IDEA TDAQ

F. Bedeschi, INFN – Pisa,

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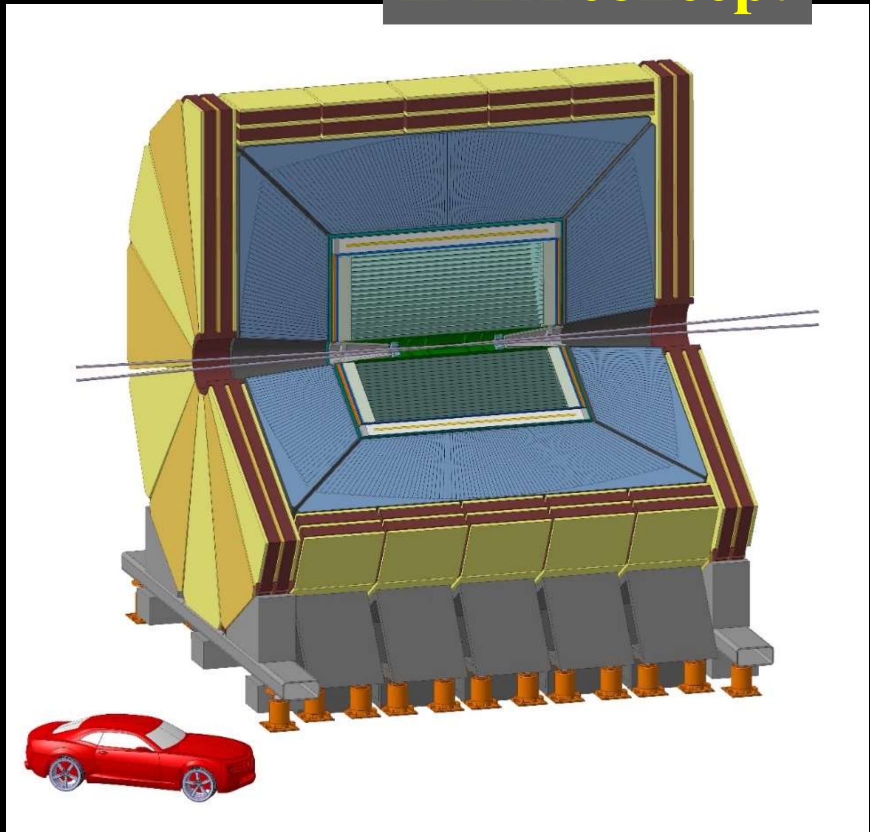
Outline

- IDEA detector
- Throughput estimates
- Conclusions

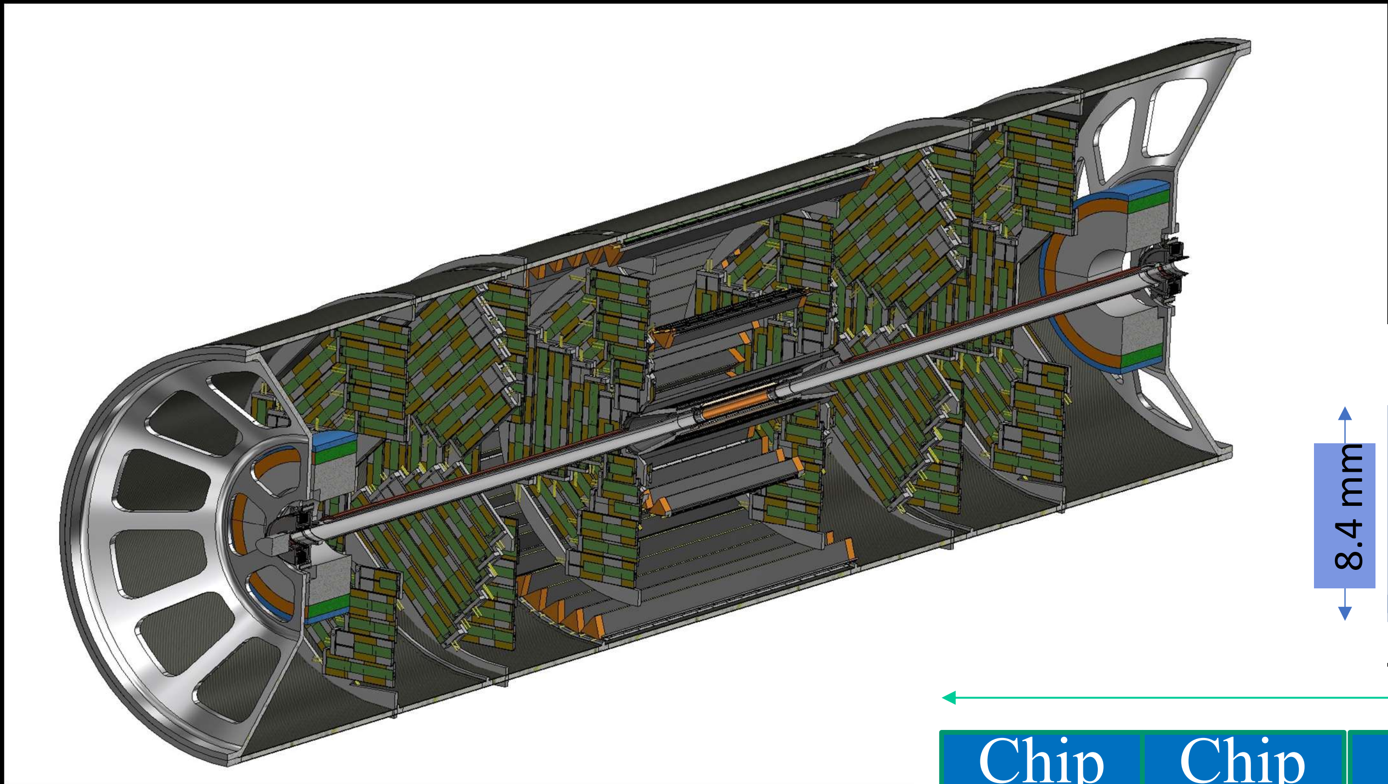
Detector concept IDEA

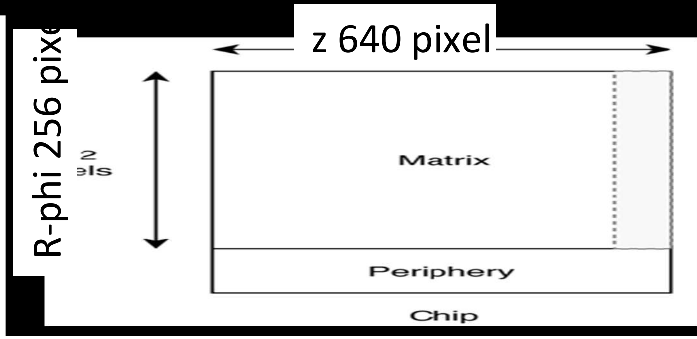
- Si pixel vertex detector
  - 5 MAPS layers
    - R = 1.2 – 34 cm
- Drift chamber (112 layers)
  - 4m long, r = 35 – 200 cm
- Si wrapper: strips
- Solenoid: 2 T - 5 m, r = 2.1-2.4
  - $0.74\ X_0$, $0.16\ \lambda$ @ 90º
- Pre-shower: μRwell (if no crystals)
- Dual Readout calorimetry
  - 2m deep/8 λ
- Crystal calorimeter inside
- Muon chambers
  - μRwell

