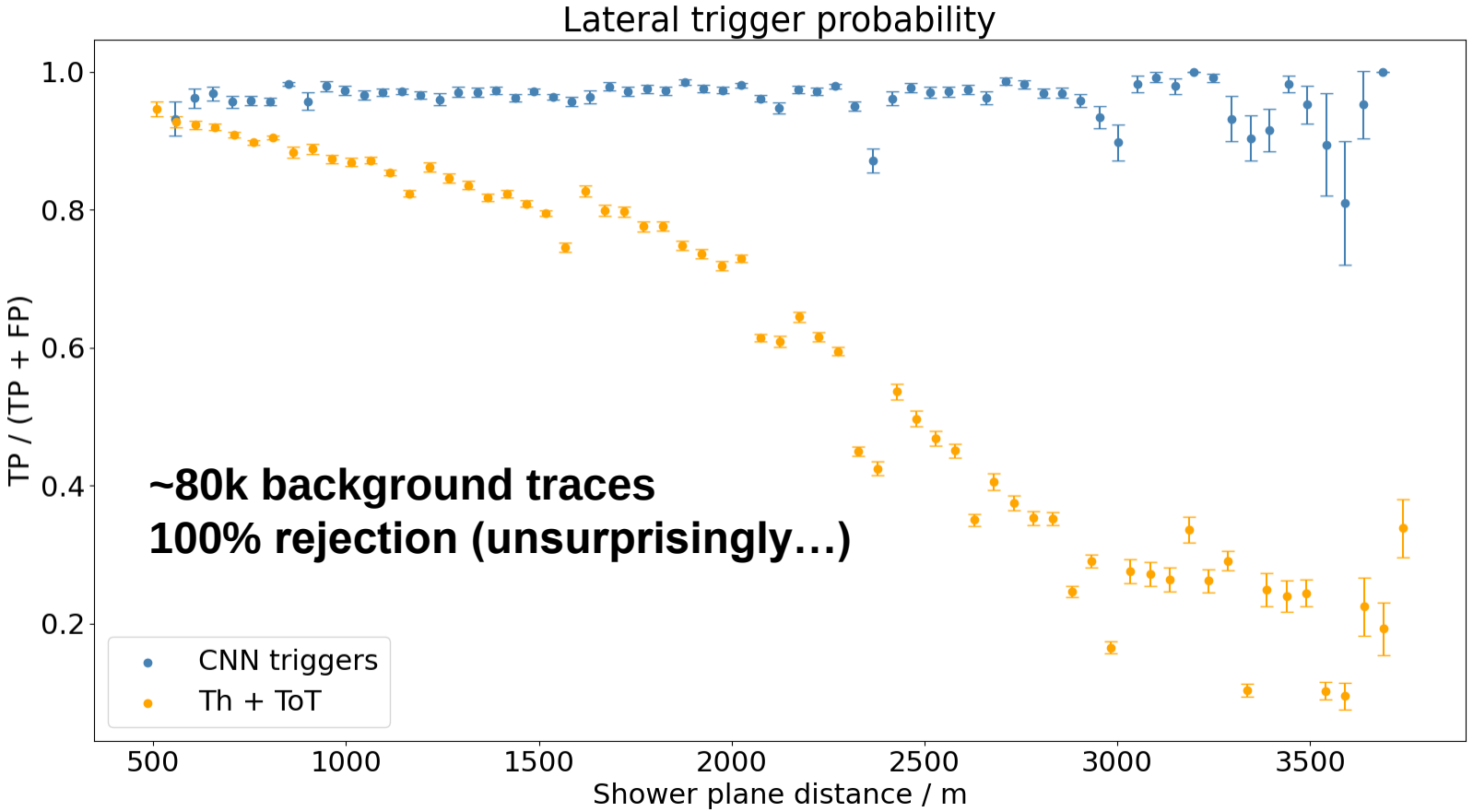
# The neural network(s)

- Implemented with tensorflow 2.8.0
- Convolutional neural networks (CNN)
  - Apply maxpooling to PMT #1, #2, #3
  - Several convolutional layers
  - Dense layer to reduce to binary output
  - Trigger when P(Signal) > P(Background)

| Layer (type) | Param # |
|---|---|
| conv1d (Conv1D) | 96 |
| conv1d_1 (Conv1D) | 1424 |
| conv1d_2 (Conv1D) | 2832 |
| conv1d_3 (Conv1D) | 1416 |
| flatten (Flatten) | 0 |
| dense (Dense) | 98 |

Total params: 5,866
Trainable params: 5,866
Non-trainable params: 0


Lateral trigger probability
TP / (TP + FP)
1.0
0.8
0.6
0.4
0.2
CNN triggers
Th + ToT
500
1000
1500
2000
2500
3000
3500
Shower plane distance / m


Lateral trigger probability
TP / (TP + FP)
1.0
0.8
0.6
0.4
0.2
~80k background traces
100% rejection (unsurprisingly…)
CNN triggers
Th + ToT
500
1000
1500
2000
2500
3000
3500
Shower plane distance / m

# Outlook / Next steps

- [x] Build larger dataset of traces (espically for lower energies)

- [ ] Test NNs on random traces provided by David Nitz…
- [ ] … and improve background model accordingly

- [ ] Drastically reduce NN input size ($20\,000$ bins currently)
- [ ] Aim for $120$ bin window as CNN input (same as ToT, etc.)