How can LLP triggering improve at HL-LHC?

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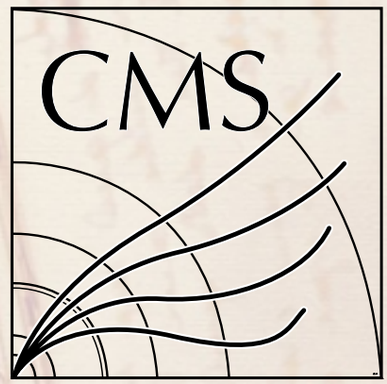
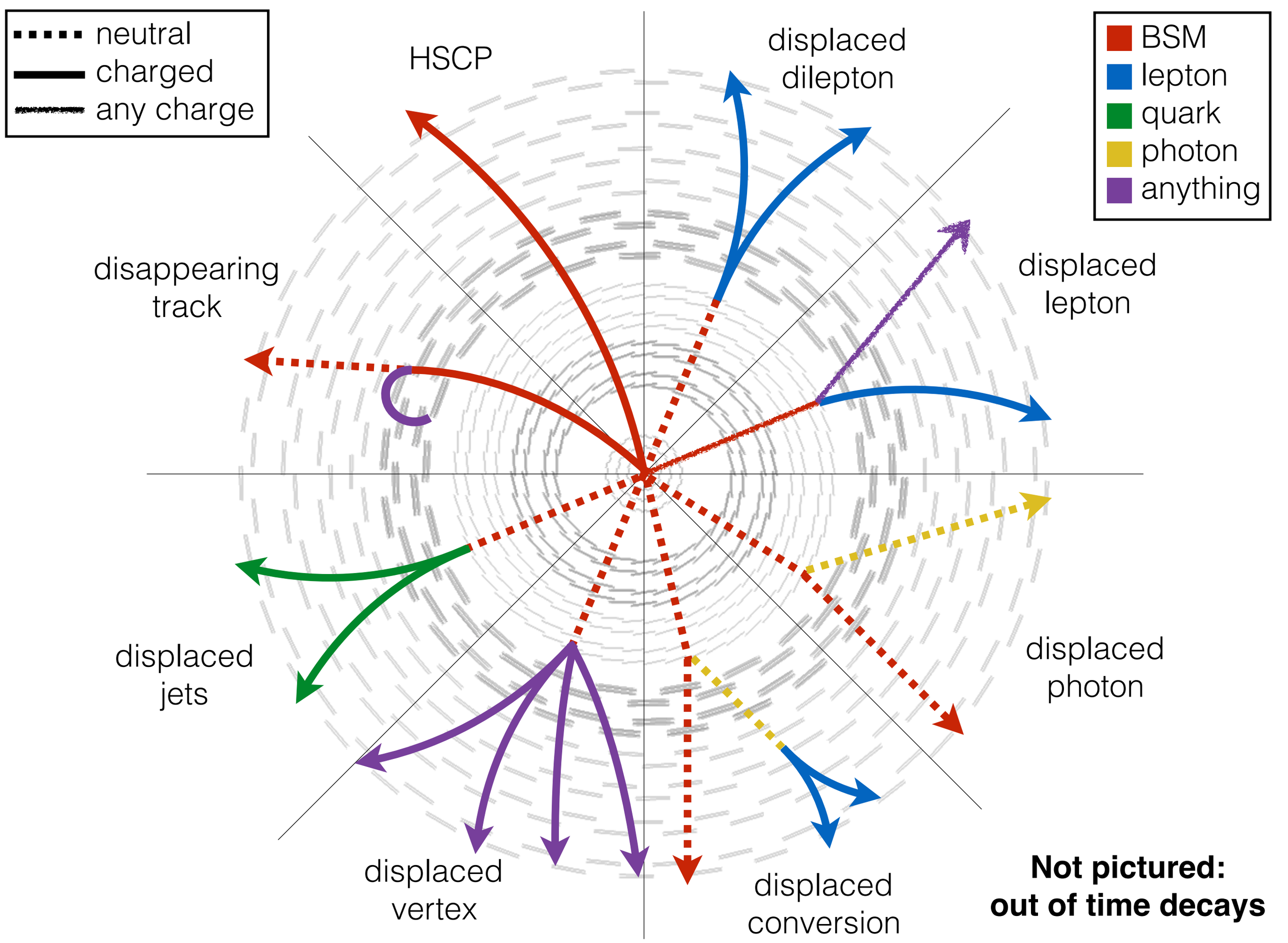
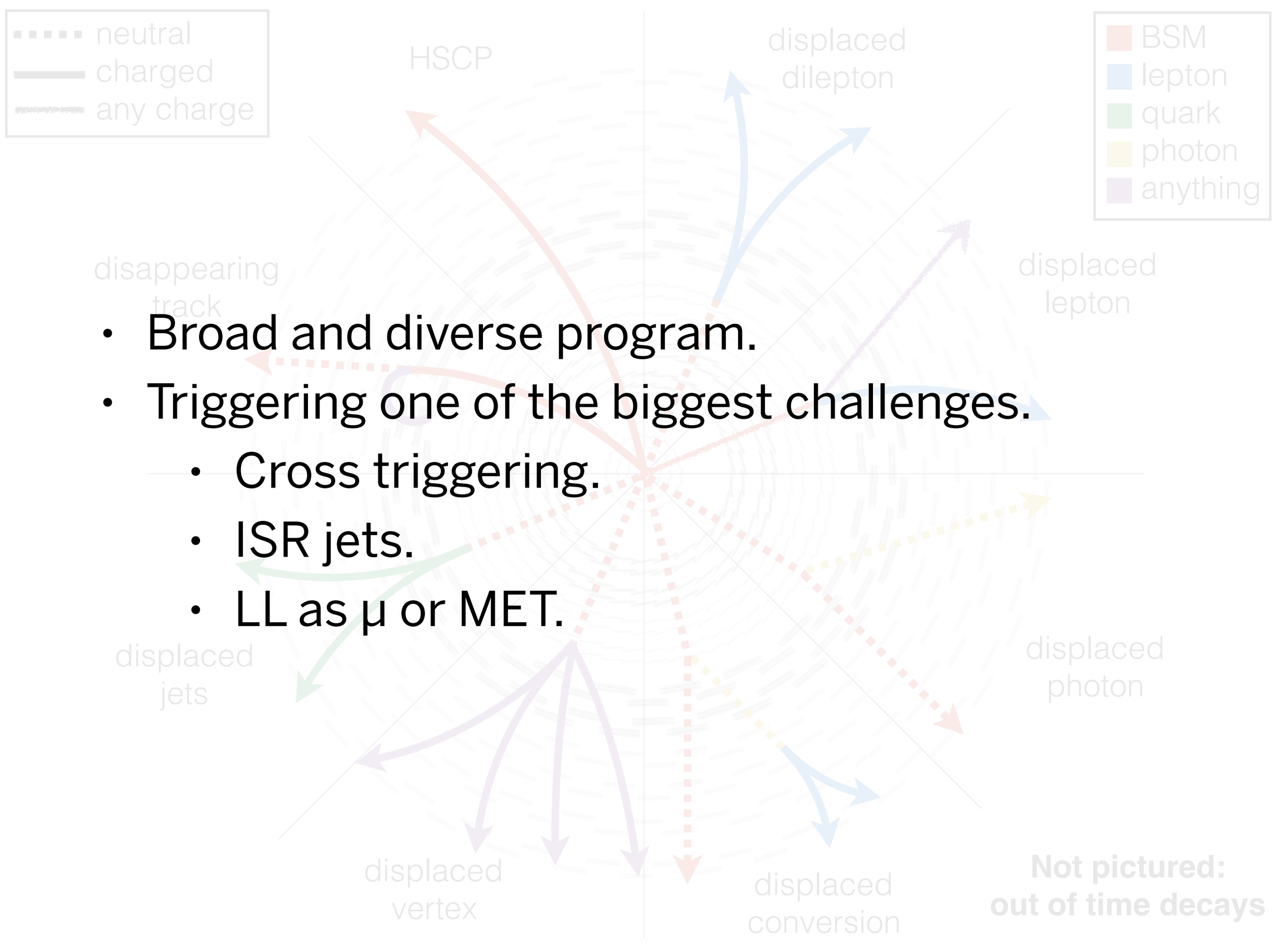
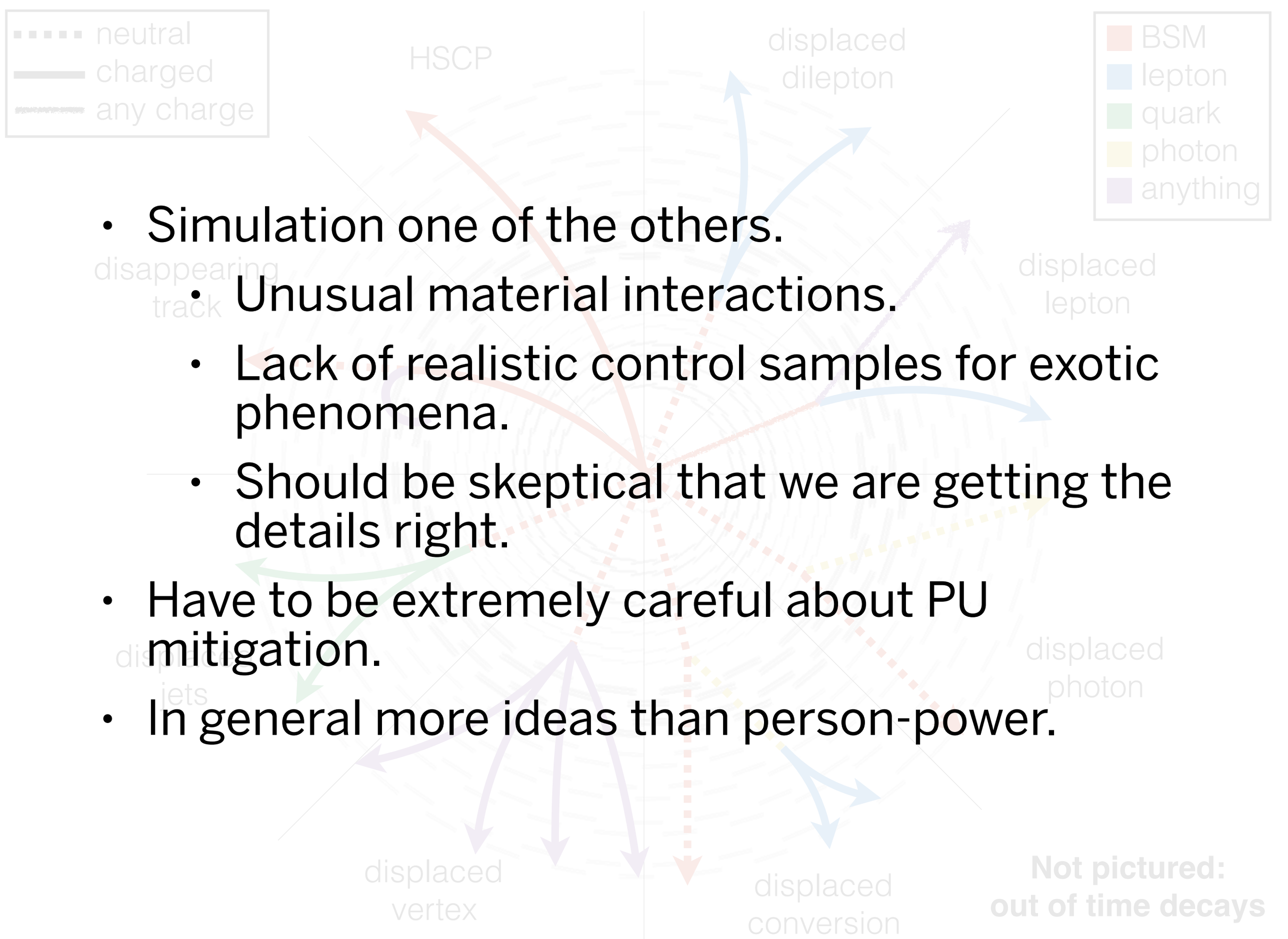
16 January 2018