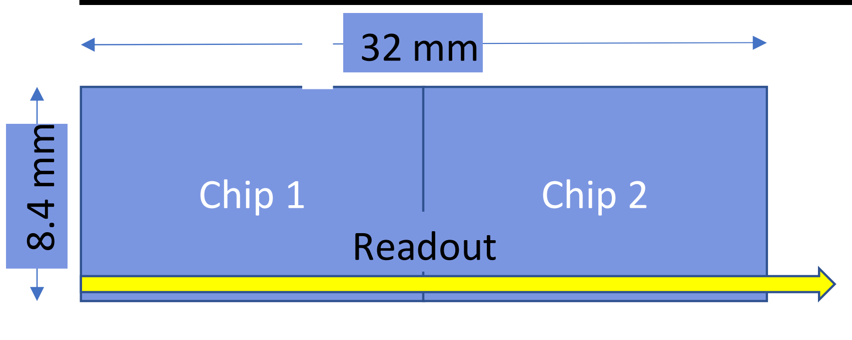
IDEA concept

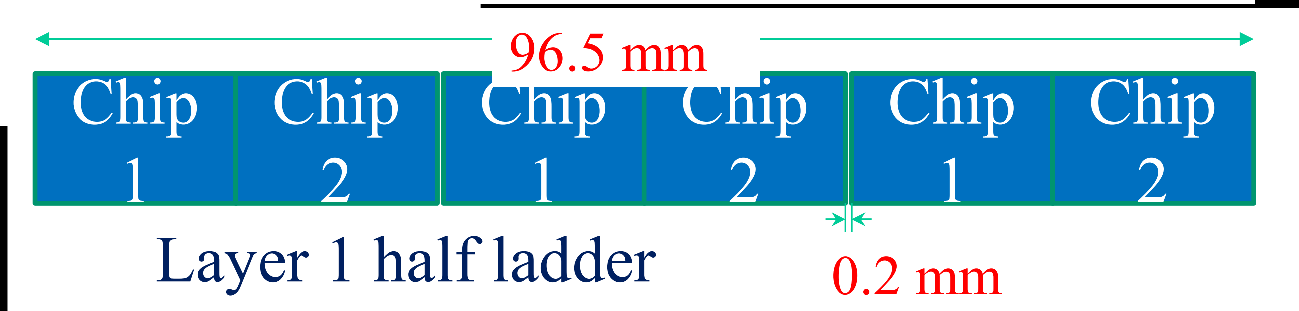


Vertex detector



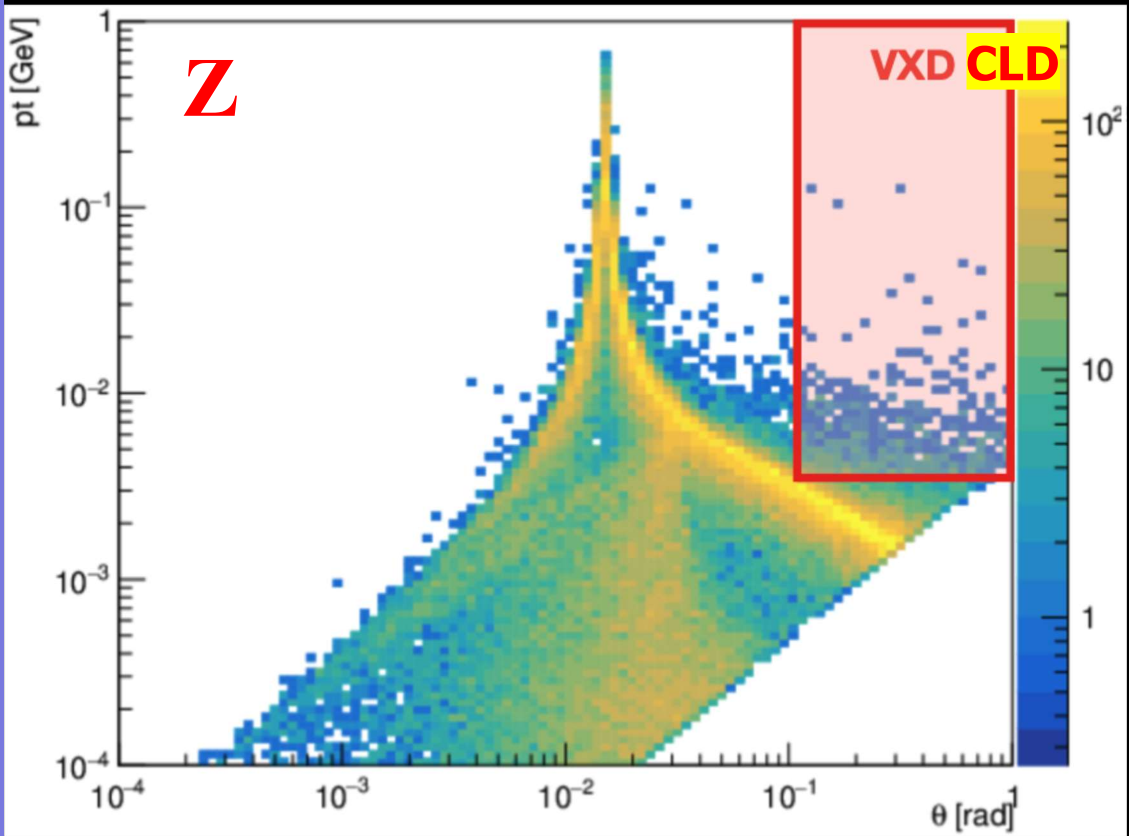


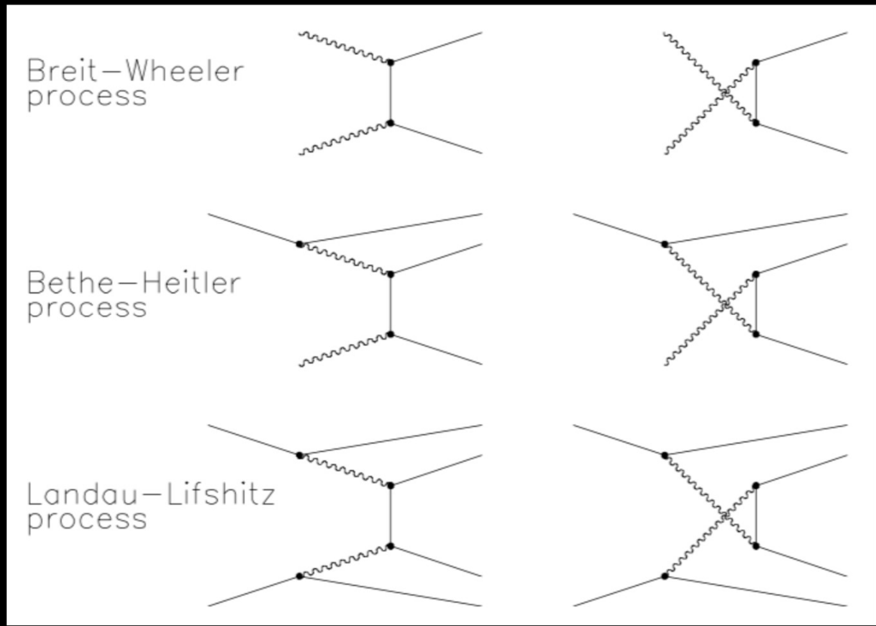




Incoherent pair background (Z)

