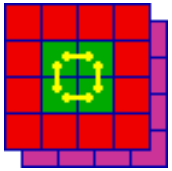
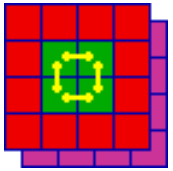
L1Topo requirements for Phase-1



- Long established task-force to outline Topological Trigger module requirements in Run-3

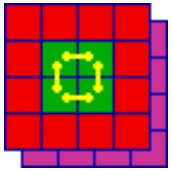
- There has been another long hiatus
- But the end is (possibly) in sight
  - Many thanks to Ian and Robin for kicking me out of my previous lethargy
- Summary
  - All information now gathered (almost)
  - Draft document complete (almost)

Outline of document



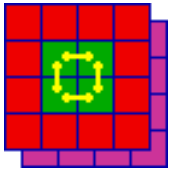
- Topo input numerology
  - All the FEXes
  - Also MUCTPI
- Trigger requirements
  - Topological Triggers
  - Non-topological triggers (thresholds, multiplicities)
- Strawman Topo Connectivity
  - How does it fit into current design?
  - How does it fit into upgraded design?
  - How do we deal with commissioning period?
    - Red as currently missing!

Outline of Talk



- Will only cover the newer material
  - Original details are provided in the backup slides
- Previously covered:
  - FEX output content
  - Analysis of simple multiplicity trigger requirements
- Covered today:
  - Analysis of current topological trigger usage
  - Assignment of topological triggers to Topo modules

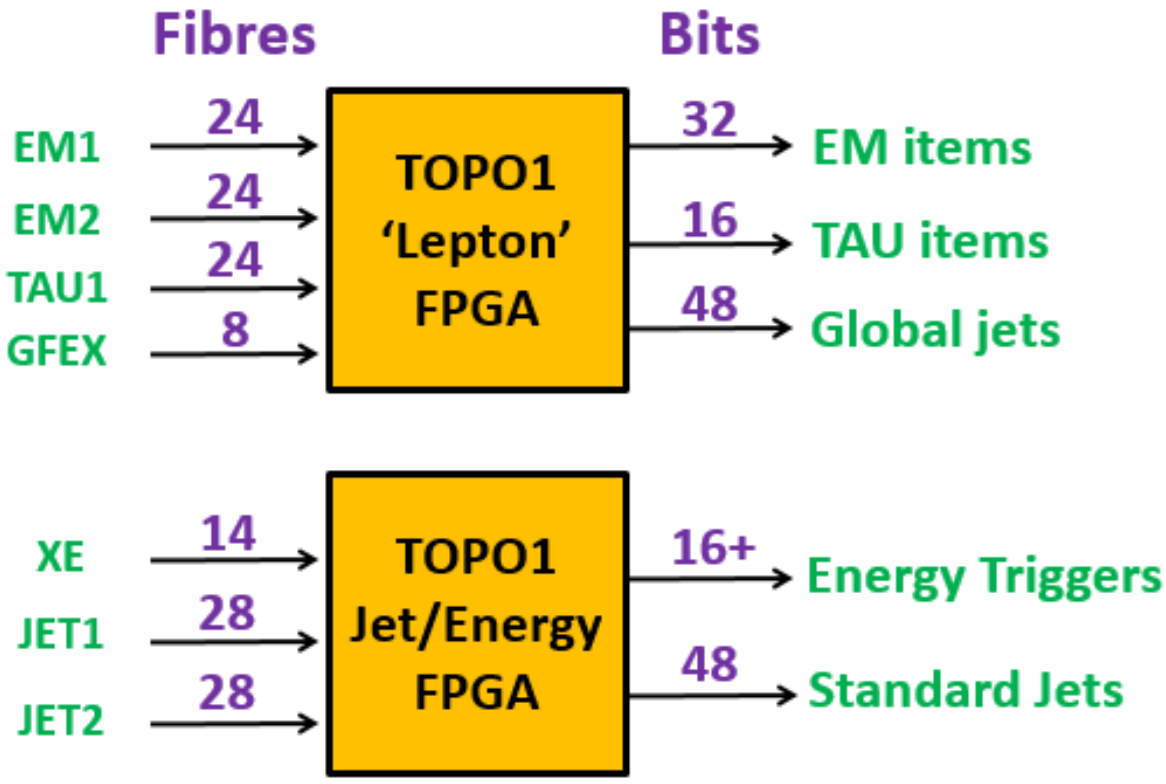
‘Typical’ Topological Menu



TOB types	Approximate number of Algorithms	Physics Case	Location
MU only	40	B Physics and S.M. J/psi	MUCTPI
EM only	8	J/psi electron	TOPO 2
Jet only	15*	SUSY, Exotics (MJJ)	TOPO 2
MU + XE	4*	Exotics (Late)	TOPO 2
MU + EM	5	Exotics (LFV)	TOPO 2
MU + Jet	7*	B-tag	TOPO 2
Jet + XE	25*	Higgs, SUSY (KF)	TOPO 2
MU + Jet + Tau	3*	Higgs (Disambiguation)	TOPO 3
EM + Jet + Tau	3*	Higgs (Disambiguation)	TOPO 3
XE + Jet + Tau	6*	Higgs (Disambiguation)	TOPO 3
XE + Jet + EM	15*	J/psi electron (tag/probe)	TOPO 3
EM + Tau	8	Exotics (LLP)	TOPO 3
	* plus more using gFex		

