# „Mini Masterclass“

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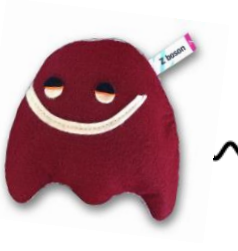
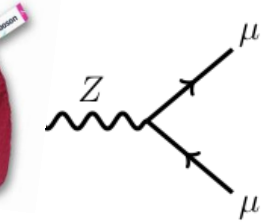
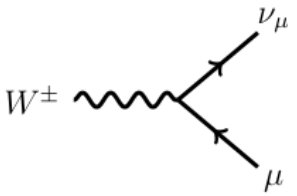
NETZWERK TEILCHENWELT

# Mini Masterclass

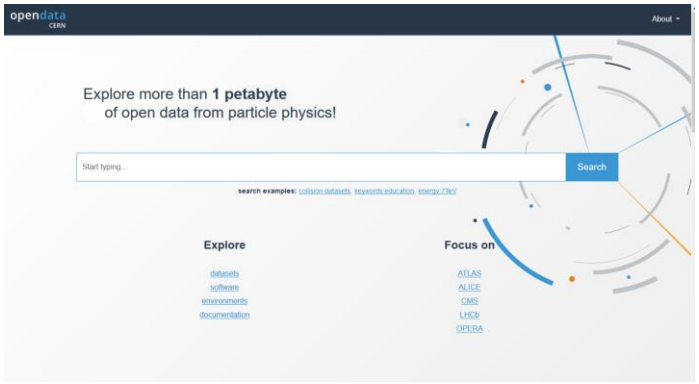




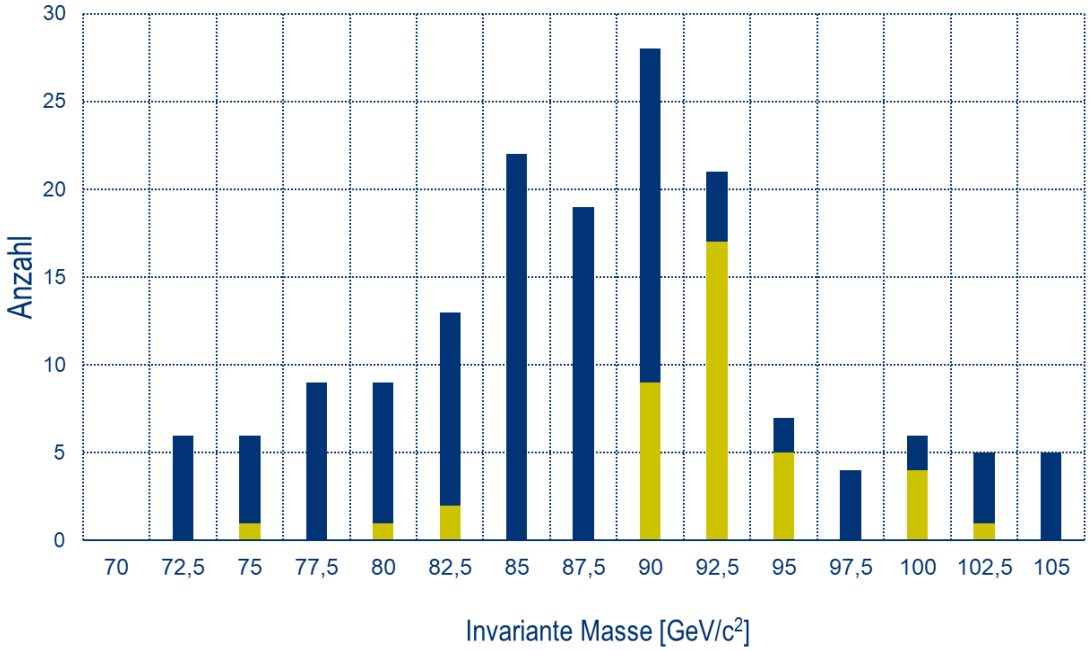

- Analysis of real events using only
  - a calculator
  - pen & sheets
  - sticky notes
- Understanding the creation of a spectrum
  - Visible “growth” of data
- Understanding selection of data
  - Making a cut in a observable
- Reconstruction of Z peak with removing of W background

# Preparation




- The following data was used:
  - http://opendata.cern.ch/record/307 (Z Boson „Signal“)
  - http://opendata.cern.ch/record/309 (W Boson „Background“)
  - Using only data in mass range 70- 120 GeV/c²
- Modification of data
  - Z Boson:
    Adding „Missing Transversal Energy MET„ using a random generator
  - W Boson:
    Adding a 2. Muon (from Z data) to end up in invariant mass of Z peak
- Finding a good balance between signal and background
- Creation of Excel sheets with data (signal and background events)