Courtesy: Andrea Ciarma, INFN-LNF





Main source of beam related backgrounds

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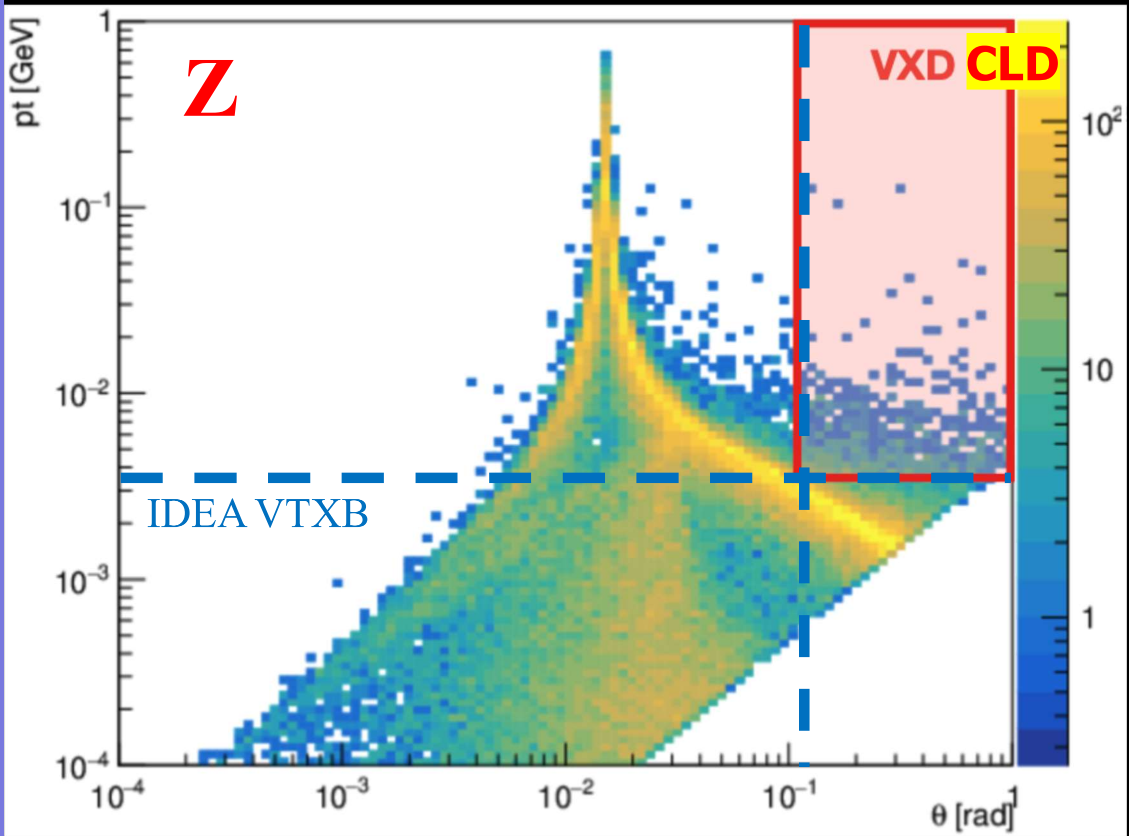

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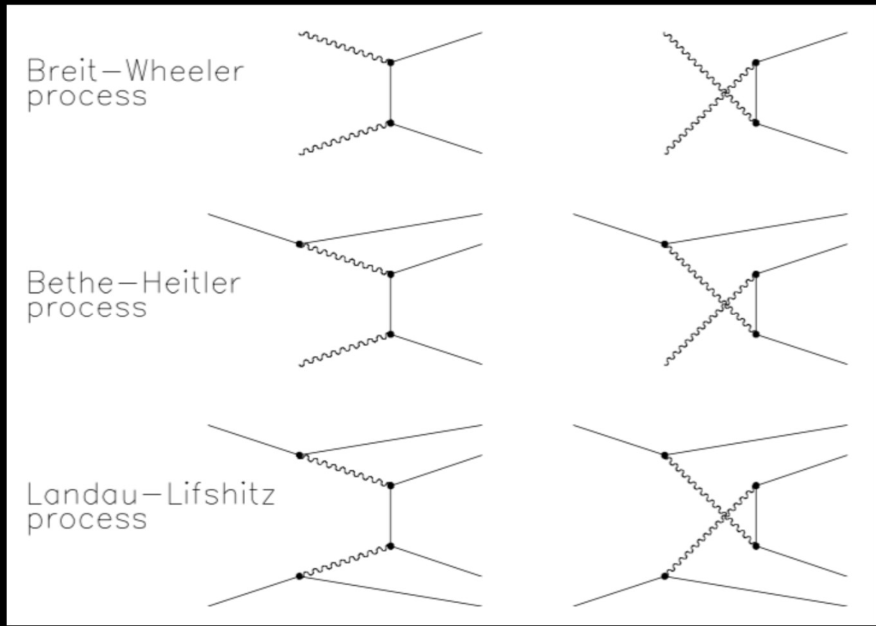

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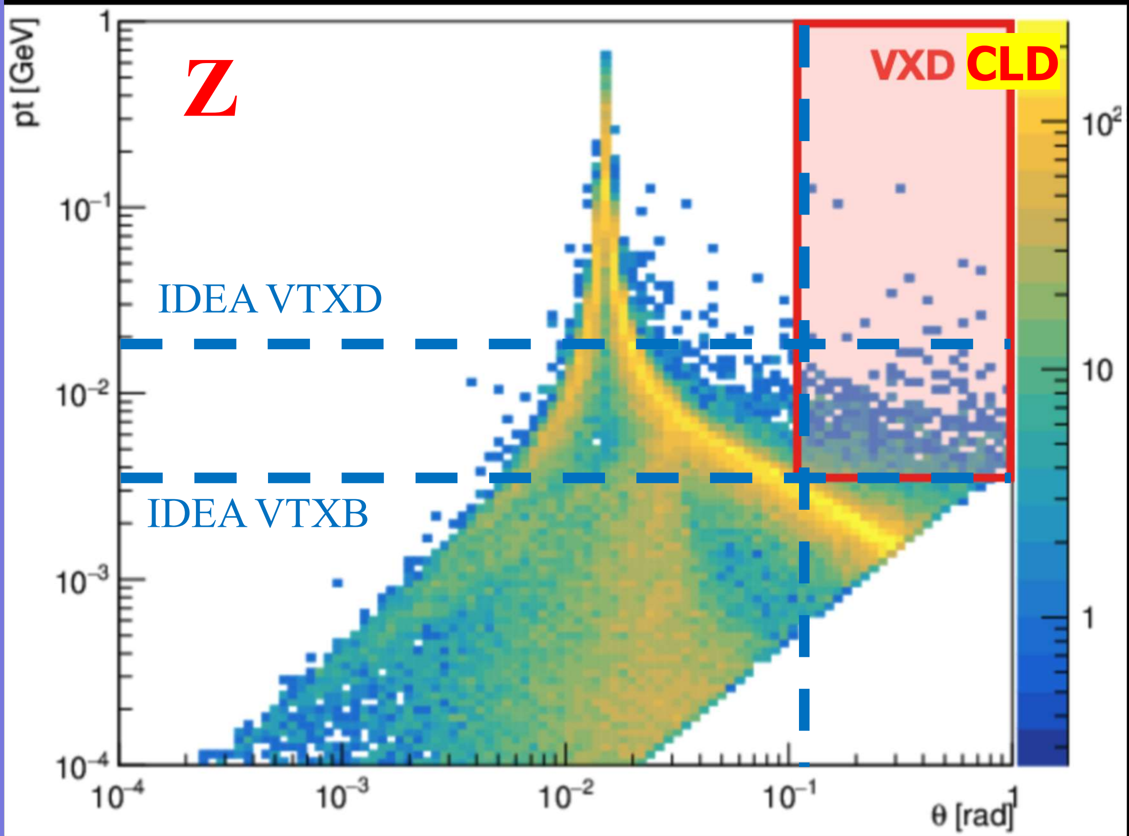