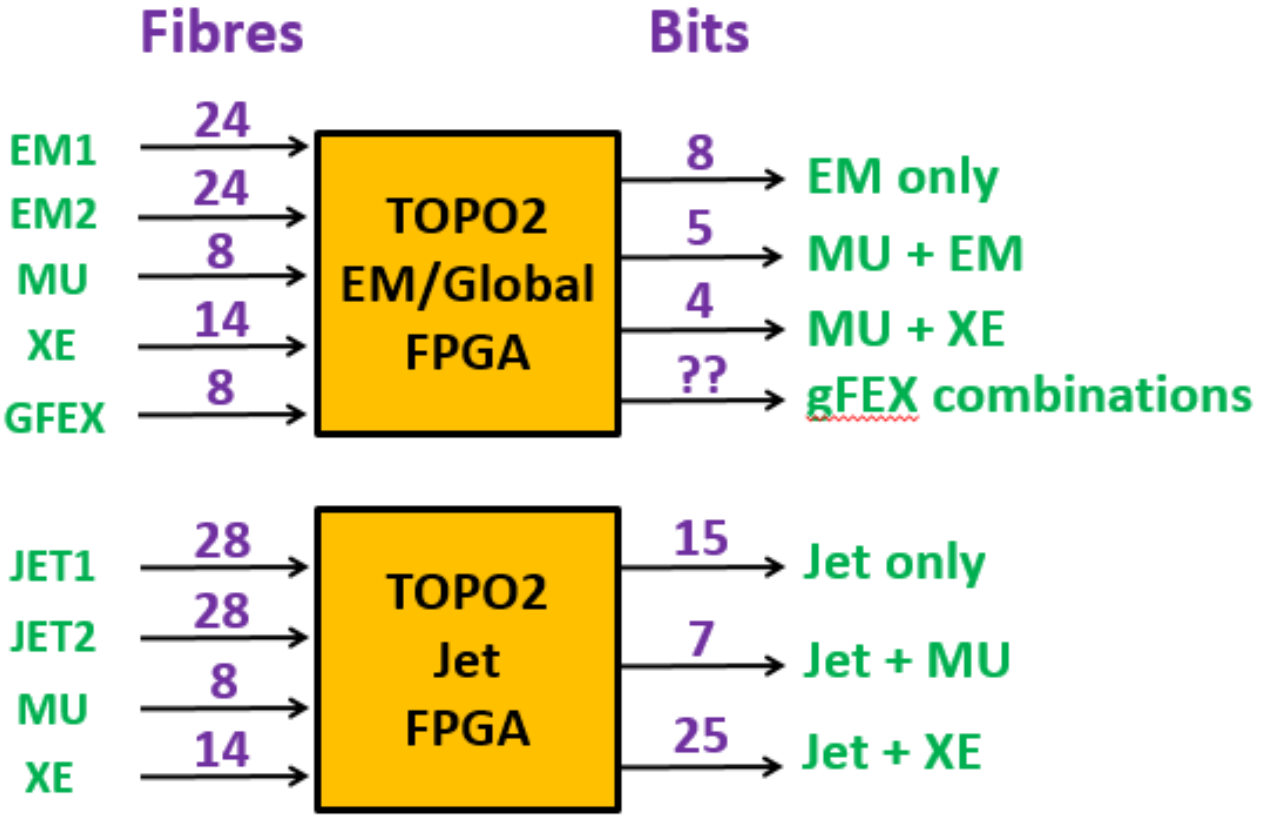
‘Simple’ TOPO1 Module

- Pure multiplicities
  - Replaces CMX
- Includes new gFEX outputs
- Simple, fast, parallel algorithms
- (No Muon inputs or outputs)
- Fits into current Topo design
  - In terms of i/o



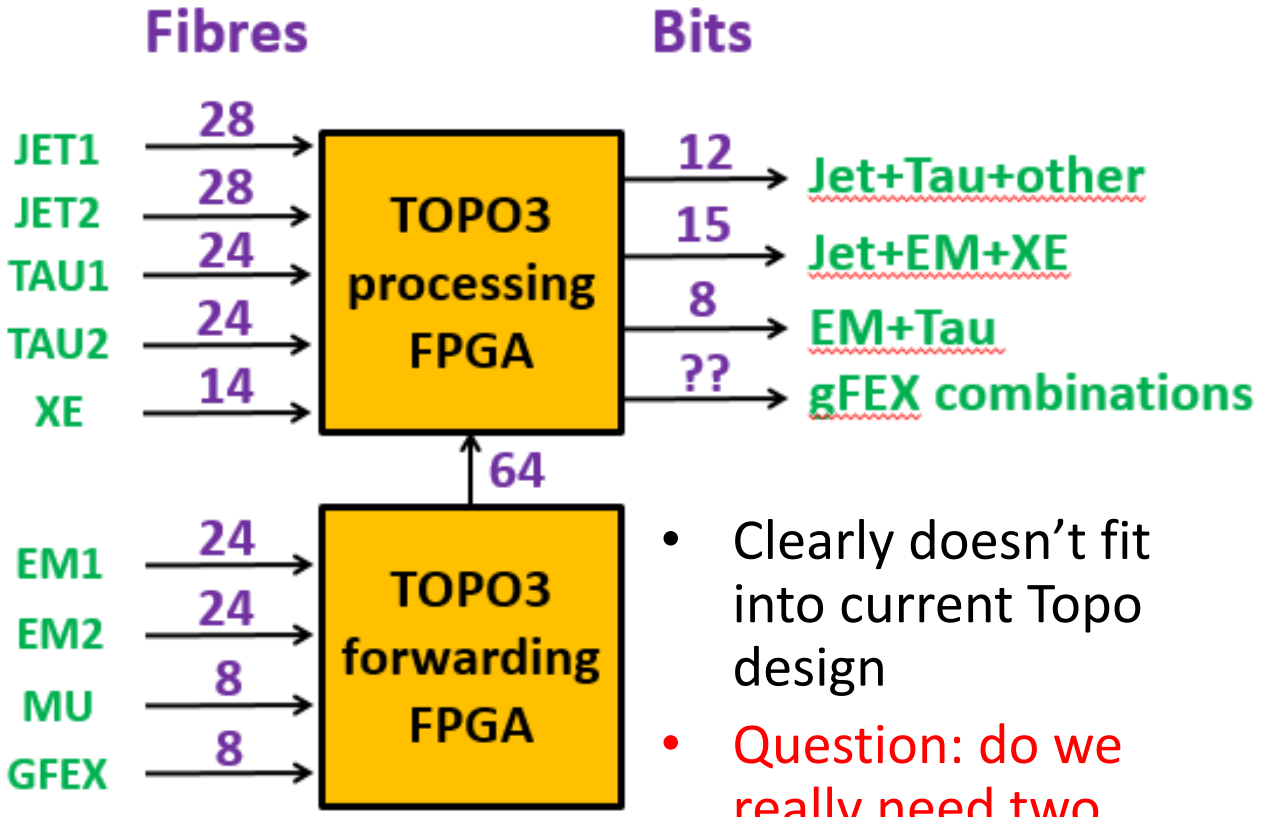
TOPO2 Module: small topological combinations

- Mostly single and double TOB type triggers
- Allows gFEX equivalent of JET triggers
- No Inter-FPGA communication
- Fits into current Topo design
  - In terms of i/o



