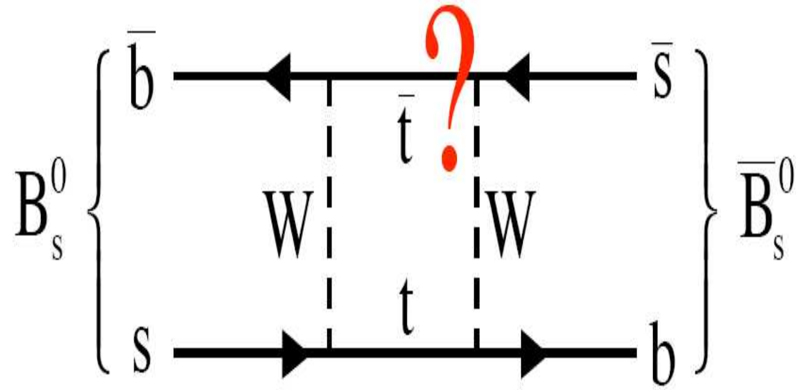
The LHCb Upgrade

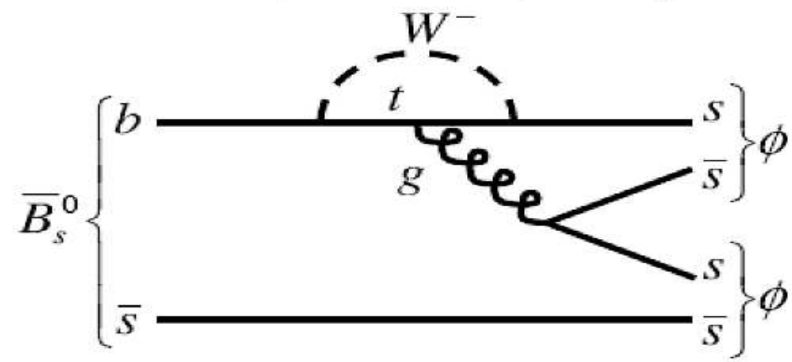
- Physics motivation.
- The luminosity upgrade.
  - Higher luminosity implications for LHCb.
  - Two phase upgrade scenario:
    - I Full software trigger.
    - II Adapt detectors to larger occupancy/radiation environment.
- Time schedule.
- LHCb and the LHC machine.
- Summary.

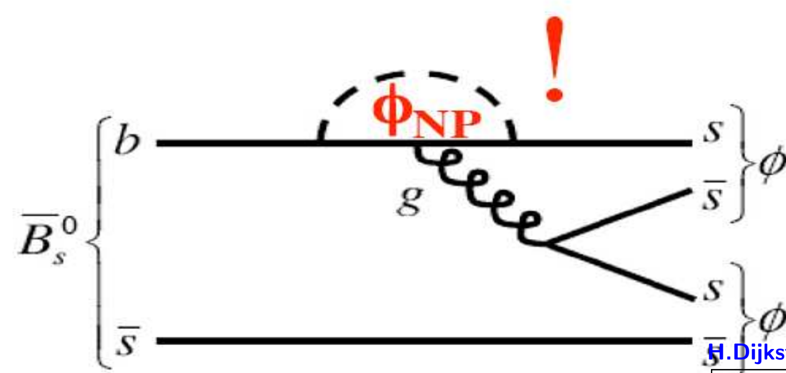
Physics Motivation

LHCb strategy:

- Look for NP
  in processes mediated by loop diagrams.
- Look for processes
  with small error in SM prediction.
- If NP found:
  this allows (statistics!) studying their couplings. Development of statistics:
  - LHCb: collect 10 fb^{-1}
  - Upgrade-I: 4-5$\times$LHCb in hadron-yield.
  - Upgrade-II: collect
    $>$20(10)$\times$LHCb in h(μ) channels.







H.Dijkstra

Example channels

NP Measurement	$10\ \mathrm{fb}^{-1}$	$100\ \mathrm{fb}^{-1}$	$\sigma(\mathrm{theory})$
$\sigma(\phi_s)$ $(\mathrm{B_s} \to \psi\phi)$	0.01	.003	0.002
$\sigma(\beta_s)$ $(\mathrm{B_s} \to \phi\phi)$	0.05	.015	<0.002
$\mathrm{Pol}(\gamma)$ $(\mathrm{B_s} \to \phi\gamma)$	0.09	0.02	<0.01
$\sigma(\mathrm{s0}_{\mu\mu})$ $(\mathrm{B^0} \to \mathrm{K}^*\mu\mu)$	0.3 GeV^2	0.07	<exp ?
$\mathrm{BR}(\mathrm{B_s} \to \mu\mu)$	$> 5\sigma$ in SM	$< 10\%$ of BR	<exp

- Mixing and CPV in charm decays.
- LFV: $\tau \to \mu\mu\mu$
- Search for (low) mass exotics: Hidden Valley models.
- Trigger requirement: able to adapt to flavour physics needs in 2nd half next decade.