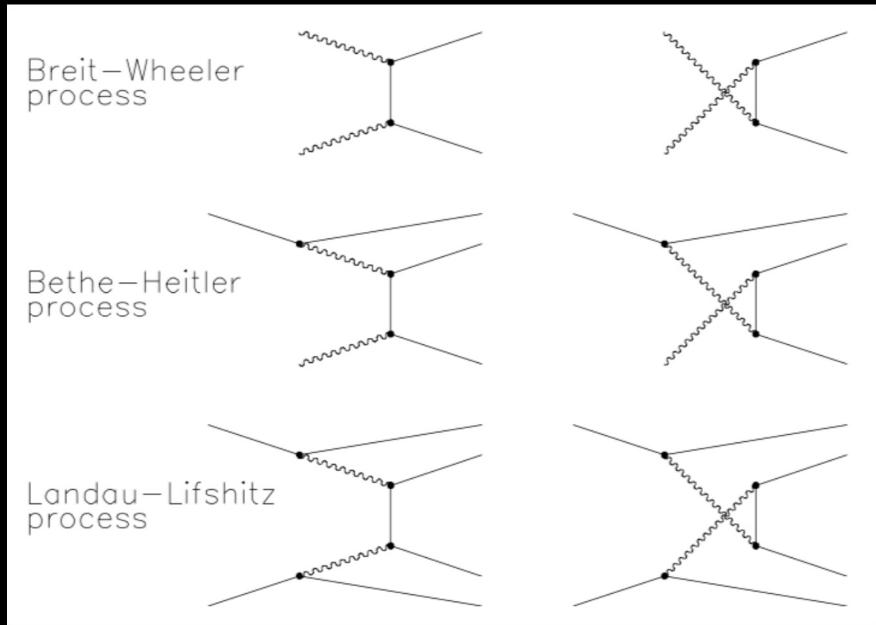

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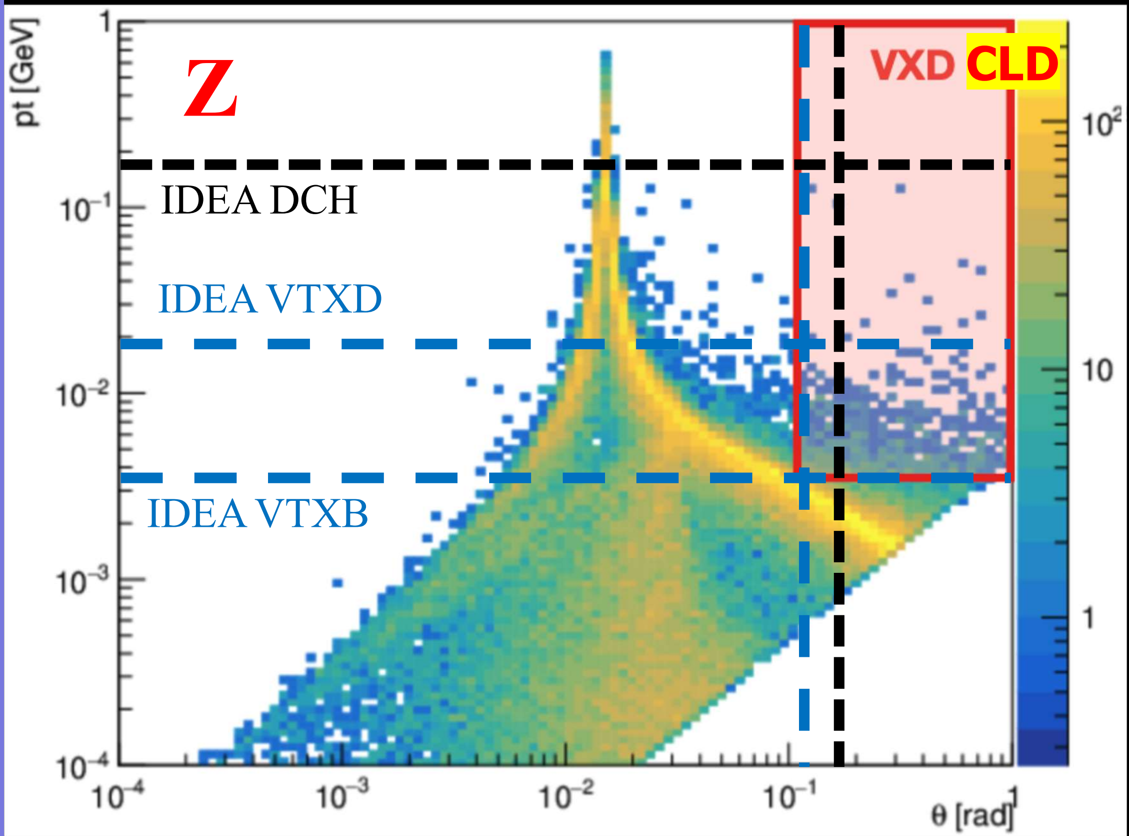