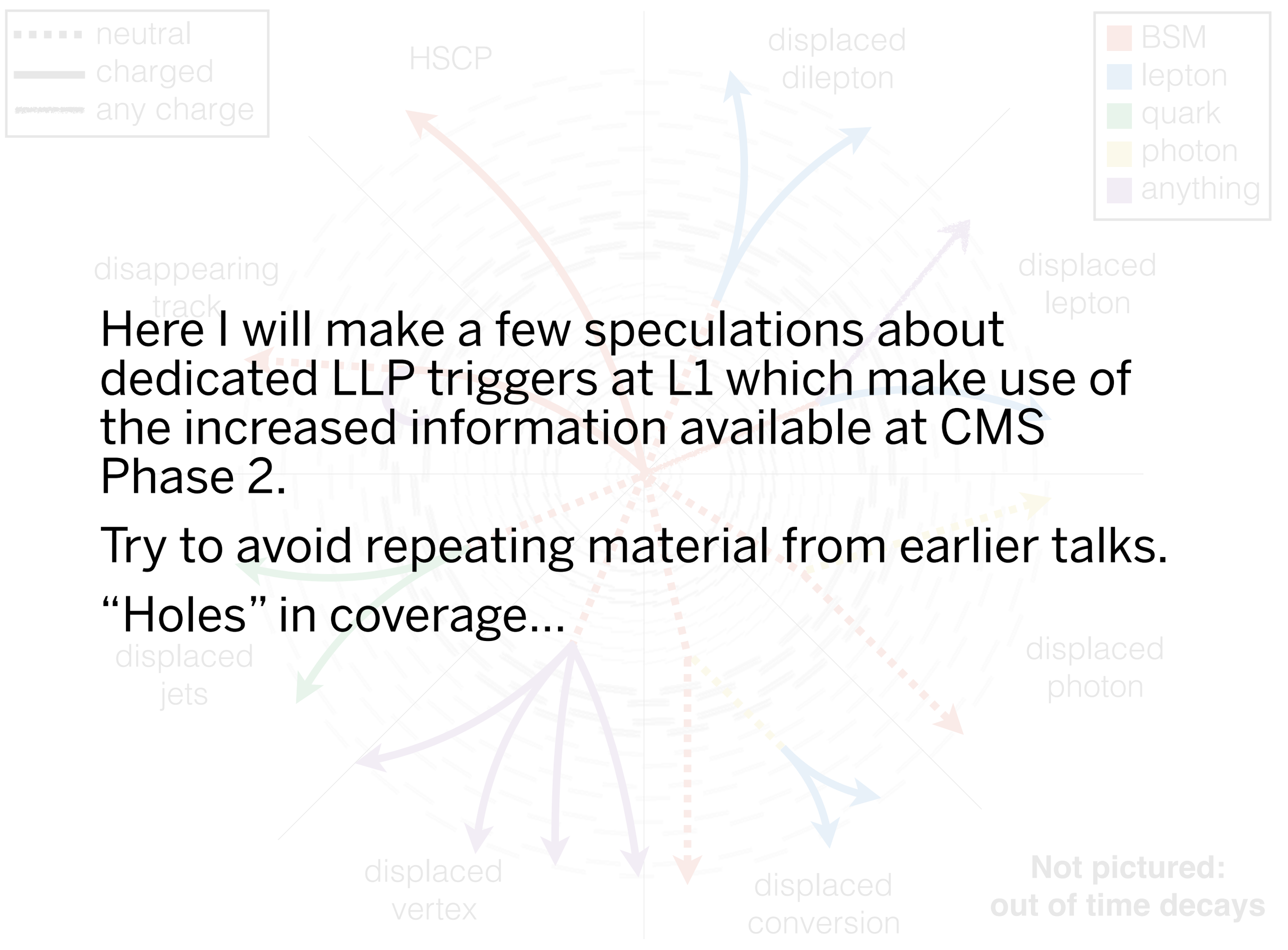

neutral
charged
any charge
BSM
lepton
quark
photon
anything
HSCP
displaced dilepton
disappearing track
displaced lepton
displaced jets
displaced photon
displaced vertex
displaced conversion
Not pictured: out of time decays



- Broad and diverse program.
- Triggering one of the biggest challenges.
  - Cross triggering.
  - ISR jets.
  - LL as μ or MET.