TOPO3 Module: Multi-TOB combinations

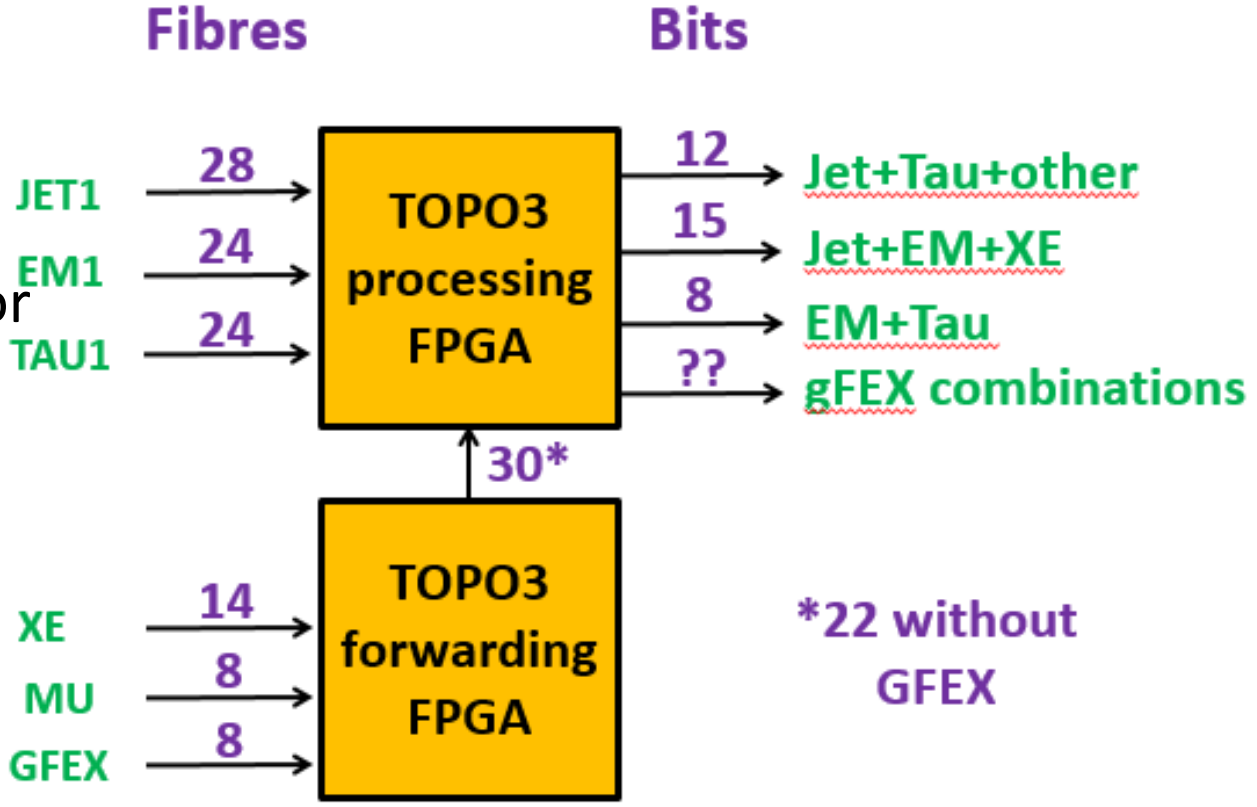
- ALL TOB types combined in one place!
- Huge input requirement for one FPGA
- Better separation possible but…
- A Jet+Tau+EM algorithm alone requires 152 links



- Clearly doesn't fit into current Topo design
- Question: do we really need two fibres for Jet/EM/Tau TOBs

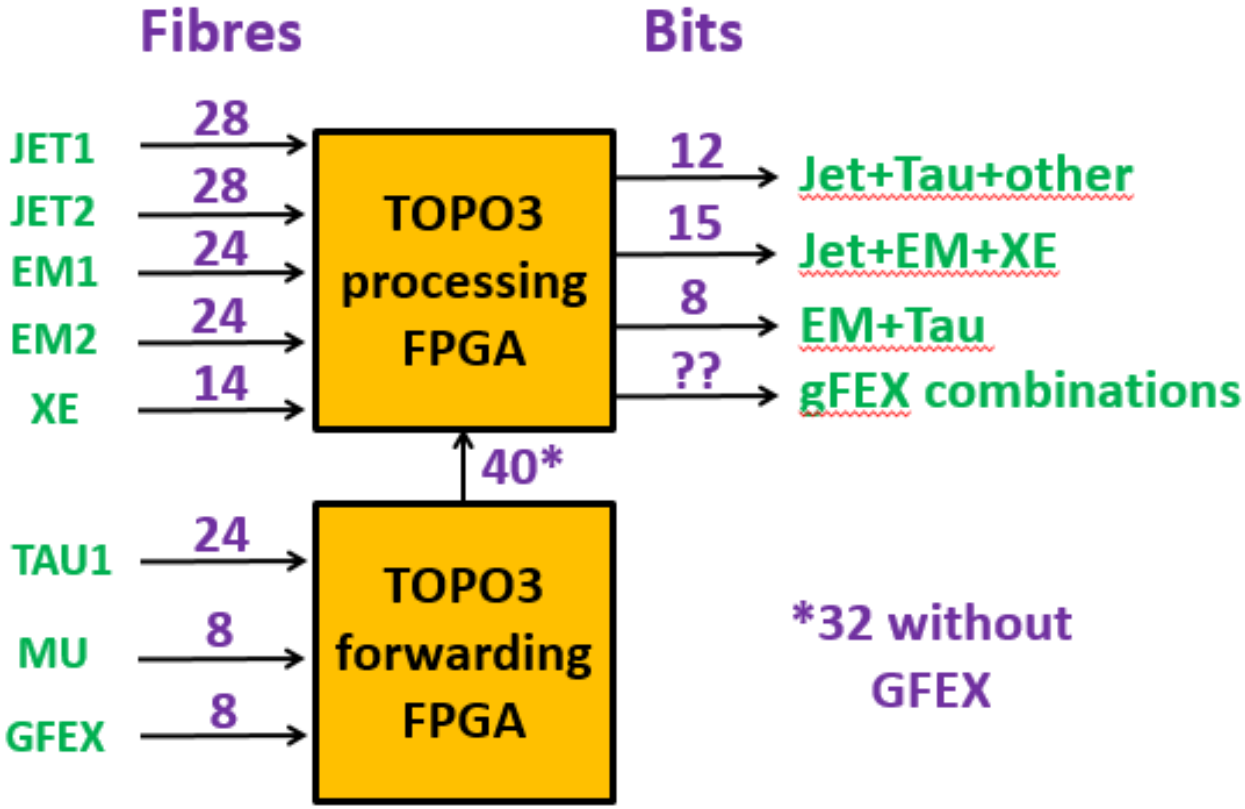
TOPO3 in current design

- If we can get away with 6/7 TOBs per EM, TAU, JET…
- Still a difficult ask for current Topo
- Also requires data forwarding, many algorithms will be slow
  - Latency problems?