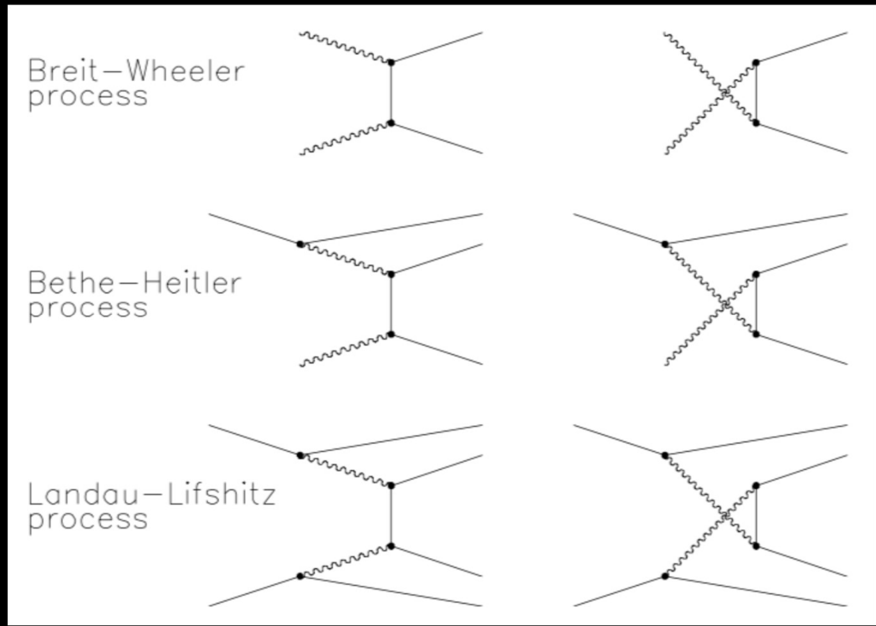

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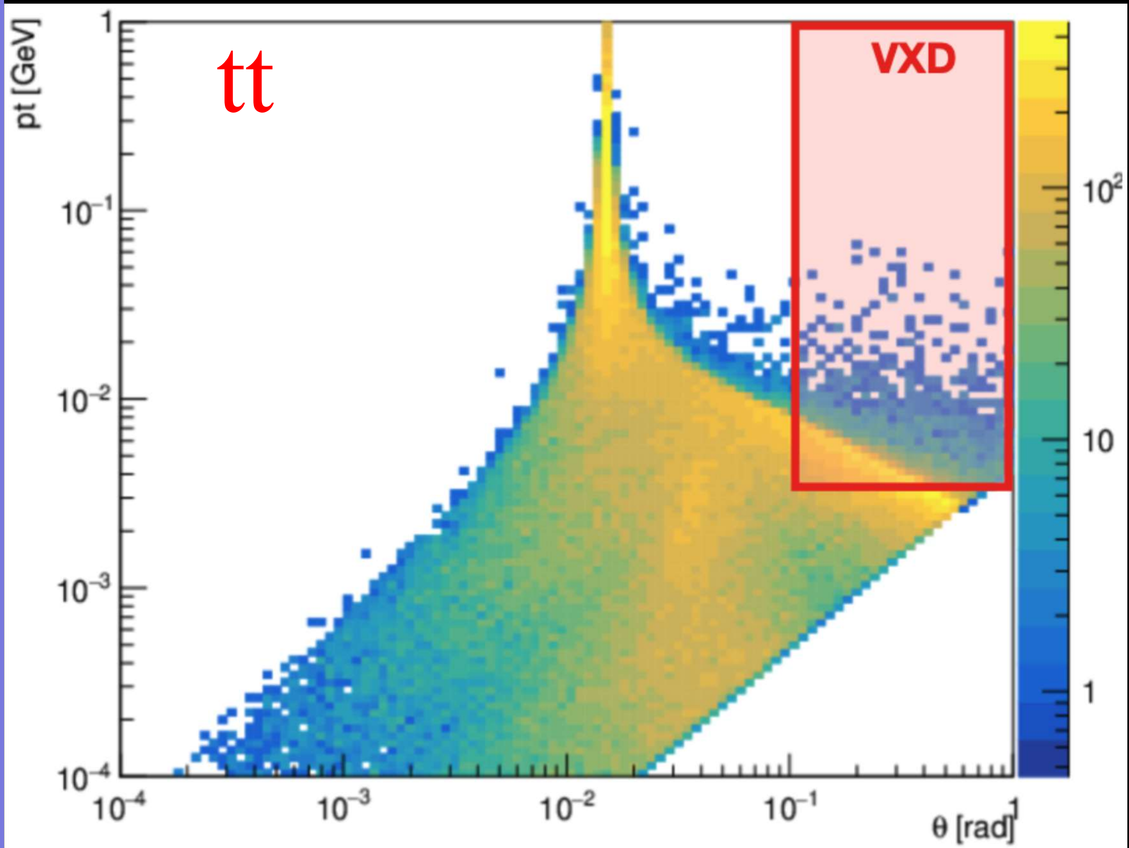
Incoherent pair background ($t\bar{t}$)



Courtesy: Andrea Ciarma, INFN-LNF

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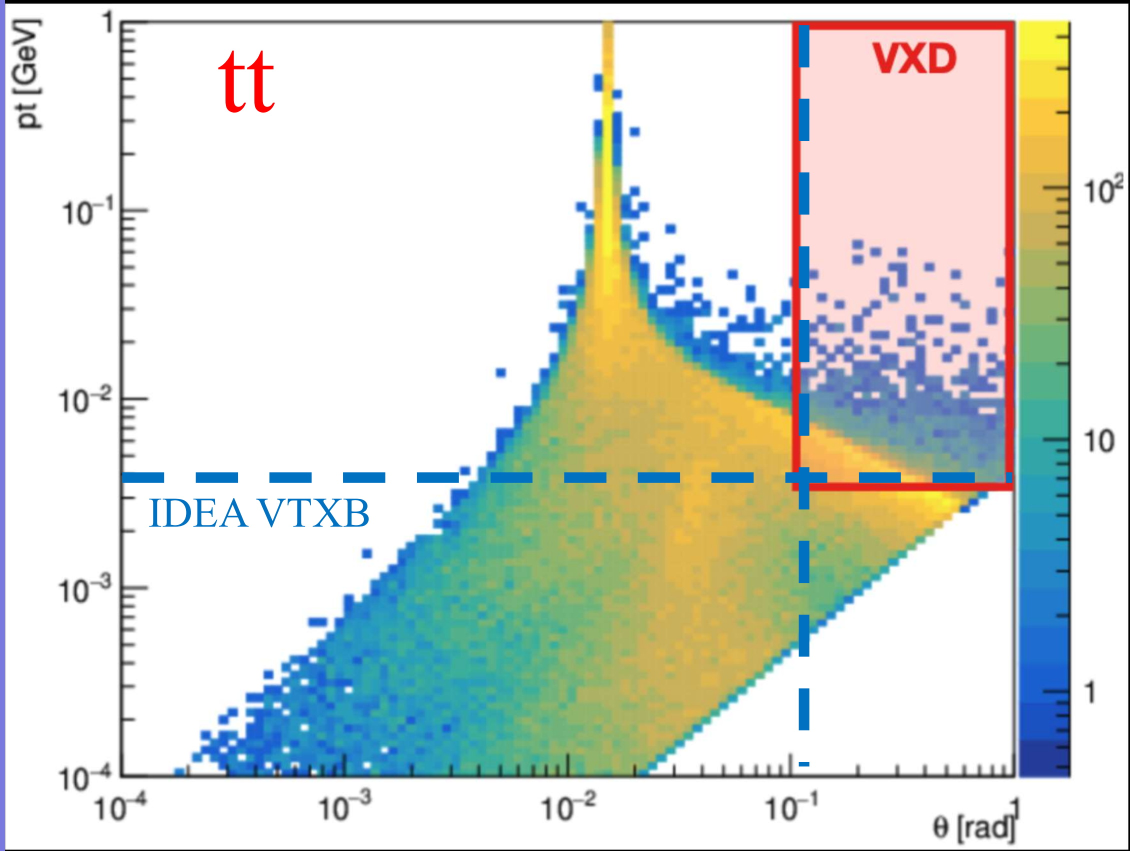

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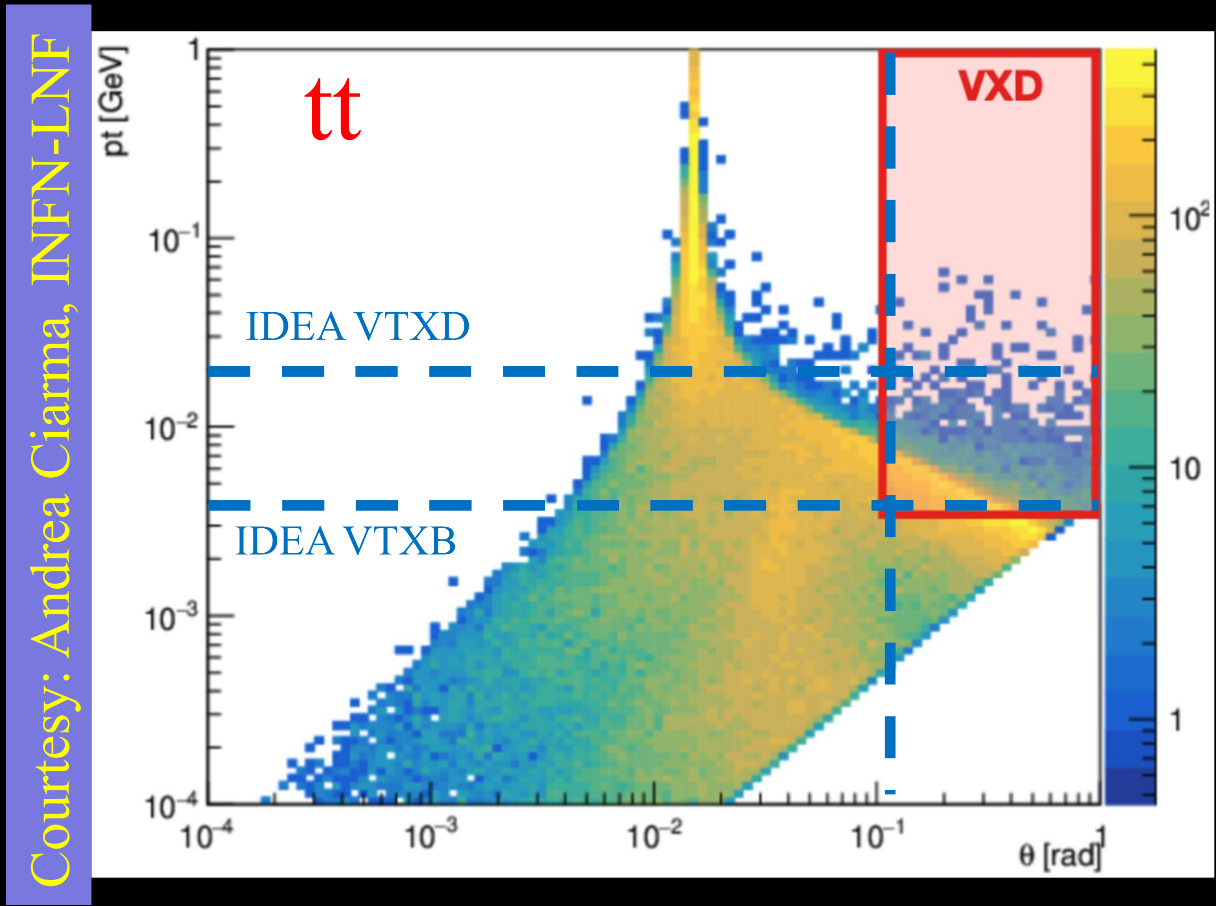