- Simulation one of the others.
  - Unusual material interactions.
    - Lack of realistic control samples for exotic phenomena.
      - Should be skeptical that we are getting the details right.
- Have to be extremely careful about PU mitigation.
- In general more ideas than person-power.

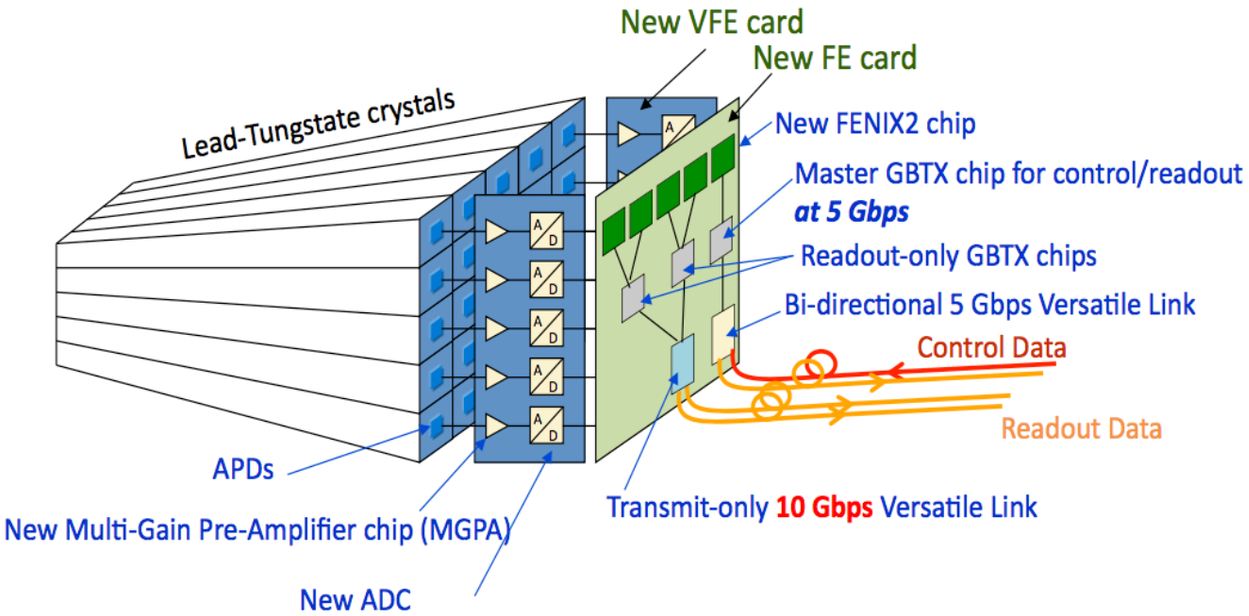


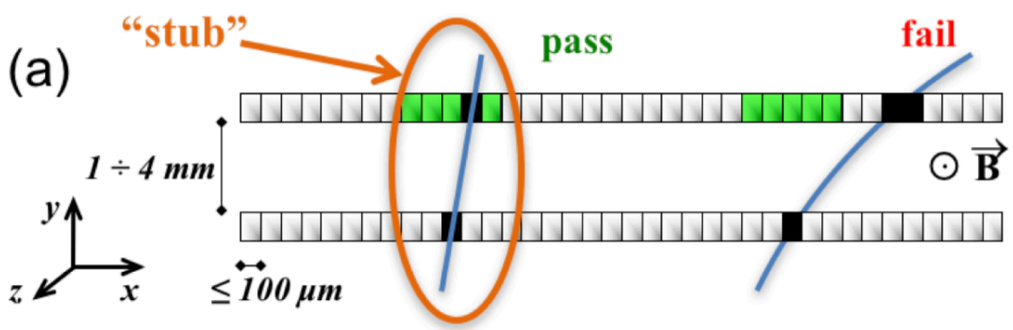
Here I will make a few speculations about dedicated LLP triggers at L1 which make use of the increased information available at CMS Phase 2.

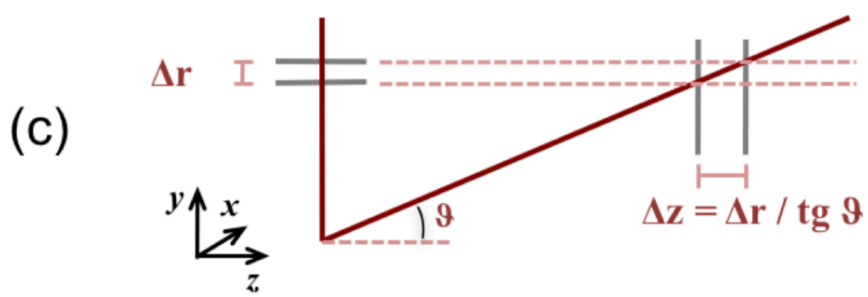
Try to avoid repeating material from earlier talks.