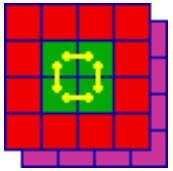


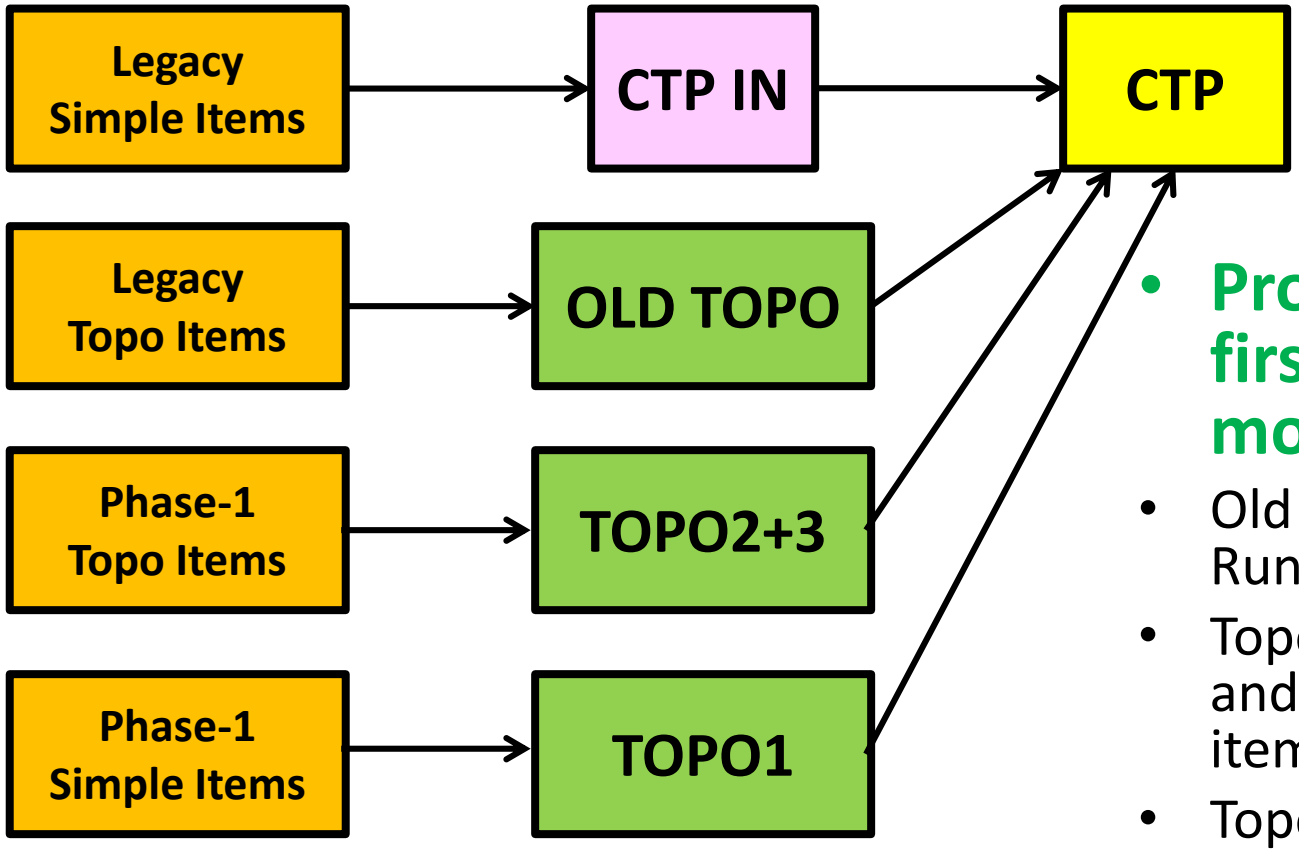
TOPO3 in upgraded design

- TAU fibre is (probably) least sensitive to overflows
- But Tau Higgs trigger is one of the big users of Topo, so be careful
- Need to study algorithms and compromises
  - Most of these triggers using truncated lists anyway?



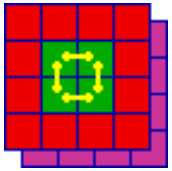
Commissioning at Phase-1





- **Proposal for first week, month (year?):**
- Old topo(s), maintain Run-2 Topo items
- Topo 2+3, develop and test Run-3 Topo items
- Topo 3, develop and test simple Run-3 items

First n days of Run-3

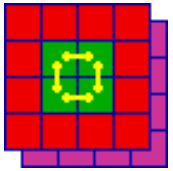


- New MUCTPI will be in place
  - Timing in possible during LS2 (probably)
  - Muon multiplicities + topo algorithms available on day 1 via new route
  - Old style Muon to TOPO connectivity gone
    - Muon + other TOB triggers not possible in legacy Topo

- FEXes and new Topo will be in place (hopefully!)
  - But my feeling is much calibration still required with beam
    - Individual super-cell timing calibration is basic minimum
    - Will need to verify that NO super-cells are triggering early
  - Beyond timing, many other 'calibrations' are necessary
    - Filters, energy, pedestal correction, threshold/isolation tuning
  - Until all these are studied with data, new system is unlikely to out-perform legacy trigger

How long will this take?

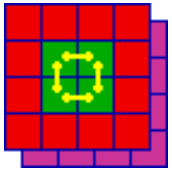
Conclusions



- Draft document nearing completion
  - Current version attached to agenda
- Next stage, feedback from task-force
  - Via email and a meeting soon…

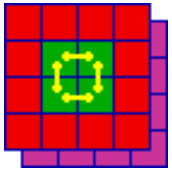
- General conclusions on Topo requirements
  - Current Topo design could be stretched to accommodate Phase-1 inputs
    - But with inevitable compromises in some algorithms
  - An upgraded design with more inputs resolves many of these issues
    - Maybe with some smaller compromises, should be studied
    - But latency is likely to be critical for some algorithms with either design

Backup



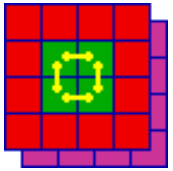
- Talk from previous L1Calo Joint Meeting

L1Topo for Phase-1
Taskforce Latest News



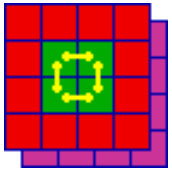
- Updated version of talk given in TDAQ week:
  - https://indico.cern.ch/event/538558/contributions/2287652/attachments/1345521/2028470/topo160929.pdf
- Warning, much of that talk wrong
  - All errors/misunderstandings are/were mine
- Taskforce has met three times so far
  - Still have work to do

Reminder: Topo Requirements Task Force - who not to blame



- Physics and Trigger Requirements
  - Brian Petersen, Martin Zur-Nedden
- Topo and Central Interfaces
  - Katharina Bierwagen, Thilo Pauly, Uli Shaeffer
- FEX Interfaces
  - Michael Begel, Weiming Qian, Elena Rocco
- Phase-2 and interested parties
  - David Sankey, Robin Middleton, Murrough Landon

Next steps (from 2nd meeting with notes)



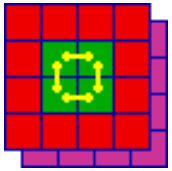
- I will set up twiki — Not done
- Also will try to have a first shot at defining i/o for a 'counting' Topo module
  - Maybe some, but not all simple thresholds can be done here
  - Starts to define grouping of information on FEX outputs

  First attempt will be presented today
- Would still like more input on Topo/CTP i/o

  I'm still a bit hazy here – next meeting
- Next meeting when I've made some progress!

  Held, now I have more to do…

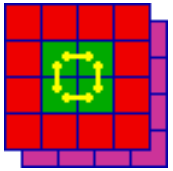
(Most of) rest of today's talk



- Concentrate on Run-3 commissioning phase
  - In many ways the most demanding period before Phase 2
- Are the current module specifications and numerology sufficient?
  - particularly 3 Topo Processors
- What's the best way to organise the Topo Modules and inputs
  - For convenience
  - For commissioning purposes
  - Do they fully address trigger needs?