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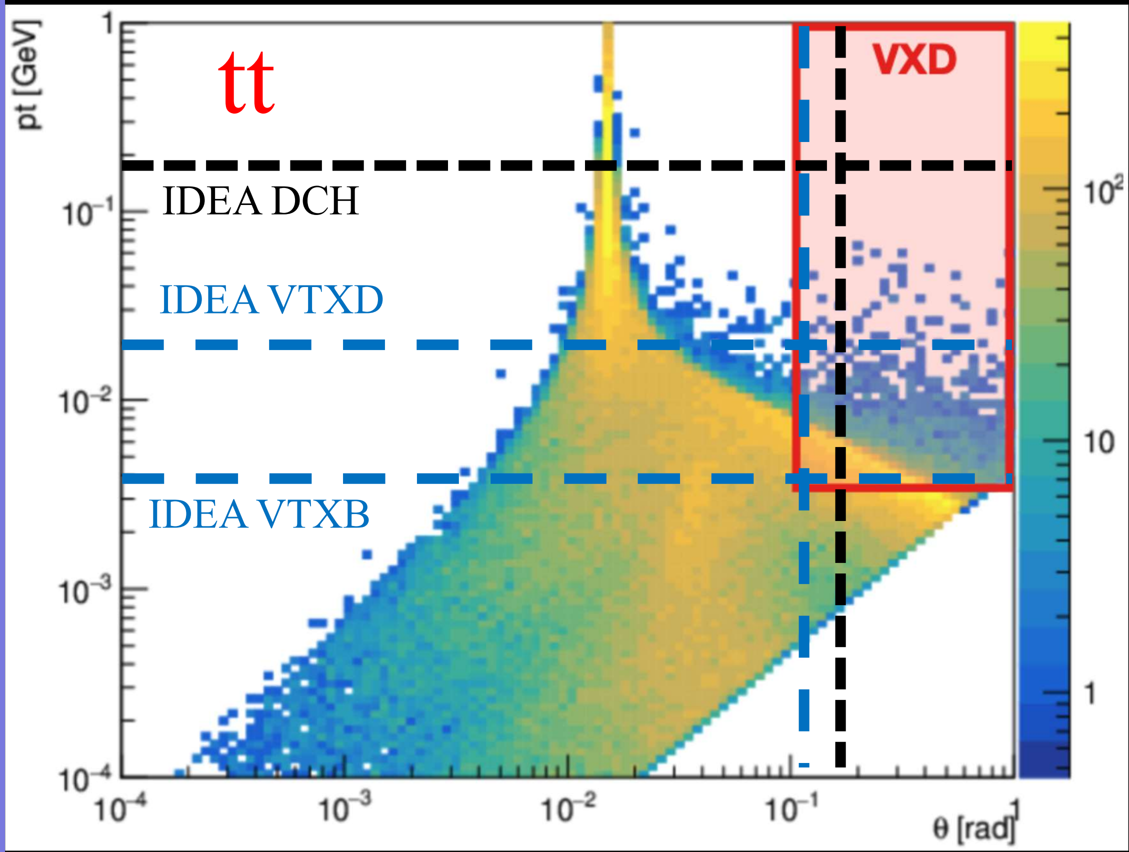


Silicon occupancy summary

Courtesy : Andrea Ciarma, INFN-LNF

- Max occupancy in inner VTX barrel layer same as CLD

		Z	WW	ZH	$t\bar{t}$
ns	average bunch spacing	30	345	1225	7598
10^{-3}	O_{max}(VXD), RW=1 μs	2.33	0.81	0.05	0.18
10^{-3}	O_{max}(VXD), RW=10 μs	23.3	8.12	3.34	1.51

  - Assume <cluster size> = 3, safety factor 5
- Occupancy scales with pixel area → better with smaller area
  - But Nr of pixels fired (ie. data volume) does not change much
- Physics signals give negligible contribution to occupancy
- Nr. Bunch crossings in 10 μs window

Z	WW	ZH	tt
329	29	8.2	1.3

  - Can recover large factors by using only correct BX
    - External trigger or downstream selection (for Pat. Rec.)

Silicon data volume

- Pixels to read out for ARCADIA L1 (15 staves x 6 modules x **2 chips x 640 x256 pixels**)
  - Z WW ZH tt
  - 7.6 2.7 1.1 0.5 x10^3 in 10 μsec window/2-chip module
  - 23.2 91.8 133.5 380.6 per bunch crossing/2-chip modeule
- Assuming 32 bits/pixel including time stamp/2-chip module
  - 24.4 8.5 3.5 1.6 Gbit/s Not triggered
  - 149 N/A N/A N/A Mbit/s triggered **200 kHz trigger rate**
  - Total layer 1:
    - 2.2 Tbit/sec (NoTrigger) → 13.4 Gbit/sec (Triggered) at Z pole → port card transmission needs 1.1 Tbit or 7 Gbit/s/side
- Other layers and disks have lower data volumes
  - Layer 2 has ~10x less data volume
- Max readout speed achievable on chip **100** - 200 MHz x 32 bits? → **3.2** - 6.4 Gbit/sec