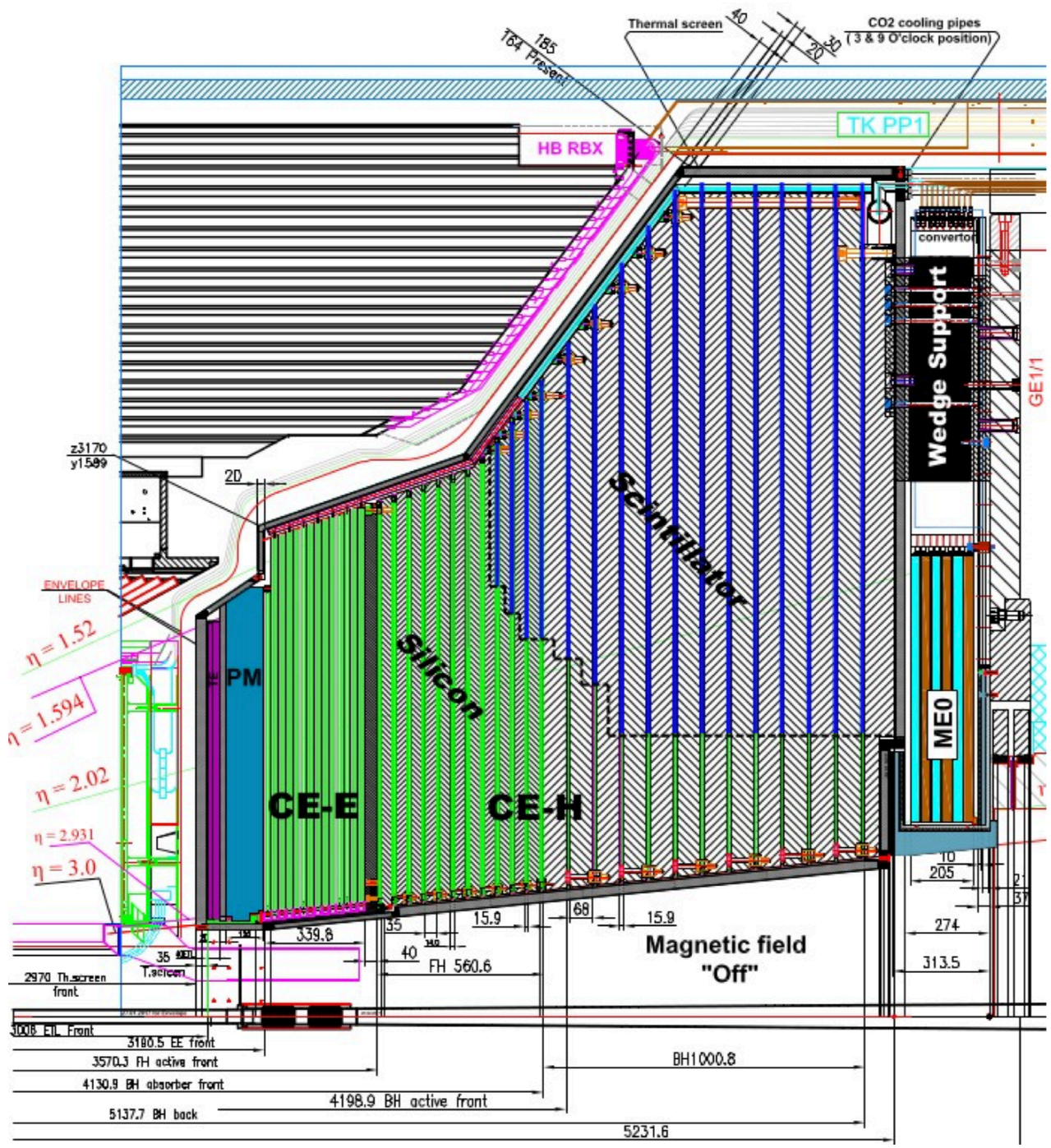
“Holes” in coverage…

Key changes


New VFE card
New FE card
Lead-Tungstate crystals
New FENIX2 chip
Master GBTX chip for control/readout
at 5 Gbps
Readout-only GBTX chips
Bi-directional 5 Gbps Versatile Link
Control Data
Readout Data
APDs
Transmit-only 10 Gbps Versatile Link
New Multi-Gain Pre-Amplifier chip (MGPA)
New ADC


(a)
"stub"
pass
fail
1 ÷ 4 mm
B
y
z
x
≤ 100 μm


(c)
Δr
ϑ
y
x
z
Δz = Δr / tg ϑ


Thermal screen
CO2 cooling pipes
(3 & 9 O'clock position)
TK PP1
HB RBX
converto
Wedge Support
GE1/1
Scintillator
Silicon
PM
CE-E
CE-H
ME0
ENVELOPE LINES
η = 1.52
η = 1.594
η = 2.02
η = 2.931
η = 3.0
Magnetic field
"Off"
FH 560.6
BH1000.8
4198.9 BH active front
5231.6

Summary of trigger strategies

Analysis	Phase 0/1	Phase 2
HSCP	Muon (prompt), MET	Muon (prompt), MET
Displaced leptons	e: EG μ: muon (no vtx.)	e: photon **(disp. e?)** μ: **muon (no vtx.)**
Displaced photon (conversions, timing)	double EG, EG + MET	**photon[s] (non-pointing)** **photon[s] (timing)**
Displaced vertex	HT	**displaced tracks**
Displaced jets	HT	**displaced tracks** **jet (non-pointing)**
Disappearing track	MET (ISR)	MET (ISR)
OOT decays	noBPTX, adj. BX	noBPTX, adj. BX **timing within BX**

Delayed photons with timing

- Expect to have ~5-10 mm resolution on photon path length from timing information in calorimeters.

- With timing alone, L1 could test hypothesis that photon comes from PV as identified by L1 tracks.

Remainder of talk

- Will explore a few possibilities for improving direct LLP trigger at L1.

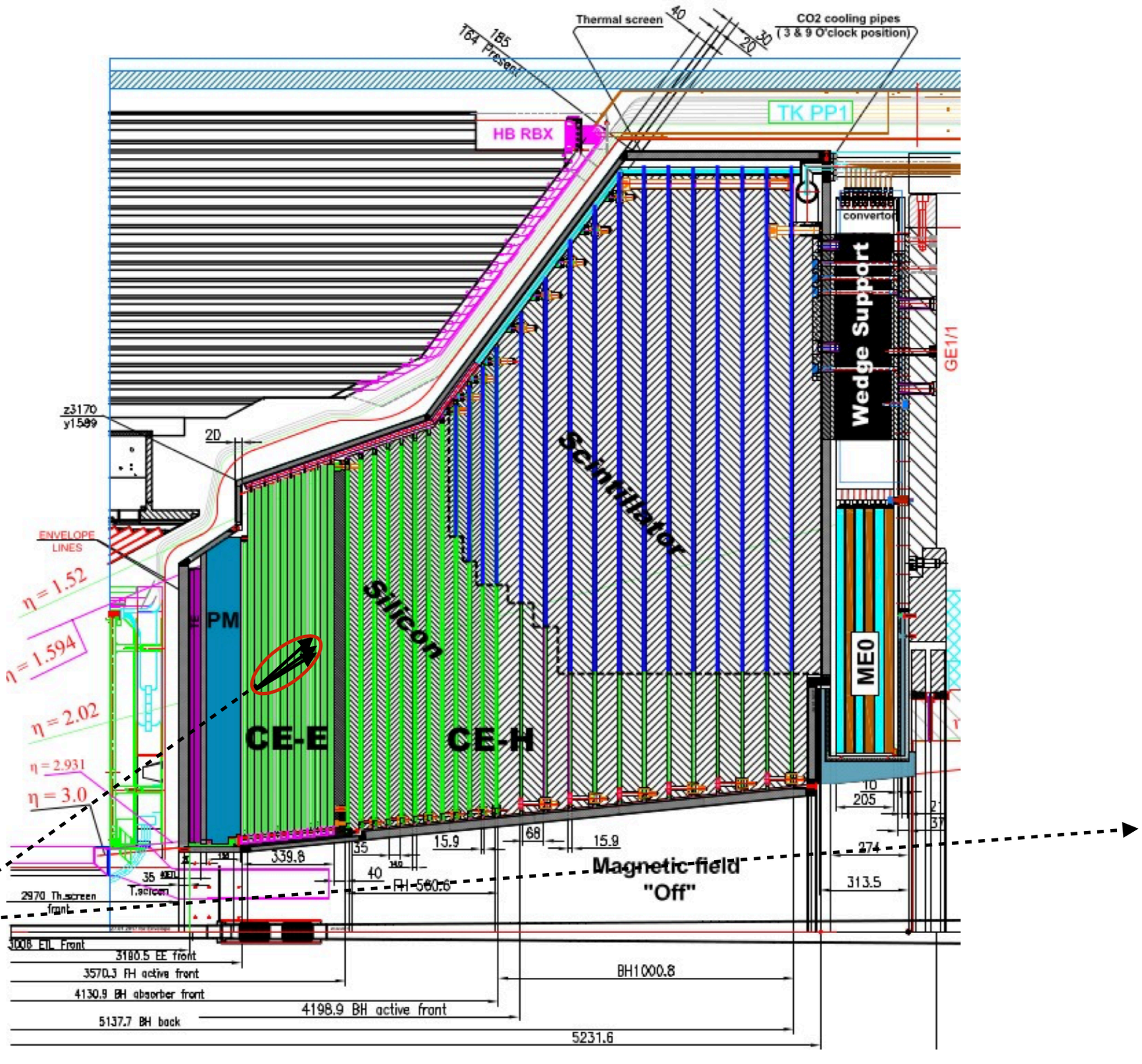
- Focus on CE since I spend most of my time working on that and it has some nice properties for this kind of thing.

