L0 Bandwidth Division for the TDR - Update

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I. L0 optimization: set-up and method

- Set-up and method
- Combination of channels -> overall trigger optimization

II. L0 optimization without tagging information

- Optimal performance for individual signal channels
- Optimal trigger performance and bandwidth division

III. L0 optimization with tagging information

- "Usage" of tagging information
- Checks on tagging performance
- Some remarks

IV. Conclusions and outline

L0 Optimization – Set-up and Method (I)

- **Set-up:**
  - ✓ use all interactions (single and multiple interaction events)
  - ✓ new: use only half of the available samples sizes
    -> ability to cross-check results on an independent sample
  - ✓ new: now also using SPD & Pile-up veto multiplicity cuts (set to values obtained by Massi)
  - ✓ new: tagging information available for inclusion in the optimization

- **Method:**
  - ➢ Optimization done with MINUIT - vary L0 thresholds and veto height of second peak
    -> systematic scanning of the whole parameter space (E_T thresholds, veto cut)
  - ➢ Maximize:
    - a) L0 efficiency <-> no tagging information considered
    - b) L0 trigger power <-> tagging information considered
      (definition detailed later)

L0 Optimization – Set-up and Method (II)

- **Some technical details:**
  - ✓ L0 thresholds are varied in a discrete way
    - -> less dependence on statistics and fake optimal settings
  - ✓ for each set of thresholds there is a corresponding minimum bias retention rate
    - -> constraint implemented in MINUIT
    - -> L0 M. B. retention = 1MHz

L0 optimization – Combination of Channels

- Present scenario: some channels representative of each type of measurement
  - ➔ each of the 5 groups is optimized separately
  - ➔ optimization such that each group has the same loss in performance
    = equal LHCb performance on each type of measurement

Quantity measured	Channel(s)	# events	# off. sel. events	# off. sel. events for optimization
α	$B_d \to \pi\pi$	49 k	3374	1690
β	$B_d \to J/\Psi(\mu\mu/ee)\ K_s$	99 k	1531	773
γ	$B_s \to D_s\ K$ $B_s \to D_s\ \pi$	337.5 k	7369	3705
$2\delta\gamma$	$B_s \to J/\Psi\ (\mu\mu)\ \Phi$	50 k	3863	1951
Rare decays	$B_d \to K^*\ \gamma$	48 k	817	410

(Using half the sample (odd-numbered events) for the optimization)

L0 optimization without Tagging Information (I)

1. <u>Optimizing each channel separately on the L0 efficiency</u> …

   ignoring the tagging information …

Max. eff. obtained with separate optimization of each channel

(eff. calculated on independent sample)

Channels	"Default" (@ last LHCC presentation) L0 eff. (%)	Optimized L0 eff. (%)
$B_d \to \pi\pi$	56.6 +/- 1.2	63.1 +/- 1.2
$B_d \to J/\Psi(\mu\mu/ee)\ K_s$	77.3 +/- 1.5	81.4 +/- 1.4
$B_s \to D_s\ K$ $B_s \to D_s\ \pi$	46.1 +/- 0.8	50.6 +/- 0.8
$B_s \to J/\Psi(\mu\mu)\ \Phi$	82.4 +/- 0.9	85.3 +/- 0.8
$B_d \to K^*\ \gamma$	72.0 +/- 2.2	91.2 +/- 1.4

(L0 thresholds as in 1/2003 <u>but SPD and veto multiplicity cuts added</u>!)

L0 optimization without Tagging Information (II)