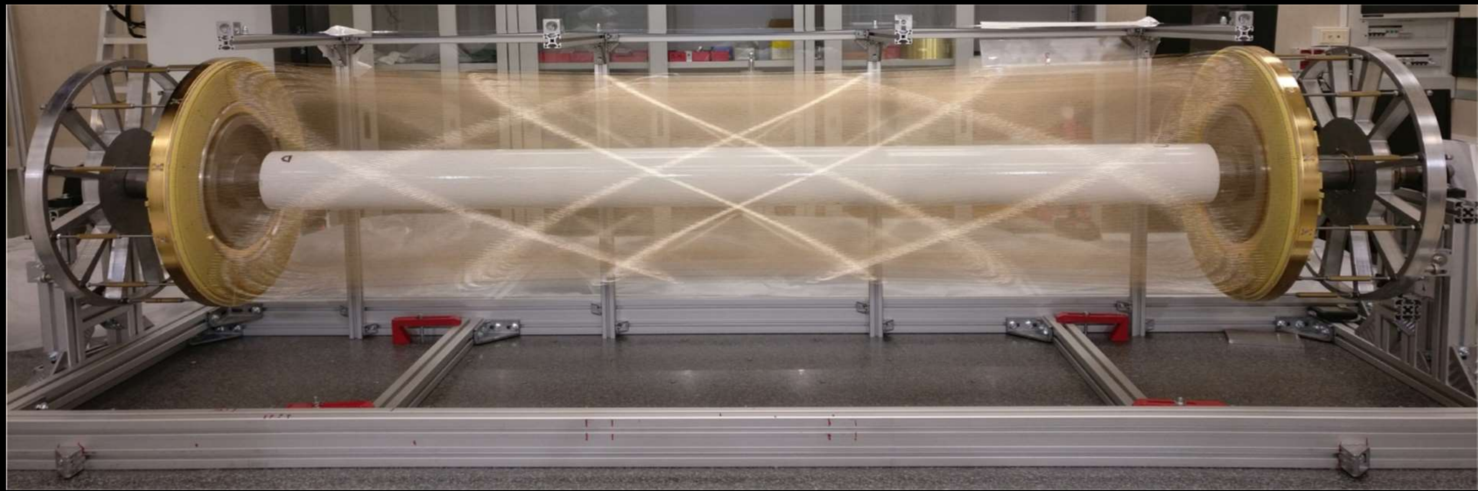
Current ARCADIA

Untriggered operation looks difficult

Drift chamber basic assumptions

- Educated guess – simulations in progress
- 91 GeV c.m. energy
  - 200 KHz trigger rate
    - 100 KHz Z decays
    - 30 KHz γγ → hadrons
    - 50 KHz Bhabha
    - 20 KHz noise/bck

- drift cells: 56,000 , layers: 112
- max drift time (≈1 cm): 400 ns
- cluster density: 20/cm
- signal digitization:
  - 12 bits at 2×10^9 bytes/s
    - 2 GHz digitizer



DCH: Unfiltered data rate

- Z decays:
  - 10^5 ev/s × 20 tracks/ev × 112 cells/track × 4×10^{-7} s × 2×10^9 Bytes/cell/s ≅ 179 GB/s
- γγ → hadrons:
  - 3×10^4 ev/s ×10 tracks/ev × 112 cells/track × 4×10^{-7} s × 2×10^9 Bytes/cell/s ≅ 27 GB/s
- Bhabha:
  - 5×10^4 ev/s × 2 tracks/ev × 112 cells/track × 4×10^{-7} s × 2×10^9 Bytes/cell/s ≅ 9 GB/s
- Noise (assume 2.5% occupancy):
  - 2×10^4 ev/s × 1.5×10^3 cells/ev × 4×10^{-7} s × 2×10^9 Bytes/cell/s ≅ 24 GB/s

< 1 TB/s with safety factors

- Total unfiltered rate (read both ends): 2 x 239 = 478 GB/s

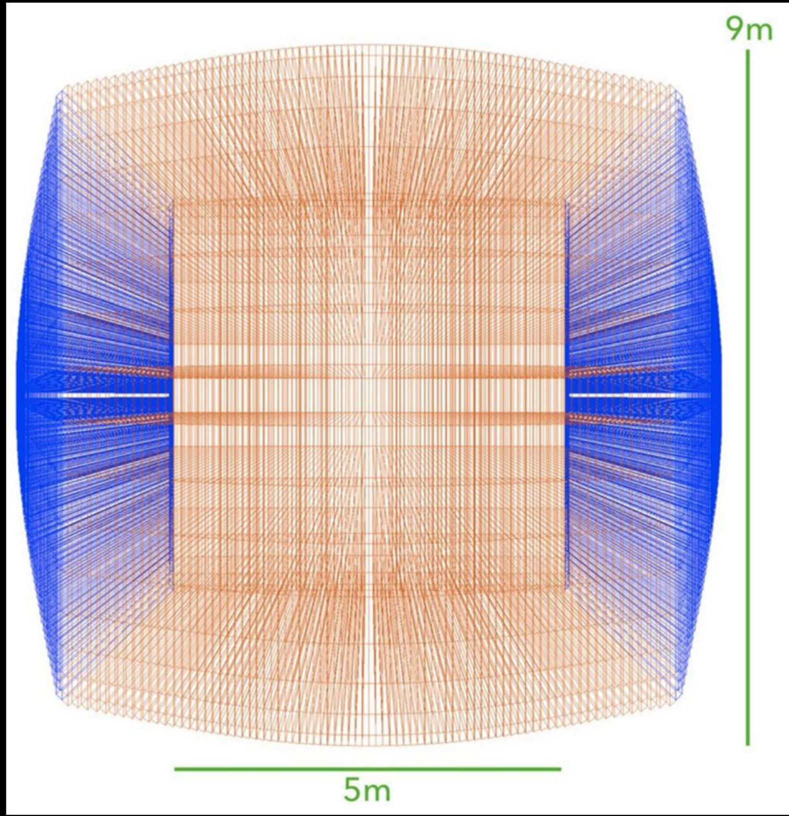
DCH: after cluster finding

- Assume on-board cluster finding and reading out only peaks (assume 2.5 peaks/cluster)
  - Readout amplitude and time of peak (2 Bytes)
- Z decays:
  - 10^5 ev/s × 20 tracks/ev × 112 cells/track × 50 peaks/cell × 2 Bytes/peak ≅ 22 GB/s
- γγ → hadrons:
  - 3×10^4 ev/s × 10 tracks/ev × 112 cells/track × 50 peaks/cell × 2 Bytes/peak ≅ 3 GB/s
- Bhabha:
  - 5×10^4 ev/s × 2 tracks/ev × 112 cells/track × 50 peaks/cell × 2 Bytes/peak ≅ 1 GB/s
- Noise (assume filtered by clustering algo) 0 GB
- Total filtered rate (read both ends): 2 x 27 = 54 GB/s

≈ 100 GB/s with safety factors

DR fiber calorimeter signal

- Assumed readout configuration:
  - Nr. of SiPM = 130 M
  - Likely grouping by 8 → 16.3 M channels
    - With 0 suppression
  - Readout: Q_T, ToA, ToT, TPk, VPk, Channel Identifier
    - Assume 16 Bytes
- Z→ jj
  - ~ 6000 fibers fired → ~ 100 kB/ev
  - 100 kHz physics rate → ~ 10 GB/s NO grouping



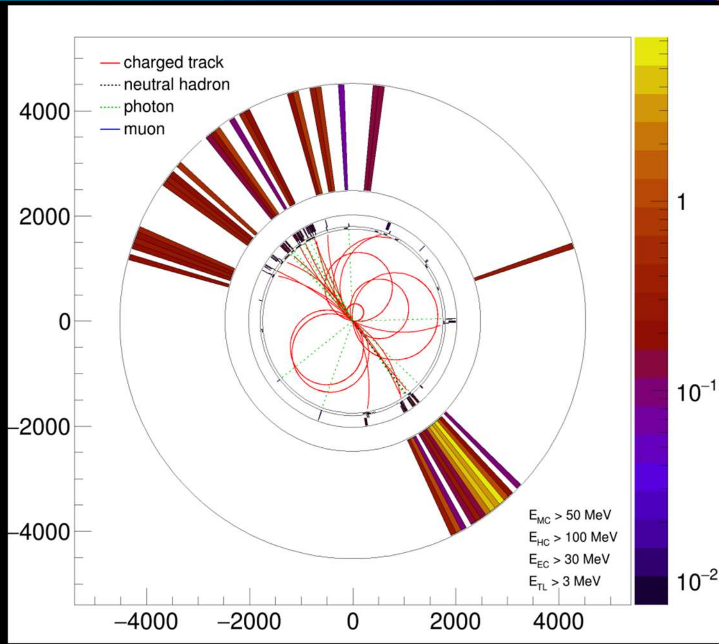
- NB. # Fibers reduced by x2-3 if crystals in front

DR calorimeter DCR

- Assumptions:
  - 200 kHz DCR /SiPM
  - 250 nsec integration time
  - Mean number of counts/SiPM $\mu = 0.05$
    - Prob. >= 1 pe = $1-\exp(-\mu) = 4.9\ \%$ → 6.4 M/ev x 100 kHz x 16 = 10.2 TB/s
    - Prob. >= 2 pe = $1-\exp(-\mu)\,(1+\mu) = 0.12\ \%$ → 156 k/ev « = 250 GB/s
    - Prob. >= 3 pe = $1-\exp(-\mu)\,(1+\mu+\mu^2/2) = 0.002\ \%$ → 2.6 k/ev « = 4.2 GB/s
    - Threshold at 2.5 pe used during recent test beams
- Dark count could be a problem
  - Thresholds and additional suppressions to be optmized (e.g. isolation, timing, ….)