- Don’t forget what Yuri, Michalis, Giovanni told us.

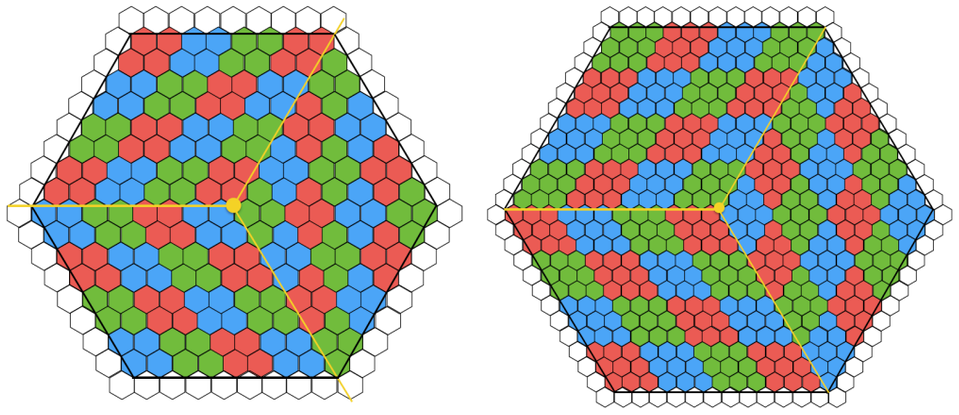
Non-pointing photon

Short or no track

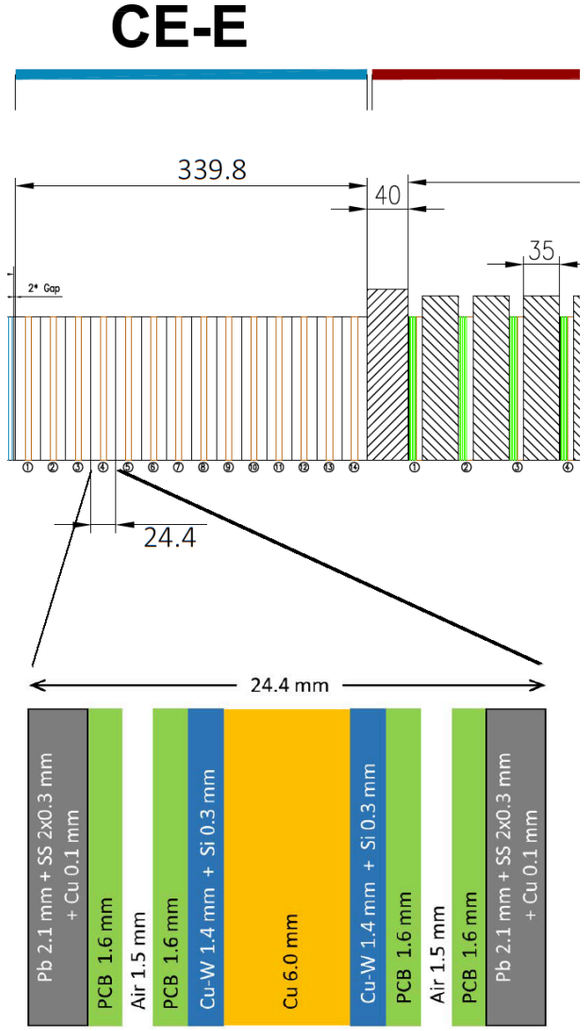
Anomalous shower shape



Non-pointing photons

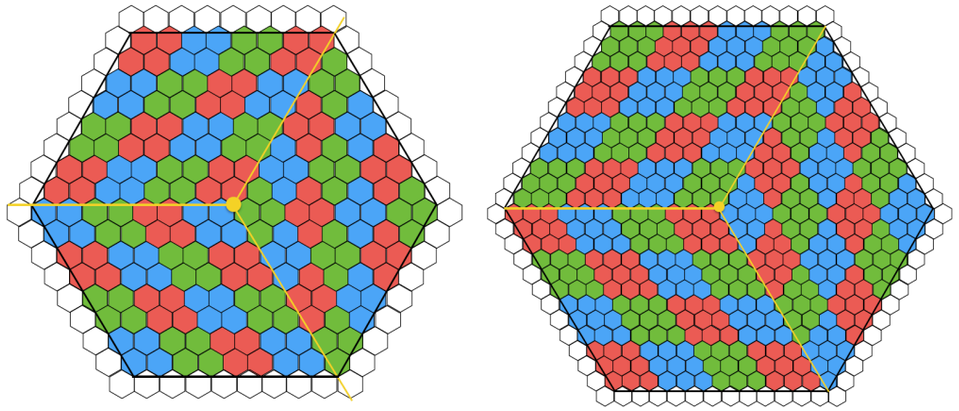


8” wafers

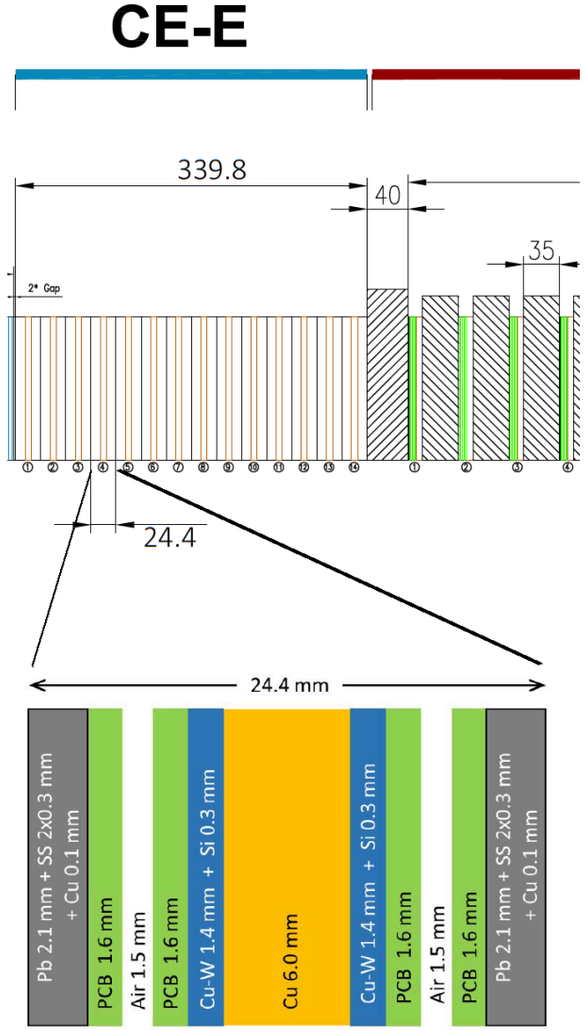


- Current L1 EM objects too coarse (calo trigger towers 0.087 × 0.087 and EG objects made by summing adjacent towers), and lacks any longitudinal segmentation, to provide any information about photon direction.
- As a result displaced photon analyses have to get around the rather high photon ET requirements by adding a second object to the trigger (usually 2nd EG object or MET).
- For sure, we can add longitudinal information at HLT to drop most prompt events.
- CE has the ability to measure EM shower angle with $\sigma(\theta) \sim 4$ mrad offline, expect ~ 7 mrad to be possible at L1 (trigger cells).