- Light on details of output, but hopefully good first guess at inputs to Topo

Commissioning at Phase-1

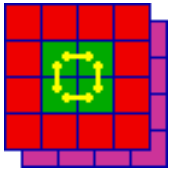


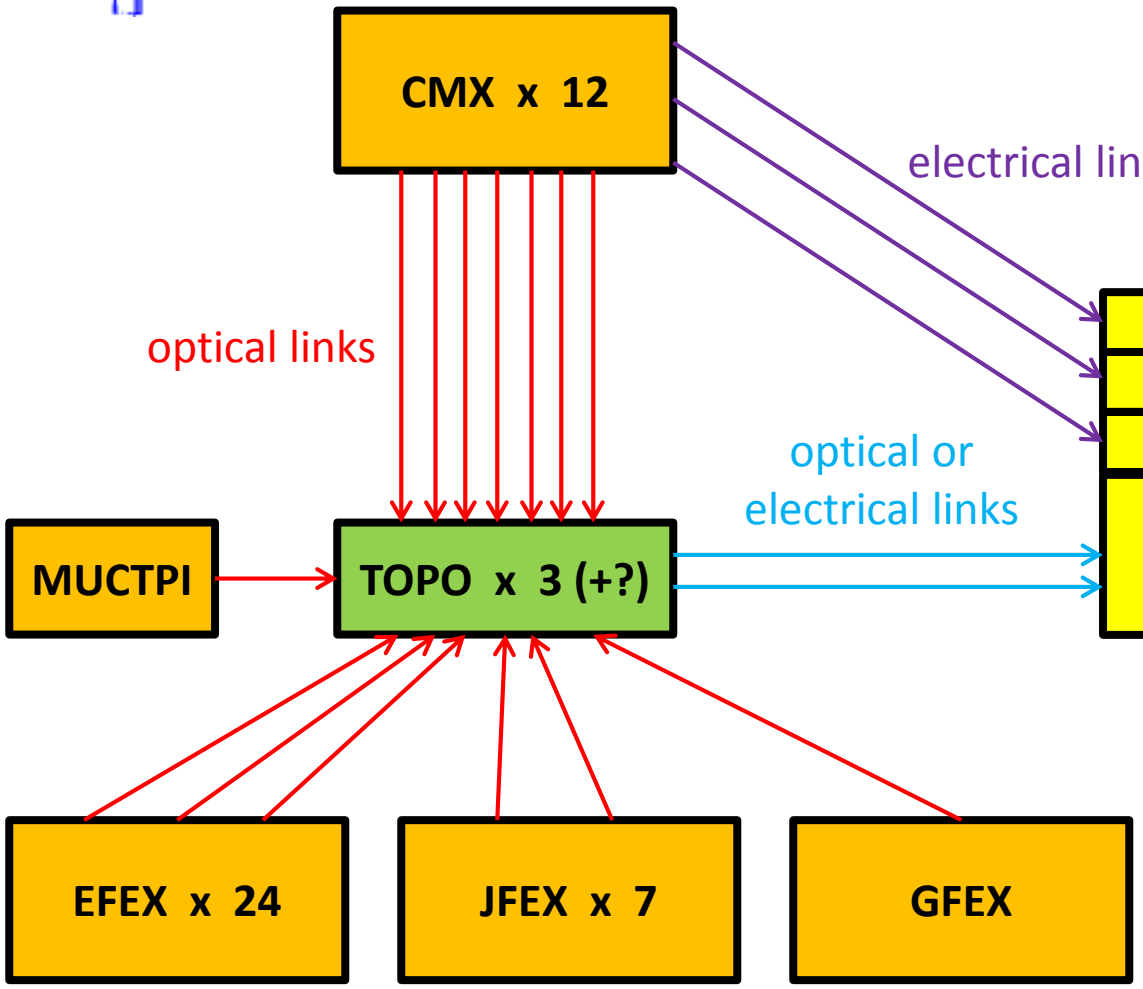
- Is it feasible to start Run-3 with minimal legacy trigger items?
  - If so, for how long?

Or, more ambitiously, run all relevant Run-2 Triggers, while also adding new ones

- How do we commission new Topo algorithms?
  - Note that includes the trivial ones!
  - This has proved a difficult issue in Run-2
    - And we'll be commissioning eFEXs, jFEXs, gFEX in parallel
- How do we use (possibly) limited CTP inputs to do all of these things simultaneously?
  - Do we need a more flexible Level-1 menu?