# Example




| Class | Signal | Backgound |
|---|---|---|
| 70 | 0 | 0 |
| 72,5 | 0 | 6 |
| 75 | 0 | 5 |
| 77,5 | 0 | 9 |
| 80 | 0 | 8 |
| 82,5 | 0 | 11 |
| 85 | 0 | 22 |
| 87,5 | 0 | 19 |
| 90 | 14 | 19 |
| 92,5 | 21 | 4 |
| 95 | 1 | 2 |
| 97,5 | 4 | 4 |
| 100 | 0 | 2 |
| 102,5 | 0 | 4 |
| 105 | 0 | 5 |
| Sum | 40 | 120 |
| | Max 1900 | Max 380 |

| | Data/TN | |
|---|---|---|
| TN | 20 | 8 |

- Test with 20 high school teachers

# Created Excel Sheets

| Run | Event | MET | E1 | px1 | py1 | pz1 | Q1 | E2 | px2 | py2 | pz2 | Q2 | Minv |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 146944 | 107557845 | 54,83 | 28,40 | -23,63 | -11,58 | -10,70 | -1 | 194,51 | -111,80 | 7,92 | 158,98 | 1 | |
| 146944 | 108469900 | 47,23 | 47,09 | 1,83 | 39,94 | -24,88 | -1 | 35,62 | 13,65 | -17,43 | 27,90 | 1 | |
| 146944 | 110239978 | 31,03 | 35,26 | 12,01 | 33,00 | -3,13 | -1 | 77,57 | 10,40 | -29,48 | 70,99 | 1 | |
| 146944 | 110425594 | 36,72 | 70,27 | -2,09 | 25,66 | 65,38 | -1 | 53,99 | 41,09 | 25,67 | -23,82 | 1 | |
| 146944 | 111293264 | 23,70 | 53,17 | -35,66 | 22,68 | -32,26 | -1 | 53,90 | 41,02 | 25,63 | -23,78 | 1 | |
| 146944 | 112365884 | 41,60 | 34,95 | 32,02 | -13,79 | 2,46 | -1 | 92,99 | -26,53 | -2,30 | -89,09 | 1 | |
| 146944 | 112800006 | 47,87 | 90,51 | -35,67 | -1,75 | 83,16 | 1 | 30,89 | 30,77 | 2,64 | -0,51 | -1 | |
| 146944 | 112800006 | 47,87 | 90,51 | -35,67 | -1,75 | 83,16 | -1 | 52,49 | 40,90 | -20,55 | 25,70 | 1 | |
| 148031 | 792020 | 11,86 | 55,76 | 46,87 | -1,51 | 30,16 | -1 | 39,58 | -26,55 | -7,30 | -28,43 | 1 | |
| 148029 | 28424284 | 11,21 | 34,41 | -5,28 | -29,94 | -16,11 | 1 | 95,85 | -36,00 | 31,93 | -82,89 | -1 | |
| 148031 | 792020 | 11,86 | 39,58 | -26,55 | -7,30 | -28,43 | 1 | 55,85 | 46,94 | -1,51 | 30,22 | -1 | |
| 148031 | 792020 | 11,86 | 55,76 | 46,87 | -1,51 | 30,16 | -1 | 39,73 | -26,65 | -7,32 | -28,54 | 1 | |
| 148031 | 38598637 | 10,94 | 104,32 | -28,58 | -3,36 | 100,27 | 1 | 35,66 | 32,47 | 4,78 | 13,95 | -1 | |
| 148031 | 20180192 | 9,71 | 82,48 | -4,55 | -38,89 | 72,59 | -1 | 34,86 | 6,62 | 34,01 | 3,90 | 1 | |
| 148031 | 792020 | 11,86 | 55,85 | 46,94 | -1,51 | 30,22 | -1 | 39,73 | -26,65 | -7,32 | -28,54 | 1 | |

Quelle: http://opendata.cern.ch/

$$\begin{pmatrix} p_x \\ p_y \\ p_z \end{pmatrix} \cdot \begin{pmatrix} p_x \\ p_y \\ p_z \end{pmatrix} = p_x\, p_x + p_y\, p_y + p_z\, p_z$$

Skalarproduct!