Non-pointing photons



8” wafers

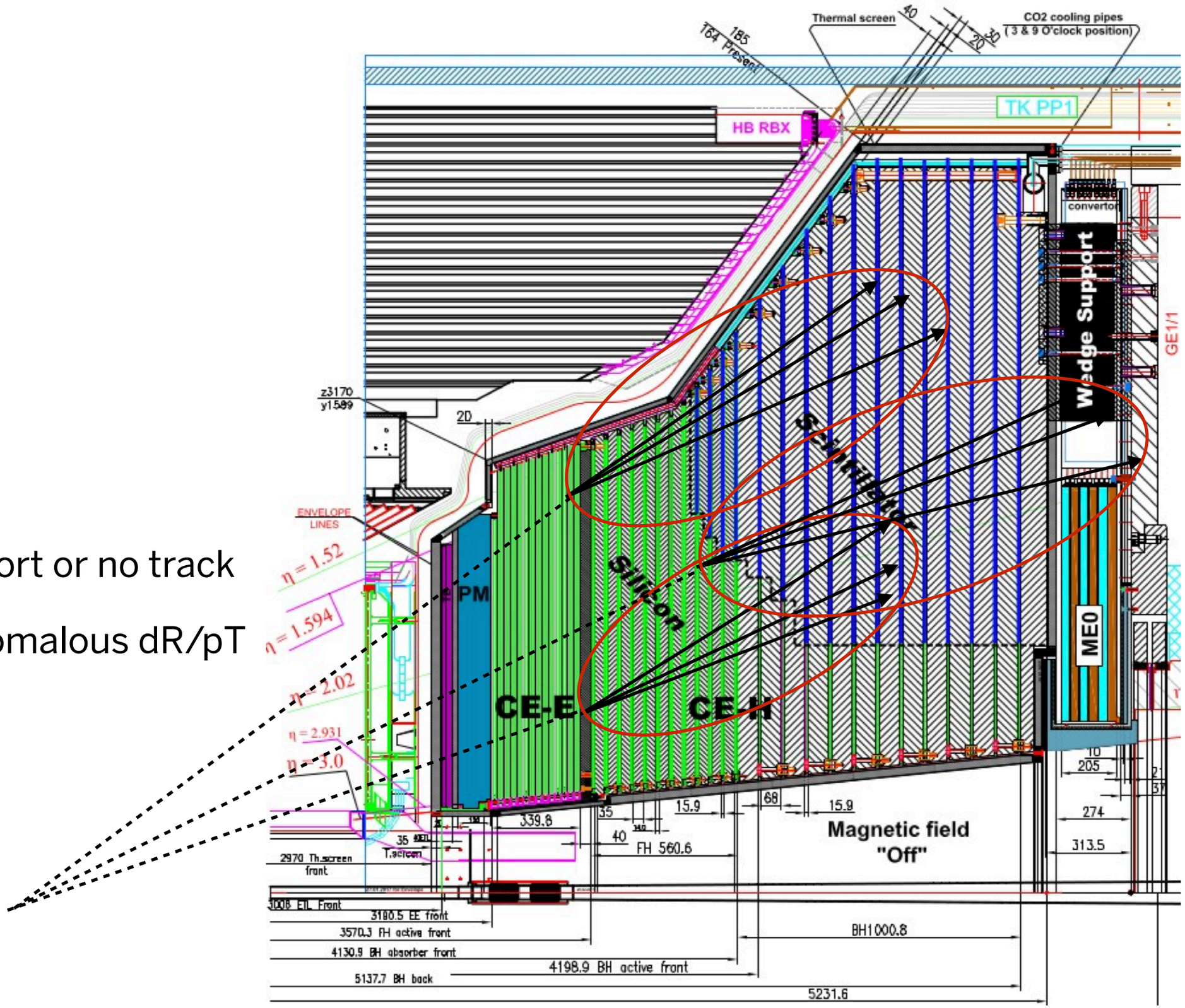


- 7 mrad → 6 mm on vertex position.
- With full 2D angle, could extrapolate to track trigger PV and compare at L1.
- With only a few bits could transmit e.g. 3 and 5 sigma incompatibility with beam spot.