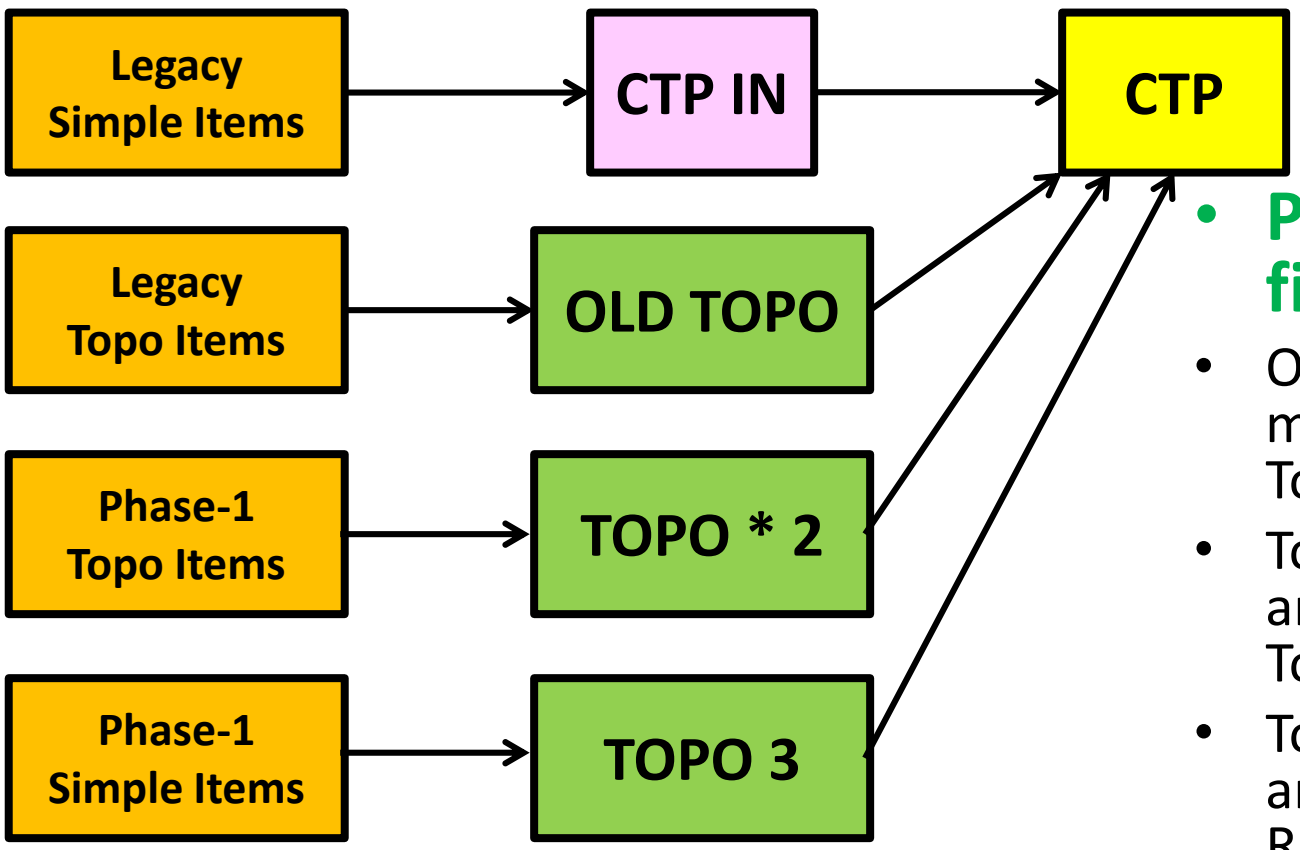
Phase-1 Commisioning





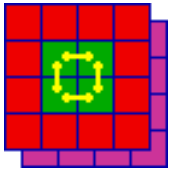
Actually legacy Topos will run in parallel with three new Topos

The big picture



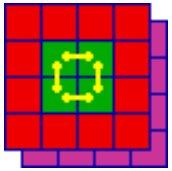
- **Proposal for first year:**
- Old topos, maintain Run-2 Topo items
- Topo 1+2, develop and test Run-3 Topo items
- Topo 3, develop and test simple Run-3 items

Assumptions



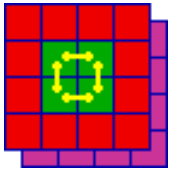
- Phase-1 Legacy menu is broadly similar to current menu
  - Not too unreasonable, if LHC luminosity is really restricted to 1.7×10^{34} for the next few years
  - Details will of course change, and there will be fine tuning
  - But in some ways things get simpler if luminosity has no big ramp-ups within one year
- Legacy Topo may need streamlining
  - Perhaps more controversial
  - Probably needed to reduce number of Level-1 items, Topo outputs
  - My feeling is that once Topo usage becomes more standard, will focus in on 'golden' algorithms
    - Rather than having a range, to test out different options
  - You can see this sort of development in the stabilisation on 'preferred' non-Topo thresholds

Consequences



- We don’t have to think too much about TOPO1 in the first year
  - Just consolidate key Topo algorithms into one (?) ‘traditional’ Topo processor
- TOPO 1+2 can be used to mirror old Topo items, but with FEX inputs
  - The devil is in the details here…
  - …but not for this talk
- TOPO3 should implement the Phase-1 equivalent of the legacy simple thresholds
  - With similar range and multiplicities to the current menu
  - Plus some extra ones due to new capabilities (eg gFEX)
  - Will concentrate on this for rest of talk
  - To do this we have to first understand the current menu

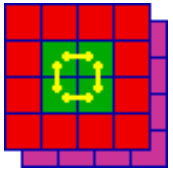
EM threshold usage



Threshold	Bits Available	Multiplicities Used	Bits Needed
EM3	3	1,2	2
EM7	3	1,2,3	2
EM8VH	3	1,2,3	2
EM8I	3	1	1
EM10VH	3	1,2	2
EM12	3	1	1
EM13VH	3	1,2	2
EM15	3	1,2	2
EM15VH	3	1,2	2
EM15I	3	1	1
EM15IH	3	1	1
EM18VH	3	1	1
EM20VH	3	1	1
EM20VHI	3	1	1
EM22VHI	3	1	1
EM24VHI	3	1	1

- Electron/gamma CMX provides 48 bits
  - 16 x 3
- Multiplicities 4-7 are **never** used
- Only 24 bits of the output are really used
- Some thresholds are just alternatives for different luminosities
  - Would not really be needed if the menu could be changed more flexibly during year

Tau threshold usage

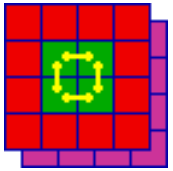


Threshold	Bits Available	Multiplicities Used	Bits Needed
TAU8	3	1	1
TAU12	3	1,2	2
TAU12IM	3	1,2	2
TAU15	3	1,2	2
TAU20	3	1	1
TAU20IM	3	1,2	2
TAU30	3	1	1
TAU40	3	1	1
TAU50	3	1	1
TAU10IM	3		0
TAU12IL	3		0
TAU12IT	3		0
TAU20IL	3		0
TAU20IT	3		0
TAU25	3		0
TAU25IT	3		0

NOT USED

- Tau CMX provides 48 bits just like EM
- Multiplicities 3-7 are **never** used
- Only ~15 bits of the output are really used
- The ‘IL’, ‘IT’ are useful labour saving devices for comparing isolation options
  - But can easily be done via emulation offline
- TAU8 is just for Background
- Other low thresholds soon to be superseded by Topo algorithms

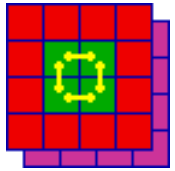
Jet threshold usage



Threshold	Bits Available	Multiplicities Used	Bits Needed
J12	3	1,2,3	2
J15	3	1,2,3,4,5,6	3
J15.0ETA25	3	3,4,5	3
J20	3	1,2,3,4	3
J25	3	1,2,3	2
J25.0ETA23	3	3	2
J30	3	1	1
J40	3	1,3	2
J20.0ETA49	3	1,2,3,4	3
J30.0ETA49	3	1	1
JJ15.23ETA49	2		0
J40.0ETA25	2	1	1
J20.28ETA31	2	1	1
J50	2	1,2,3	2
J75	2	1	1
J85	2	1	1
J100	2	1	1
J120	2	1	1
J400	2	1	1
J15.31ETA49	2	1,2	2
J20.31ETA49	2	1	1
J30.31ETA49	2	1	1
J50.31ETA49	2	1	1
J75.31ETA49	2	1	1
J100.31ETA49	2	1	1

- Jet CMX provides 60 bits:
  - 15 x 2 plus 10 x 3
- More extensive usage of most thresholds, multiplicities
- Still only ~40 bits of the output are really used
- 2-3 thresholds either not used, or for very specialised usage
  - Probably more naturally performed in a Topo algorithm

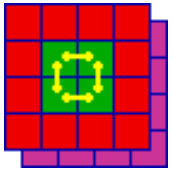
Muon threshold usage



Threshold	Bits Available	Multiplicities Used	Bits Needed
MU4	3	1,2,3	2
MU6	3	1,2,3	2
MU10	3	1,2	2
MU11	3	1	1
MU15	3	1	1
MU20	3	1,2	2

- MUCTPI provides 18 bits:
  - 6 x 3
- Also no usage of high multiplicity bit
- Only 10 bits of the output are currently used