# Exercice No 1.

- $M_{inv} = \sqrt{(E_{\mu^1} + E_{\mu^2})^2 - (\overrightarrow{p_{\mu^1}} + \overrightarrow{p_{\mu^2}})^2}$

| E1 | px1 | py1 | pz1 | Q1 | E2 | px2 | py2 | pz2 | Q2 | Minv |
|---|---|---|---|---|---|---|---|---|---|---|
| 28,40 | -23,63 | -11,58 | -10,70 | -1 | 194,51 | -111,80 | 7,92 | 158,98 | 1 | |
| 47,09 | 1,83 | 39,94 | -24,88 | -1 | 35,62 | 13,65 | -17,43 | 27,90 | 1 | |

- Calculate the Invariant Mass of your first Events
- Write the value in the Minv column

$$\begin{pmatrix} p_x \\ p_y \\ p_z \end{pmatrix} \cdot \begin{pmatrix} p_x \\ p_y \\ p_z \end{pmatrix} = p_x\, p_x + p_y\, p_y + p_z\, p_z$$

Skalarprodukt!

# Exercice No 2.

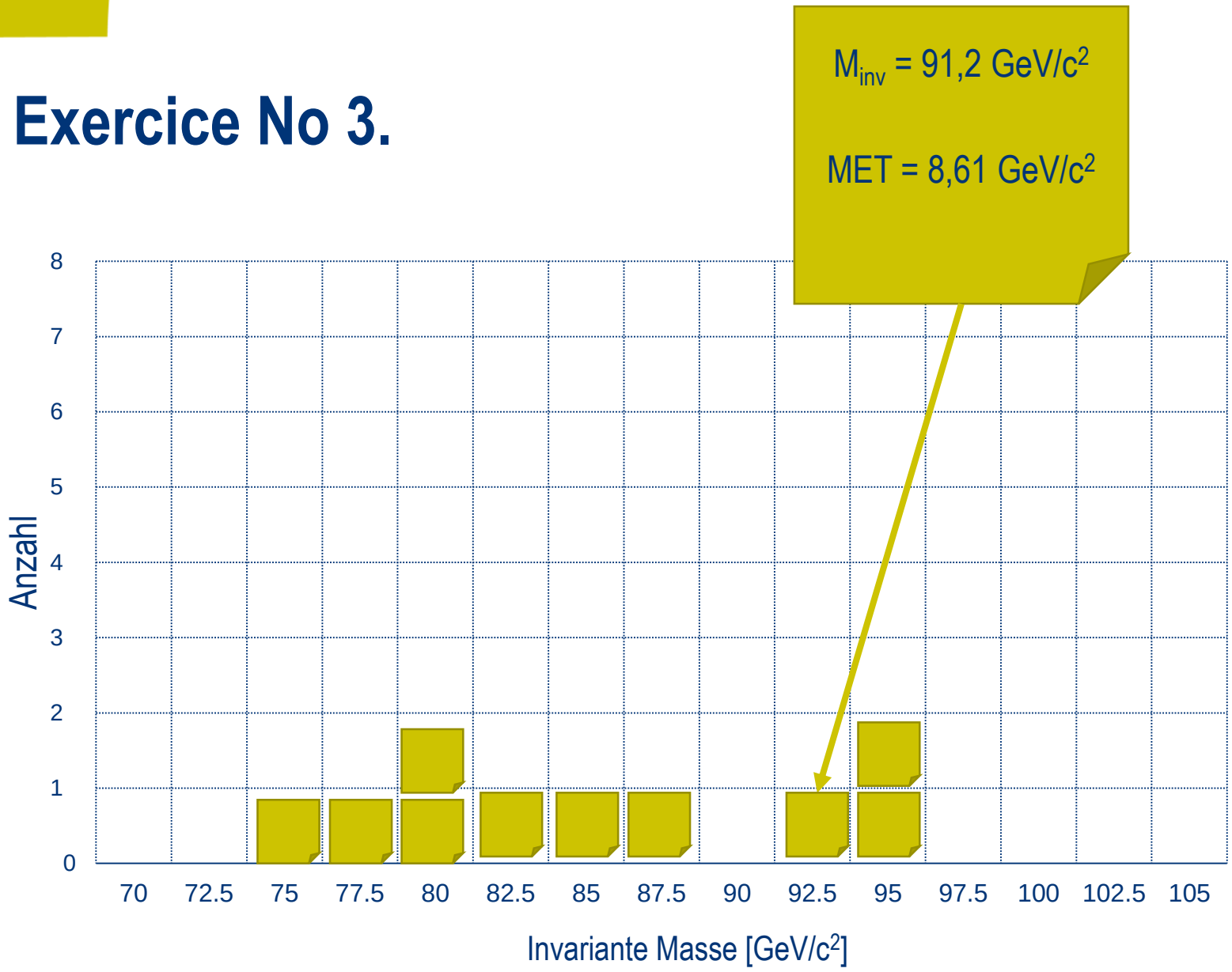
- $M_{inv} = \sqrt{(E_{\mu^1} + E_{\mu^2})^2 - (\overrightarrow{p_{\mu^1}} + \overrightarrow{p_{\mu^2}})^2}$
- Write the invariant mass & the respective missing transversal energy (MET) on a sticky note

| Run | Event | MET |
|---|---|---|
| 146944 | 107557845 | 54,83 |
| 146944 | 108469900 | 47,23 |