Non-pointing jets

NB: DAQ path MIP-sensitive
L1 path not

Emerging jet

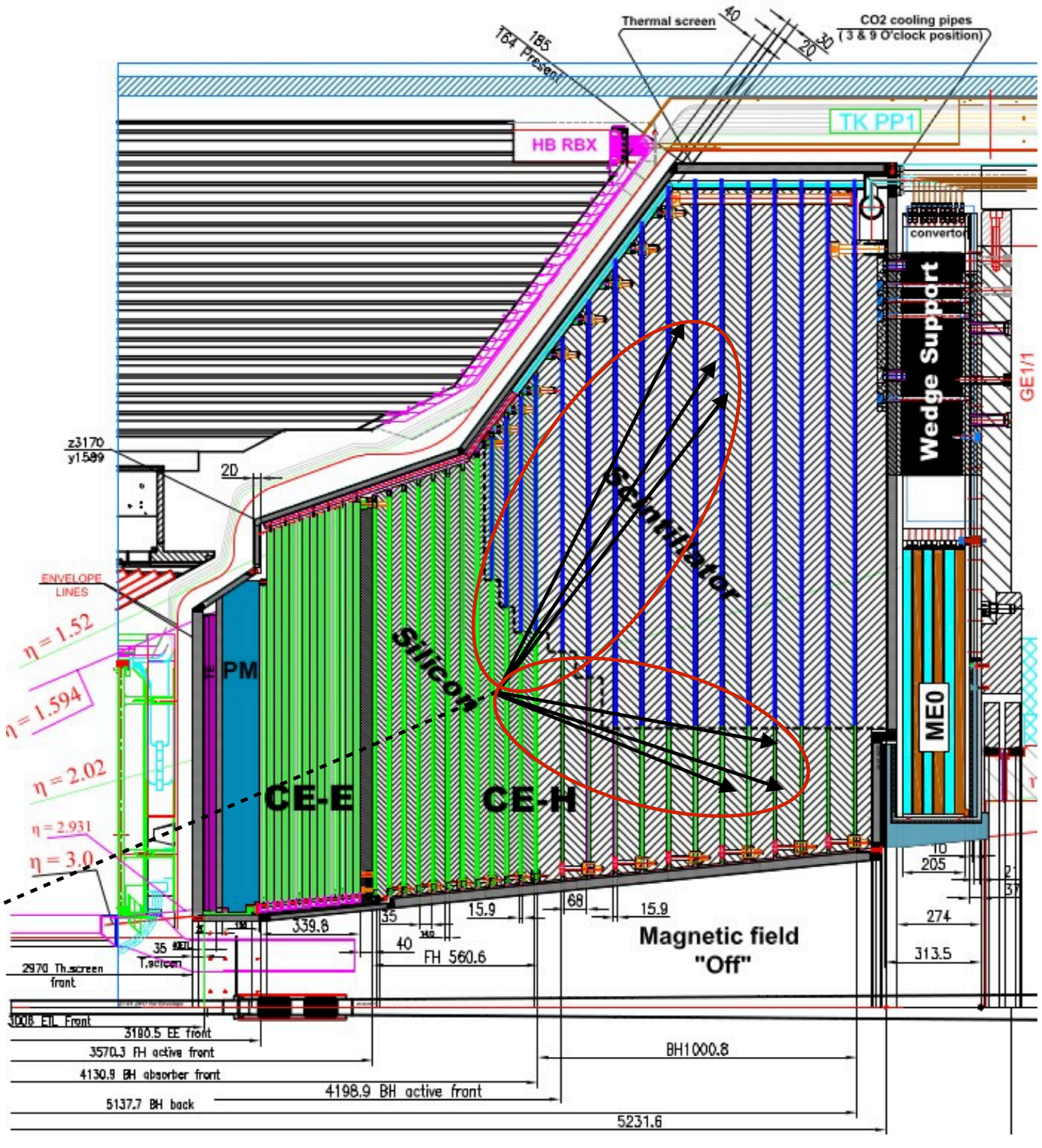


Short or no track

Anomalous dR/pT

Vtx tagging

Non-pointing jets



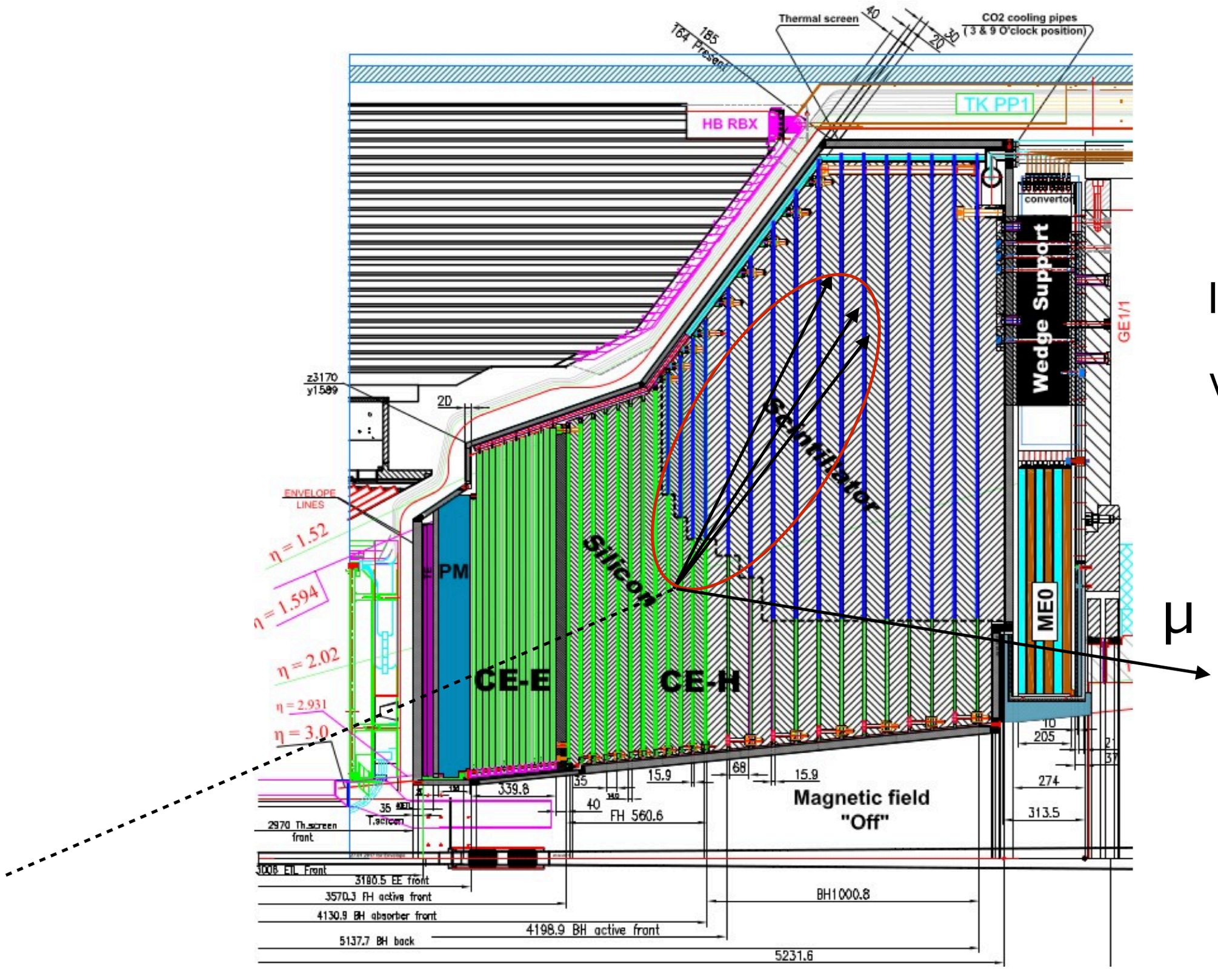
Short or no track

Anomalous dR/pT

IP tagging?

Vtx tagging

Non-pointing jets



IP tagging?

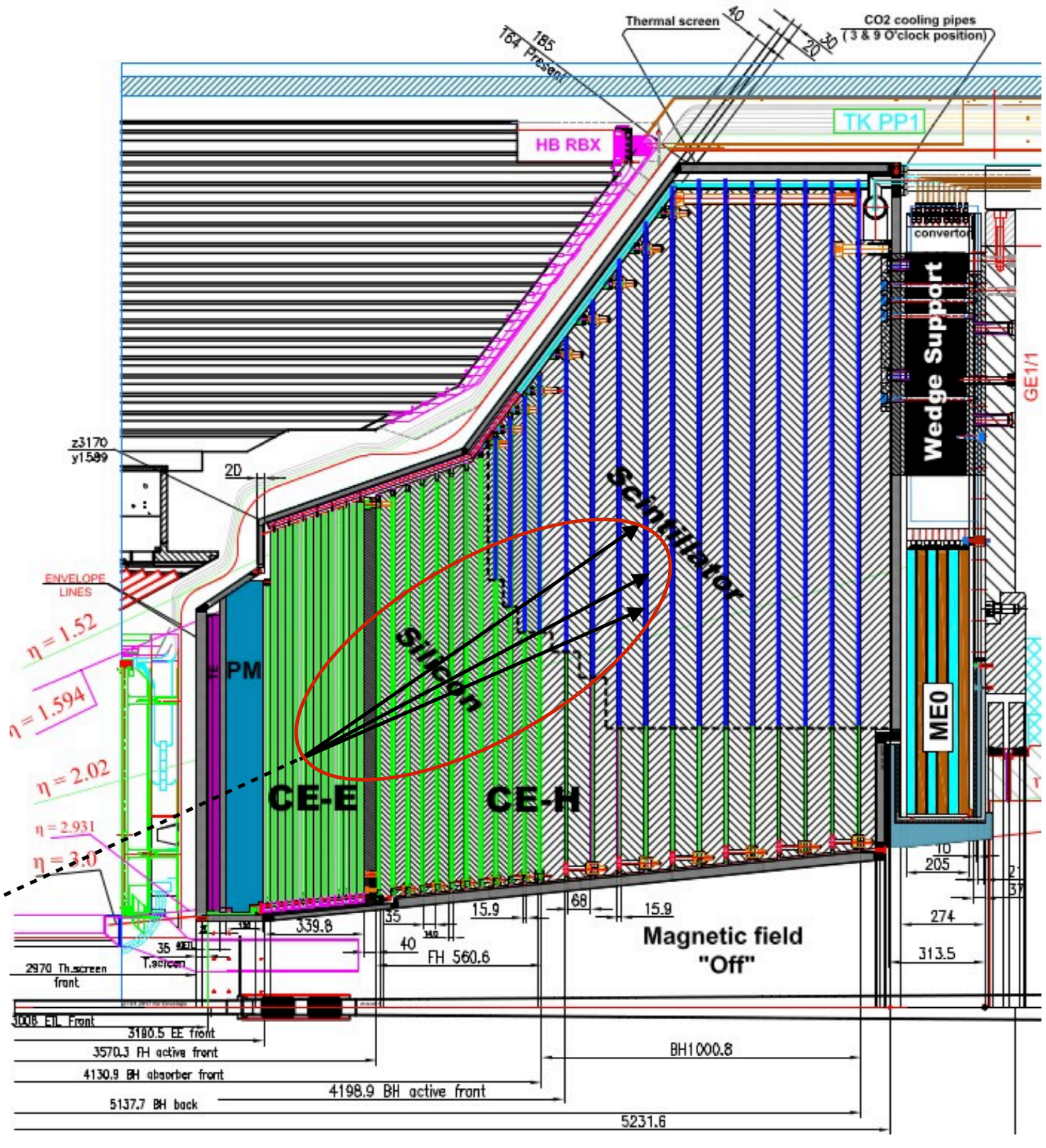
vtx tagging

Displaced tau?