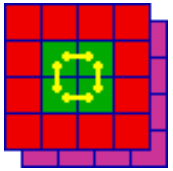
Energy Thresholds and Heavy Ions



- Total Energy:
  - 16 thresholds available
  - Rarely used in proton-proton
  - Probably too few for Heavy Ions
- Missing Energy:
  - 16 thresholds available
  - Only 8 are used in current menu
    - And half of them are back-up/fall-back thresholds
    - No real need for back-up if menu were more flexible
- Missing Energy Significance:
  - 8 thresholds available
  - Only 2 used in anger
  - Surely the natural territory of Topo and (eventually) gFEX

- Note that the needs of Heavy Ions and proton running are quite different
  - But we only ever have to support one at a time (hopefully)
  - Prefer not to clutter up menu/Topo usage with both sets at the same time

Summary of Lessons from current non-Topo items



- The menu doesn't come near to occupying all the bits we currently provide
  - Though it may very well be occupying all the CTP inputs!
- Allowing some breathing space for the Run-3 TOPO 3 outputs, could look something like:

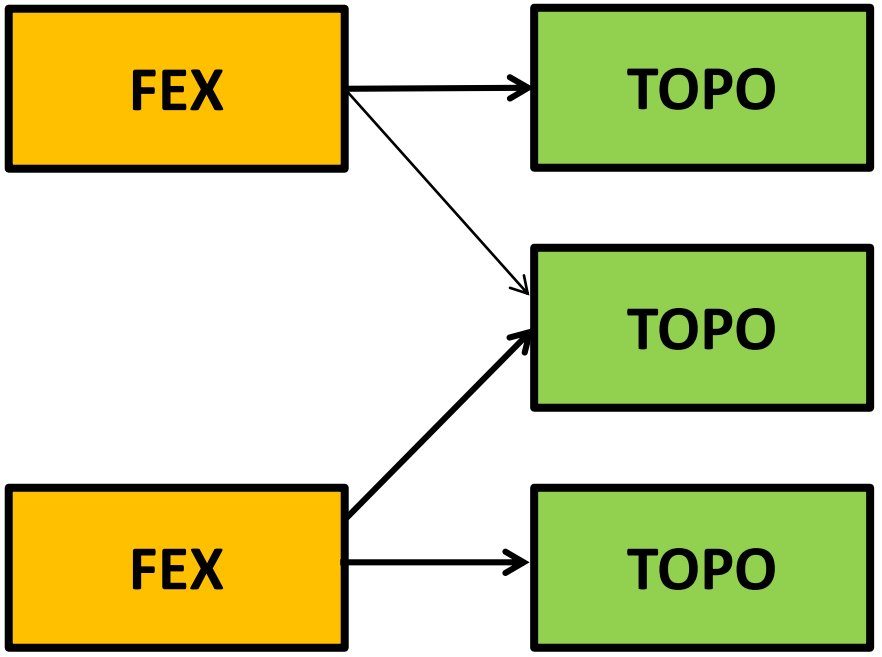
	Threshold bits in current menu	Requirement for Run3
EM	24	32
Tau	13	16
MU	10	16
XE/TE	8/8*	16
Jets	40	48
gFEX	0	48**

* Approx, need to boost for Heavy Ions?
** Includes gFEX jets, and global items, might be too small

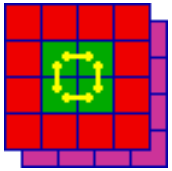
- What about the inputs?

Overall strategy

- Each type of FEX provides several copies of the same set of data (TOBs etc)
- These copies can be sent to a individual Topo/FPGAs
  - But not necessarily **ALL** outputs to **EVERY** Topo/FPGA
  - Only those that need it for the algorithms they perform
- Ideally can group algorithms into logical sets requiring subset of TOBs
  - To avoid extra latency in FPGA-FPGA link
- Easy for simple thresholding algorithms in TOPO3
  - May be impossible to avoid in some more complex cases

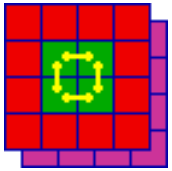


eFEX outputs



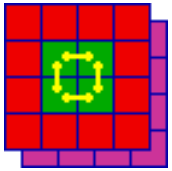
- 24 modules, 2 x 16 fibre outputs
  - Various options for partitioning of outputs possible
  - My current preferred option:
    - 1 x high priority/threshold EM TOBs
    - 1 x low+high priority/threshold EM TOBs
    - 1 x high priority/threshold TAU TOBs
    - 1 x low+high priority/threshold TAU TOBs
- Each link contains up to 7 objects
  - eFEX coverage about 2x current CPM
    - CPM saturates at 5 TOBs (only occasionally an issue for EM3)
    - eFEX saturation at 7+7 TOBs should be easily sufficient
      - For Phase-1 anyway, may need re-think for Phase-2
- With 4 different link outputs, 8 copies are possible
  - More than enough to feed 2 FPGAs in 4 Topos

jFEX outputs



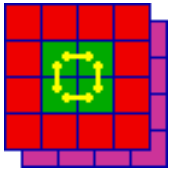
- 7 modules, 4 x 12 Fibre outputs
  - 2 x 12 from Jet/Energy FPGAs (Missing Energy etc)
  - 2 x 12 from pure Jet FPGAs, separate regions
  - Suggest 1 link for Energy TOBs, 2 per jet TOBs
    - 1st Jet link, all TOBs up to a limit
    - 2nd Jet link, overflows, if any
- Each Jet link contains up to 6 TOBs (??)
  - jFEX FPGA region is <2 x current JEM coverage
    - JEM saturates at 4 TOBs (currently rare except in HI)
    - Saturation at 6+6 should be sufficient in most regions
      - Probably also for Forward region
- With 3 different link outputs per FPGA, only 4 full copies
  - Enough to feed 2 FPGAs in 2 Topos
  - Could sacrifice some overflow links for extra energy/priority jet links