2. Optimizing the trigger on the L0 efficiency …

for a minimal total loss in efficiency …

Channels	Max L0 eff. (%)	"Optimal trigger" L0 eff. (%)	Loss in L0 eff. (%)
$B_d \to \pi\pi$	63.1 +/- 1.2	58.3 +/- 1.2	7.6
$B_d \to J/\Psi(\mu\mu/ee)\ K_s$	81.4 +/- 1.4	79.7 +/- 1.5	2.1
$B_s \to D_s\ K$ $B_s \to D_s\ \pi$	50.6 +/- 0.8	47.2 +/- 0.8	6.7
$B_s \to J/\Psi(\mu\mu)\ \Phi$	85.3 +/- 0.8	84.9 +/- 0.8	0.5
$B_d \to K^*\ \gamma$	91.2 +/- 1.4	84.9 +/- 1.8	6.9

```
=======================
Optimized L0 cuts (GeV)
=======================
 Hadron        =  4.20
 Muon          =  0.60
 Electron      =  3.00
 Photon        =  4.20
 Di-muon       =  9.40
 Pi0 Local     =  4.20
 Pi0 Global    =  3.20
 Sum Et        =  5.00
 VetoSumPeak2  =  inf.
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```
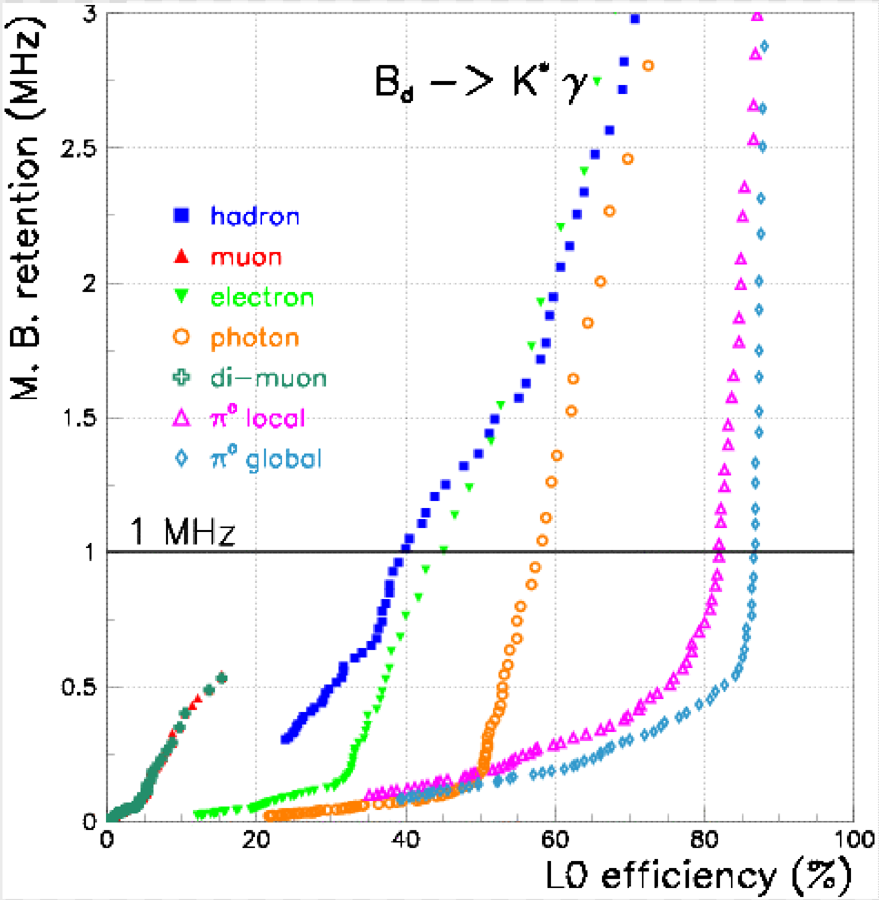

… trigger optimization on the L0 efficiency for a same loss in each group

gives losses in efficiency ~ 11% -> total loss > total loss in above scenario …

L0 optimization – case of B_d->K*γ

Max. efficiency obtainable inclusively by each trigger!



✓ each curve corresponds to considering separately the combination
L0 trigger = sub-trigger + NO pile-up veto
(because max. obtained with no veto)
-> it shows how much one could in principle obtain independently from each trigger

➨ **After optimization ...**
(on this single channel!)

justification