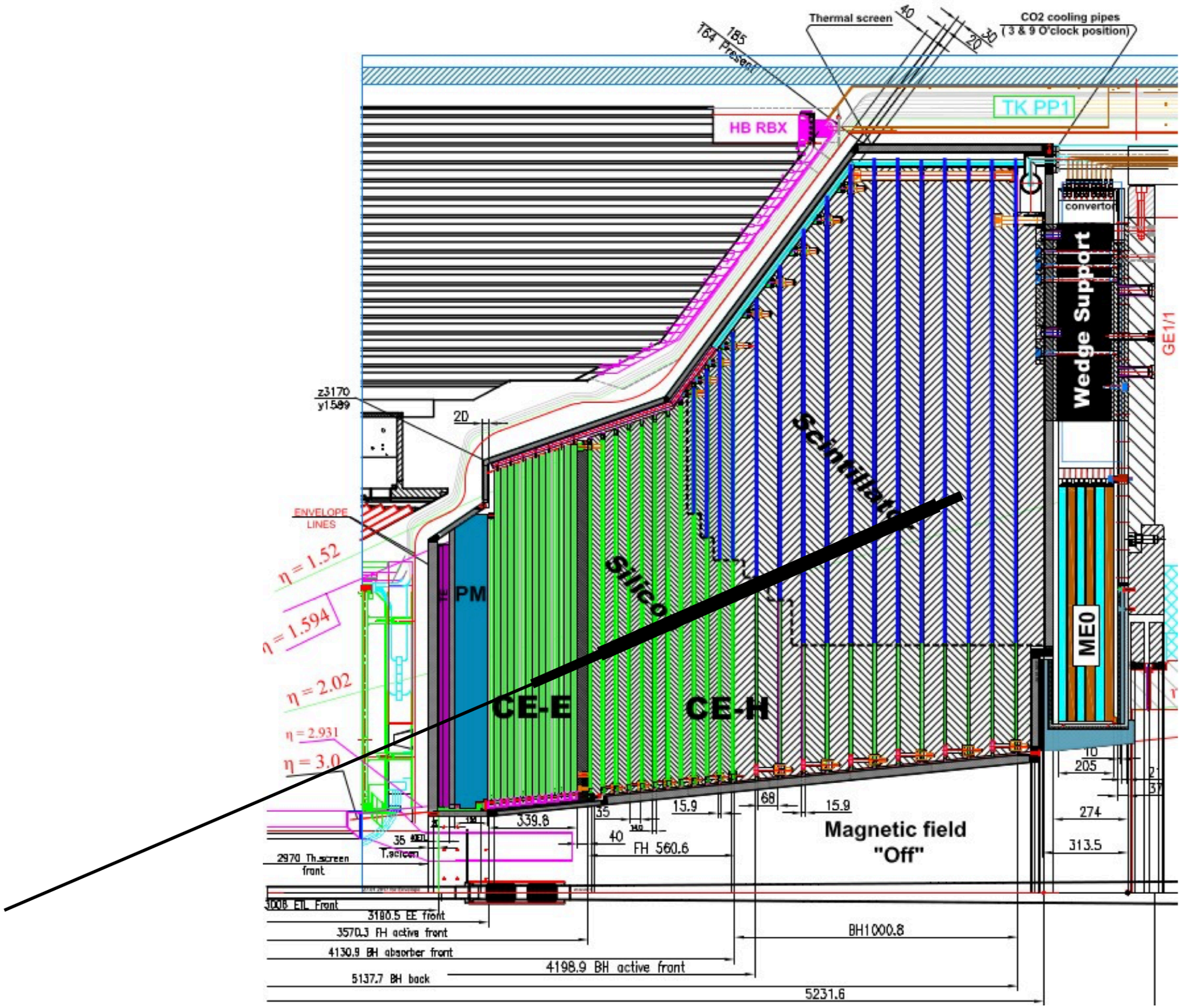
Short or no track

Small cluster mult.

Anomalous dR/pT



SIMP



not a jet
weird topology

shower shape?

μ

Reminder: Calo L1 data flow

Table 2.1: Summary of the logical input data to the Phase-2 L1 trigger.

Detector	Object	N bits/object	N objects	N bits/BX	Required BW (Gb/s)
TRK	Track	100	400	40 000	1 600
EB	Crystal	16	61 200	979 200	39 168
HB	Tower	16	2 304	36 864	1 475
HF	Tower	10	1 440	13 824	553
EC	Cluster	200	400	80 000	3 200
EC	Tower	16	2 400	38 400	1 536
MB DT	Stub	70	240	33 600	1 344
MB RPC	Cluster	15	3 200	48 000	1 902
ME CSC	Stub	32	1 080	34 560	1 382
ME RPC	Cluster	15	2 304	34 560	1 382
ME iRPC	Cluster	41	288	11 808	472
ME GEM	Cluster	14	2 304	32 256	1 290
ME0 GEM	Stub	24	288	6 912	276
Total	-	-	-	-	53 980

EC cluster

Quantity	N bits	Comment
E_T	2×16	with and without PU subtraction
Endcap	1	
f_{EE}	13	E_T fraction in EE
f_{BH}	12	E_T fraction in BH
L_{max}	6	Max energy layer
η	11	Shower start
ϕ	11	Shower start
z	10	Shower start
N_{cells}	8	
Quality	12	
Extra flags	12	
Minimum total	128	

EC cluster

Quantity	N bits	Comment
E_T	2×16	with and without PU subtraction
Endcap	1	
f_{EE}	13	E_T fraction in EE
f_{BH}	12	E_T fraction in BH
L_{max}	6	Max energy layer
η	11	Shower start
ϕ	11	Shower start
z	10	Shower start
N_{cells}	8	8b polar angle
Quality	12	8b azimuthal angle
Extra flags	12	
Minimum total	128	

EC cluster

Quantity	N bits	Comment
E_T	2×16	with and without PU subtraction
Endcap	1	
f_{EE}	13	E_T fraction in EE
f_{BH}	12	E_T fraction in BH
L_{max}	6	Max energy layer
η	11	Shower start
ϕ	11	Shower start
z	10	Shower start
N_{cells}	8	8b polar angle
Quality	12	8b azimuthal angle 4b η width
Extra flags	12	4b ϕ width
Minimum total	128	

EC cluster

Quantity	N bits	Comment
E_T	2×16	with and without PU subtraction
Endcap	1	
f_{EE}	13	E_T fraction in EE
f_{BH}	12	E_T fraction in BH
L_{max}	6	Max energy layer
η	11	Shower start
ϕ	11	Shower start
z	10	Shower start
N_{cells}	8	kAngle ? 16b : 0 kWidth ? 8b : 0
Quality	12	
Extra flags	12	
Minimum total	128	

Conclusion

- Direct triggering on LLPs rather than relying on other features of final state would allow us to access some possibilities which are otherwise rather well hidden.
- Cluster start and max layer are already quite useful.
- Some additional cluster information may help at a relatively low overhead:
    - Angle w.r.t. nominal?
    - Shower width variable?
    - Trigger logic for such objects has to be explored and simulated.
- Have to evaluate if extra complexity and expense is worth the effort.
    - Help from community to articulate expanded physics reach from direct triggering per object.