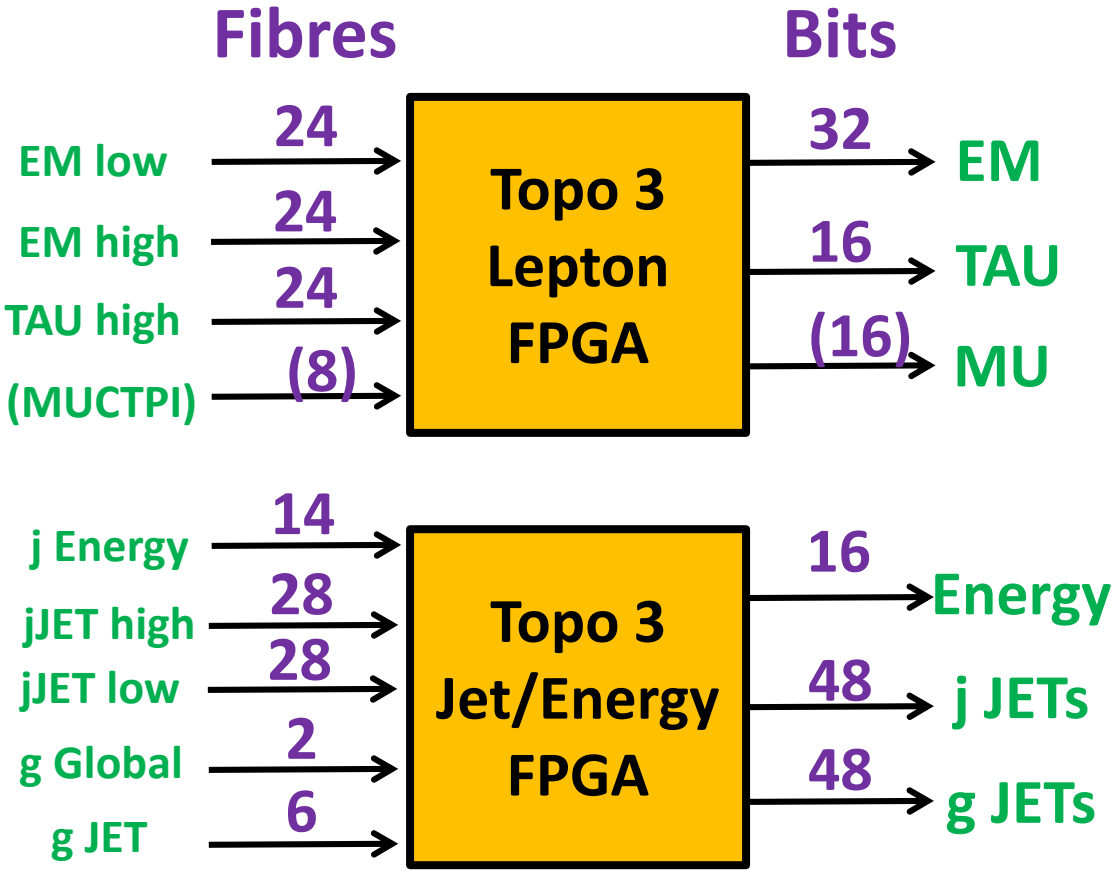
gFEX outputs



- 1 module, 4 x 12 Fibre outputs
  - Similar to jFEX, 1 x 12 for global quantities and 3 x12 for jets, of various types
  - Not so easy to describe, as many different jet and global algorithms in parallel
  - However, Michael seemed happy with 8 Fibres to each Topo FPGA
    - 2 from global, 2x3 from local
- Less easy to predict link occupancy
  - No current system to make an educated guess
  - Many different objects
  - But hopefully 8 links is generous enough
- With 2 different link outputs per FPGA, 6 copies are possible
  - Easily sufficient for 3 Topos

TOPO 3 Connectivity (aka Simple Topo)



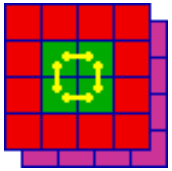


	Threshold bits in current menu	Requirement for Run3
EM	24	32
Tau	13	16
MU	10	16
XE/TE	8/8*	16
Jets	40	48
gFEX	0	48**

* Approx, need to boost for Heavy Ions?
** Includes gFEX jets, and global items,

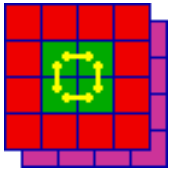
- Need to work out CTP connectivity
  - electrical and/or
  - optical
- Low latency not such an issue here (probably)
- Note, no TAU low threshold/priority inputs
  - Only needed by Topo algorithms

Comments on Simple Topo



- Looks feasible in terms of inputs
  - But already clear input fibre count is tight per FPGA
  - Already at ~80 inputs just for jet inputs
  - This looks tighter to me now I've understood the jFEX outputs more fully
- Note that already reduced maximum required FEX output copies from 6 to 5
  - Further reduction possible:
    - eg don't need high priority EM/TAU elsewhere (?)

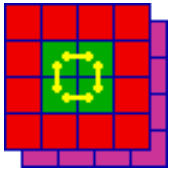
Topo Topos Connectivity



- Next stage of the process
  - Need to understand what inputs needed by each Topo algorithm
  - Partition similar algorithms into FPGAs
  - Use input link numerology suggested by TOPO 3, see if it is suitable for Topo Topos

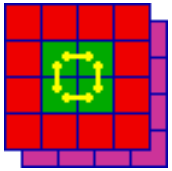
- Some algorithms require many inputs
  - But there mayb be restrictions too in terms of unnecessary combination
    - Are high priority/threshold EM objects need at all?
    - But jets on their own already take up a large number of links
  - Do any algorithms overflow the 80 link input per FPGA?
    - I'm hoping not many
    - In these cases FPGA-FPGA link is required, plus extra latency
    - Or some other alternative…

A new Topo revision



- Already decided to increase Topo output bandwidth
  - For Phase-2 compatibility
- Could also augment Topo capacity
  - Move to Ultrascale FPGA
  - 120 fibre inputs
  - More processing resources
    - Current Topo is already very stretched
- Obviously a ‘bigger’ Topo is going to be easier to handle
  - Less concern about input intricacies
  - Probably removes need for FPGA-FPGA added latency
- But is it necessary?
  - Difficult to be sure, we need to study further

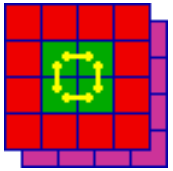
A brief slide on Phase-2



- The Task Force is meant to have at least one eye on Phase-2
  - Future re-usability, of Topo, if possible

- My Opinion
  - Topo (Level-0/1 or whatever) is NOT so important to architectural decisions
  - Compared to the rest of ATLAS, it's not a cost driver
    - Complex and costly, yes, but small in number
    - Compared to replacing millions of channels of readout, etc
  - If you need a new module with a few more links and a bigger FPGA, it's probably not such a big issue in terms of hardware design
    - Once the initial design is well validated
  - The real difficulty in Topo is not the hardware, it's the firmware
    - This is probably true independently of the exact number of i/o links etc
  - Replacement strategy for ATLAS lifetime
    - OPAL had working lifetime of 10 years, also one complete CTP replacement after ~5 years
    - We have no experience (yet) of the working lifetime of these complex modules
    - Replacing FEXes/Topo/CTP and similar every few years may be a worthwhile exercise anyway

A brief slide on Phase-2



- The Task Force is meant to have at least one eye on Phase-2
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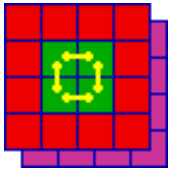
Recent News, Phase-2 Decision:

Phase-2 Topo architecture likely to be new/different

No need to think too hard about forward compatibility

Conclusions



- Proposal for Simple Topo connectivity made
  - Had one iteration with the task force, leading to some updates
  - Need to understand connectivity to CTP
  - If reasonable can move onto Topo algorithm connectivity
  - Starting to look at current and potential future Topo algorithms

- Run 3 setup seems feasible with current module specifications
  - But recent understanding of jFEX outputs makes it look tighter than I'd originally thought
  - One potential big pitfall: latency
  - it might all be a lot easier with new modules containing more links
    - Would probably lead to simpler cabling, and less need to distinguish dedicated Topo modules
      - SIMPLE IS GOOD
    - Maybe some need for fibre spaghetti remains