$M_{inv}$ = 91,2 GeV/$c^2$

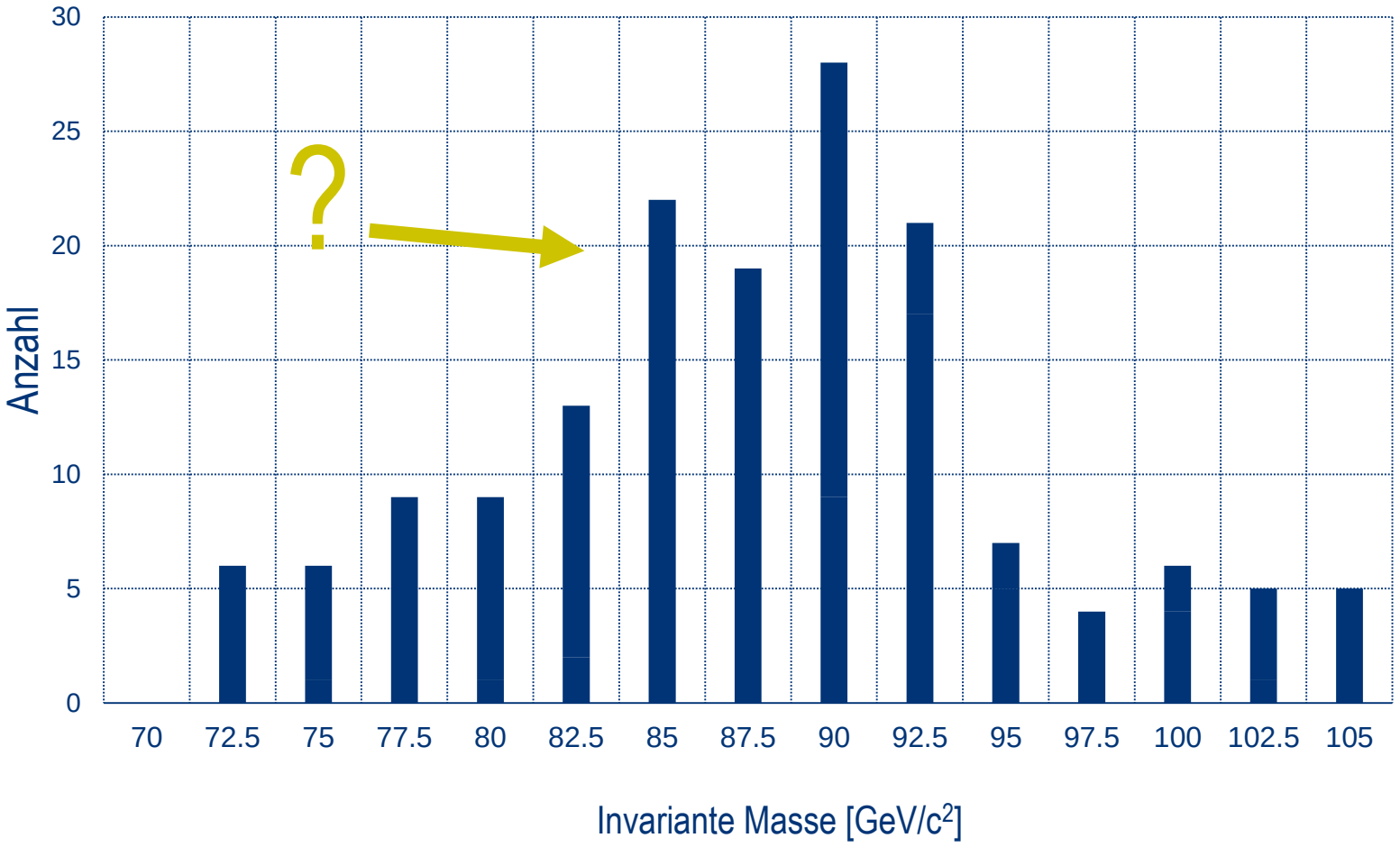
MET = 8,61 GeV/$c^2$

# Exercice No 3.



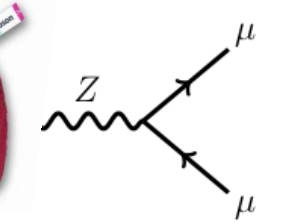

Aufkleben
Anzahl

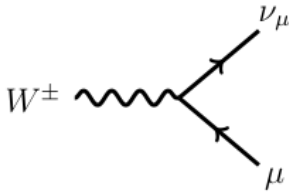
# Invariant Mass



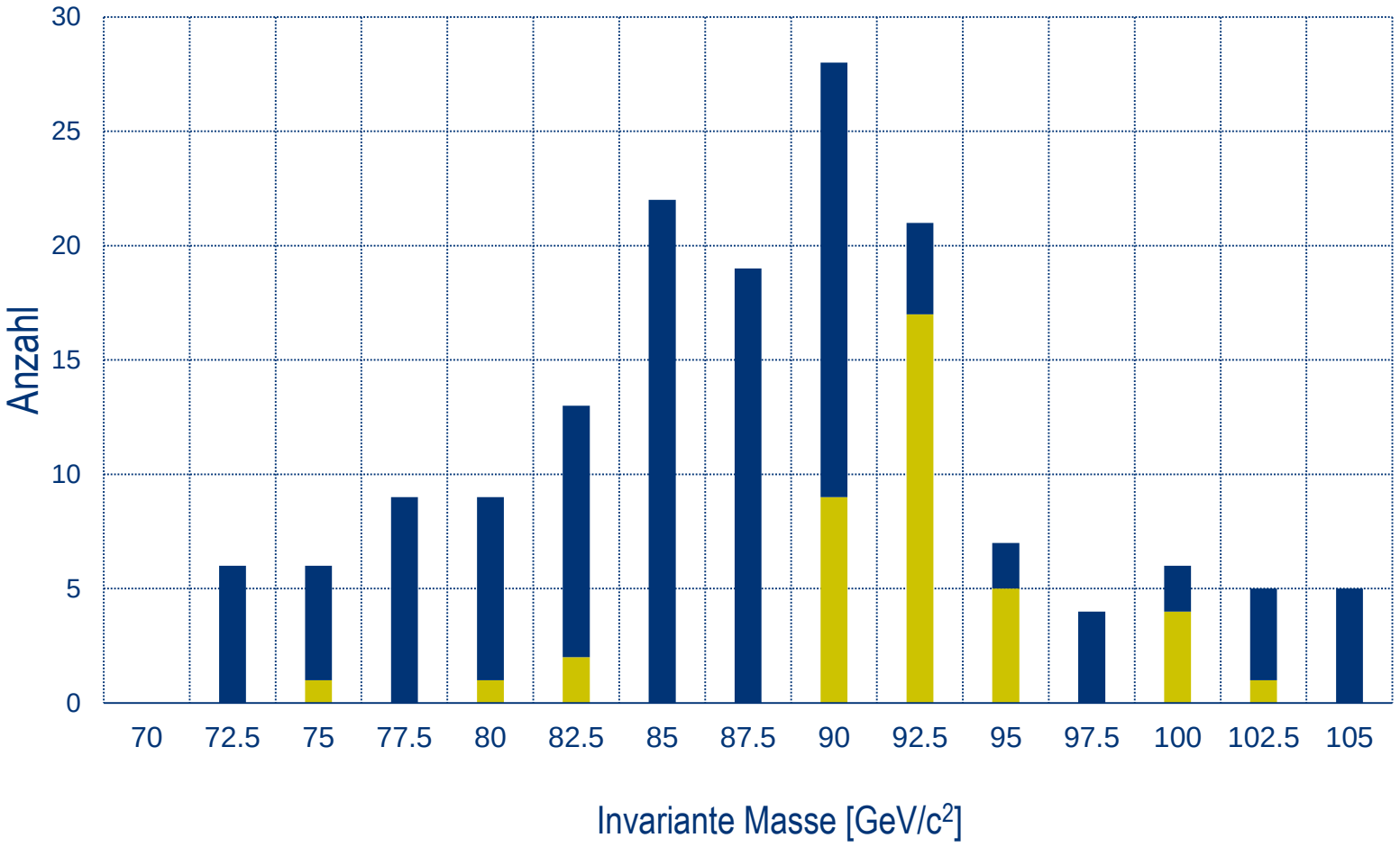
# „Cuts“

- „Cun“ on Events with MET > 20 GeV/$c^2$
  - Remove all sticky notes with MET > 20 GeV/$c^2$



# Signal & Background



# Outlook


- Possible Variation
  - Do not use scalar product, but give $p_\perp$ and angle
  - Only use signal entries
  - Give invariant mass
- Create a real “real” CMS data set for this
  - Including a manual how to use it