Throughput crystal option

- Single dijet event at √s=90 GeV (1x1 cm² crystal section)
  - 510 active crystals with 10 MeV readout threshold →0.2 MIP in front crystal
  - ~220 active crystals with 30 MeV readout threshold →0.5MIP in front crystal
  - ~70 active crystals with 100 MeV readout threshold →~2MIPs in front crystal
- 4 Bytes/crystal + 2 Bytes for timing

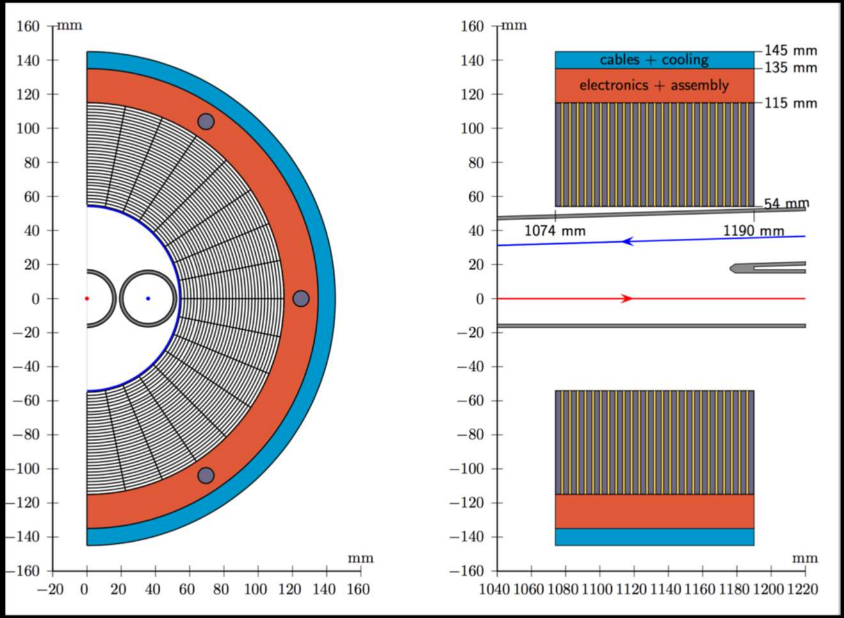


< 10 kB /event → total at 100 kHz trigger rate: <1GB/s

Dark count rate << MIP readout threshold

Luminometer

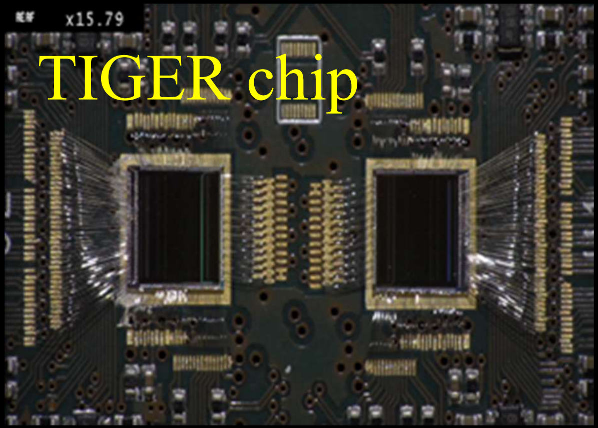
- Physics
  - Bhabha + rad. Bhabha ~ 250 nb
  - Total rate ~ 500 kHz
  - Additional contributions
    - γγ, SR, beam halo, …?
- Detector
  - 10 bit range needed
  - 45 GeV e- → 660 channels hit
- Throughput
  - 10 bit x 500 kHz x 660 ch x 2 (sides) = 6.6 Gbit/s ~ 1 GB/s   data driven
- If all interactions have some signal – Assume 500 ch total on average
  - 10 bit x 30 MHz x 500 ch = 150 Gbit/s ~ 18 GB/s



Muon system

Detector	Strip pitch [mm]	Area [m^2]	Number of tiles	Strips per tile	Channels [k]
Preshower	0.4	130	520	2500	1300
Muon detector	1.2	1525	6100	830	5060

- Readout configuration
  - 64 ch → 1 TIGER chip
  - 14 TIGER → 1 FEB = 896 ch
    - 1 FEB/detector tile (50x50 cm^2)
  - 4 FEB (3584 ch) → 1 GEMROC card
- Physics signals
  - 100 kHz Z (20 tracks/ev)
    - 3.3 kHz Z→μμ
  - 30 kHz γγ → hadrons (~10 tracks/ev)
  - 3 stations of muons counters
  - Cluster size 5 strips



Muon detector throughput

- Each GEMROC packet contains:
  - 272 bits for IP and UDP protocols, 193 bits for header and trailer, 64 bits for each hit
- For a track traversing all 3 stations of the muon detector:
  - 1 (track) x 3 (stations) x 2 (XY) x 5 (strips) x 64 bit/strip + 3 GEMROC x (193 + 272) bit/GEMROC = 3315 bits /track
- Considering a rate of 3.3 KHz of Z-> μ+μ- events:
  - 3315 bits x 3300 Hz x 2 (μ tracks) = ~22 Mbits/s ~3 MBytes/s
- Current TIGER has no zero suppression: expect an electronic noise of ~kHz/ch
  - 1 (strip) x 64 bit/strip x 5,060 k channels x 1 kHz ~40 Gbyte/s
  - With an on-board suppression of a factor 100 → data size ~400 Mbyte/s
- Muon detector data size ~ **400 Mbytes/s** Noise dominated!

Pre-shower throughput

- Each GEMROC packet contains:
  - 272 bits for IP and UDP protocols, 193 bits for header and trailer, 64 bits for each hit
- For one track traversing the pre-shower detector:
  - 1 (track) x 1 (stations) x 2 (XY) x 5 (strips) x 64 bit/strip + 1 GEMROC x (193 + 272) bit/GEMROC = 1105 bits /track
- Considering a rate of 100 KHz (Z events) x 20 charged particles:
  - 1105 x 2 x 10^6 (events) = ~2 Gbits/s = 250 MBytes/s
- Considering a rate of 30 KHz ($\gamma\gamma$ events) x 10 charged particles:
  - 1105 x 3 x 10^5 (events) = ~0.3 Gbits/s = 40 MBytes/s
- From experience with the TIGER chips: electronic noise of ~kHz/ch
  - 1 (strip) x 64 bit/strip x 1.3 x 10^6 channels x 1 kHz ~10 Gbyte/s
  - With an on-board suppression of a factor 100 → data size ~100 Mbyte/s
- Pre-shower data size ~ **350 Mbytes/s** Signal dominated

Comments/Questions

- Efficient on-board zero/noise suppression needed for many systems
- Data throughput looks manageable except pixel detector inner layer(s)
  - Trigger advisable for vertex pixel detector
- Timing and assigning data to bunch crossing?
- Is trigger calibration possible with 0 bias triggers?
  - E.g. trigger every pre-scaled number of beam crossings
- Which detectors provide the trigger and how?
- Can HLT handle the triggerless output?
  - How much data write out?

Additional Slides