```
======================
Optimized L0 cuts (GeV)
======================
 Hadron        =  5.40
 Muon          =  4.20
 Electron      =  3.60
 Photon        =  3.80
 Di-muon       =  2.00
 Pi0 Local     =  4.80
 Pi0 Global    =  2.40
 Sum Et        =  5.00
 VetoSumPeak2  =  inf.
----------------------
```

L0 optimization with Tagging Information

- L0 optimization using the tagging information:
  - maximize the trigger power rather than the efficiency …
- Tagging information available:
  - muon tagging
  - electron tagging
  - opposite-side kaon tagging & same-side kaon tagging (only relevant for B_s decays)
- "Usage" of tagging information in L0 optimization:
  - B_d decays:

    use only opposite-side kaon tagging as the kaon tag
  - B_s decays:
    - opposite- and same-side kaon tags are both available

  ➔ how to combine the tagging information … ?

Tagging Information (I)

- **Combination of tagging information:**
  - Marta Calvi and Clara Matteuzzi's proposal, LHCb-light meeting, 25/3/2003:
    - ✓ if only 1 tag in the event: take decision on that tag (sign of tag)
    - ✓ if $e + \mu$ tags: chose tag from the highest momentum particle

      -> left with at most 3 tags …

    - ✓ $e + K_{OS}$

      $\mu + K_{OS}$

      $K_{OS} + K_{SS}$ -> consider event as untagged if the 2 tags disagree

      $e + K_{SS}$

      $\mu + K_{SS}$

    - ✓ $\mu + K_{OS} + K_{SS}$ -> tag = sum of all tags
    - ✓ $e + K_{OS} + K_{SS}$

Tagging Information (II)

- Combination of tagging information – adaptation to the L0 optimization:
  - reason: no information on the tagging particles momenta at L0
  - algorithm:

```
 TagFlag = 0
IF ( not a Bs ) KSSTag = 0
IF ( (ElTag and Mutag) <> 0 ) ElTag = 0
SumOfTags = ElTag + MuTag + KOSTag + KSSTag
IF ( SumOfTags >= 1 )   TagFlag = 1
IF ( SumOfTags <= -1 )  TagFlag = -1
```

(TagFlag = 0 / 1 / -1 for untagged / correctly tagged / wrongly tagged events)

Tagging Information (III)

- **General definitions:**

  - wrong tag fraction

    omega = (# wrongly tagged events) / (# tagged events)

  - tagging efficiency

    eff = (# tagged events) / (# offline selected events)

  - tagging effective efficiency

    eff_eff = eff x (1 - 2 x omega)^2

… have to be slightly modified for the trigger optimizations …

Tagging Information (IV)

- Tagging-dependent definitions used in the L0 optimization:

  - wrong tag fraction

    omega = % of triggered and tagged events wrongly tagged

    = (# triggered & wrongly tagged events) / (# triggered + tagged events)

  - combined trigger+tag efficiency

    eff_trigtag = % of selected events that pass L0 and are tagged

    = (# triggered & tagged selected events) / (# selected events)

  - trigger power

    P = eff_trigtag x (1 – 2 x omega)^2

Quantity to be optimized !

L0 optimization – Combination of Channels

- Samples available in our "grouping scenario":

Quantity measured	Channel(s)	# events	# off. sel. events	# off. sel. events for optimization with combined tag	(Combined) tagging effective efficiency (%)
α	B_d -> $\pi\pi$	49 k	3374	425 (1690 sel.)	1.3 +/- 0.5
β	B_d -> $J/\Psi(\mu\mu/ee)$ K_s	99 k	1531	257 (773 sel.)	0.7 +/- 0.6
γ	B_s -> D_s K B_s -> D_s π	337.5 k	7369	1063 (3705 sel.)	1.9 +/- 0.4
$2\delta\gamma$	B_s -> J/Ψ $(\mu\mu)$ Φ	50 k	3863	707 (1951 sel.)	2.8 +/- 0.7
Rare decays	B_d -> K^* γ	48 k	817	- (410 sel.)	-

- The tagging effective efficiencies have errors ~ 20-80% !

… then the statistics are still reduced when calculating the trigger power …
(trigger efficiency included)

Statistics on Tagging Information (I)

- Details for $B_d \rightarrow \pi\,\pi$

Tag	Tagging Efficiency	Wrong Tag Fraction	eff*(1-2*omega)^2
MuTag	5.09 +/- 0.53 %	36.05 +/- 5.18 %	0.40 +/- 0.30 %
	(86 / 1690)	(31 / 86)	
ElTag	2.07 +/- 0.35 %	48.57 +/- 8.45 %	0.00 +/- 0.02 %
	(35 / 1690)	(17 / 35)	
KOTag	19.35 +/- 0.96 %	37.61 +/- 2.68 %	1.19 +/- 0.52 %
	(327 / 1690)	(123 / 327)	
Comb.	25.15 +/- 1.06 %	38.59 +/- 2.36 %	1.31 +/- 0.54 %
	(425 / 1690)	(164 / 425)	

Effective efficiency after combination of tagging info.
(see above for details)

Then for the default trigger setting …

Tag	Trig+Tag Efficiency	Wrong Tag Fraction	Trigger Power
Comb.	15.27 +/- 0.87 %	37.98 +/- 3.02 %	0.88 +/- 0.45 %
	(258 / 1690)	(98 / 258)	

Quantity to be optimized

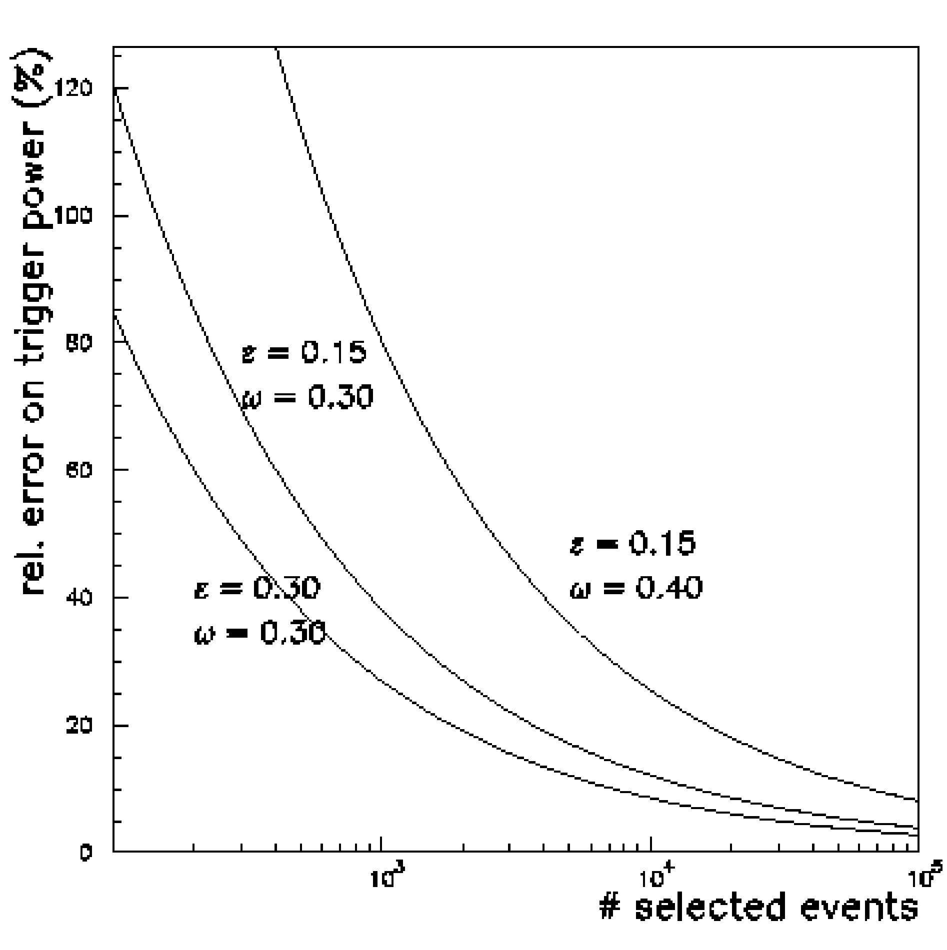
Statistics on Tagging Information (II)

- Error on the trigger power versus the # of selected events

➔ need ~ 10-20 k selected events per channel for a relative error on the trigger power ~ 10% !

➔

Channel(s)	# events
$B_d \to \pi\pi$	500 k
$B_d \to J/\Psi(\mu\mu/ee)\ K_s$	2000 k
$B_s \to D_s\ K$ $B_s \to D_s\ \pi$	1500 k
$B_s \to J/\Psi(\mu\mu)\ \Phi$	500 k
$B_d \to K^*\ \gamma$	100 k



Conclusions and Final Remarks

- L0 trigger is performing well
- Optimization on trigger efficiencies shows a reasonable working point
- Inclusion of tagging in the L0 optimization needs further statistics
- Is it feasible to provide more statistics for a handful of channels used in the L0 optimization?

  Set of specific channels can be discussed and agreed upon …