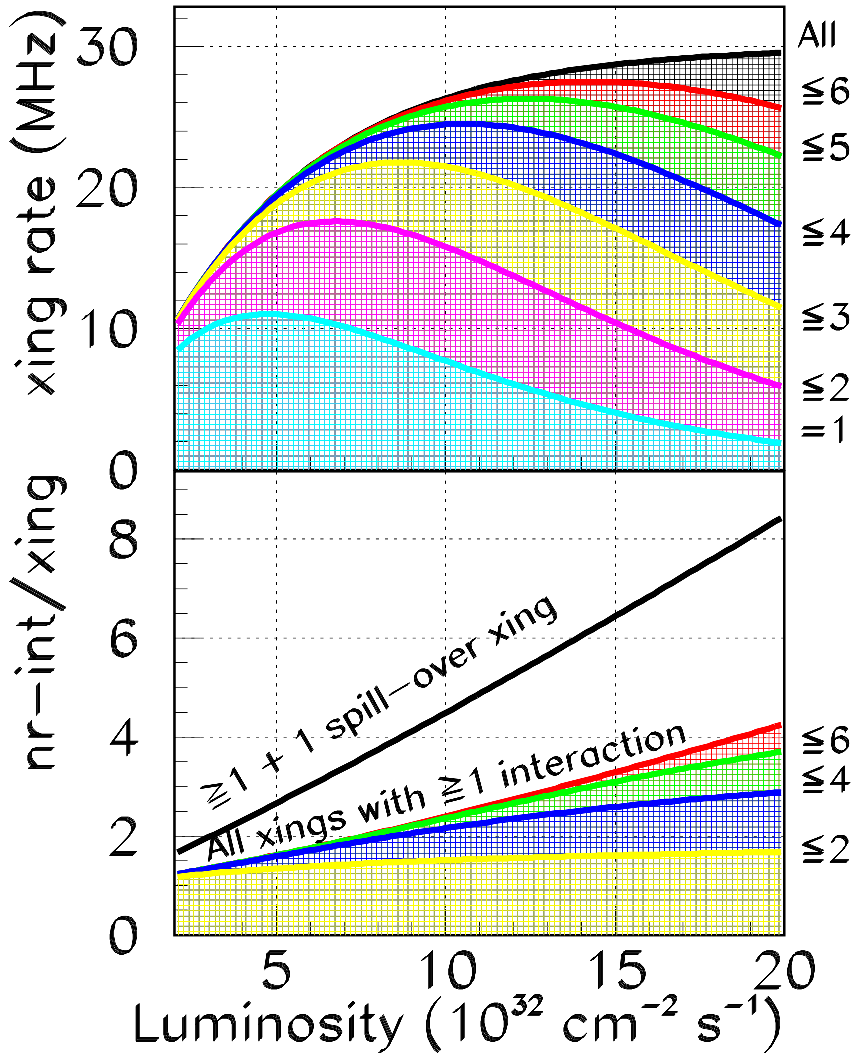
LHCb and Luminosity

LHC: we (will..) have the machine!

- $L_{\rm LHC}^{\rm peak} \approx 10^{34}\ {\rm cm}^{-2}{\rm s}^{-1}$
- Assume $\sigma_{\rm visible} = 63$ mb.
- $@2.10^{32}$: ~ 10 MHz xings with ≥ 1 int.
- $@10^{33}$: ~ 26 MHz xings with ≥ 1 int.
- nr-int/xings:
  only factor 2 increase up to $@10^{33}$!

What is limiting LHCb to use larger L?

- L0 Hadron trigger:
  "designed/works" till $\sim 2.10^{32}$.
- Efficient tracking "works" till $\sim 10.10^{32}$.
- $> 10.10^{32}$:
  radiation damage starts to kick in too.



H.Dijkstra

First Upgrade Step: the Trigger?

Several (MC) studies done, conclusions:

- First level trigger: cut on p_{T}.AND.IP/track simultaneously.
- Hence: need to reconstruct all primary vertexes (PV) per bunch crossing.

Solution: software trigger on a large CPU farm with an input rate $\leq$ 30 MHz.
This gives the additional flexibility to adapt to the physics landscape in the next decade.

Note:

- All present FE are limited to 1 MHz read-out rate.
- 2.5 μs is maximum time for a trigger reconstruction+decision, far too short for a CPU farm to return the trigger decision.

As a consequence, first step in our upgrade scenario:

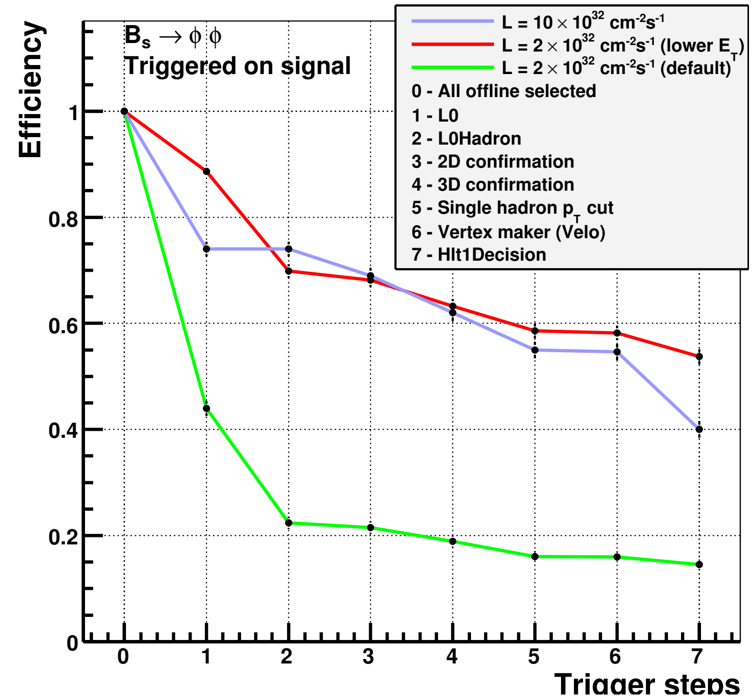
- All FE electronics has to be able to read-out at 40 MHz.

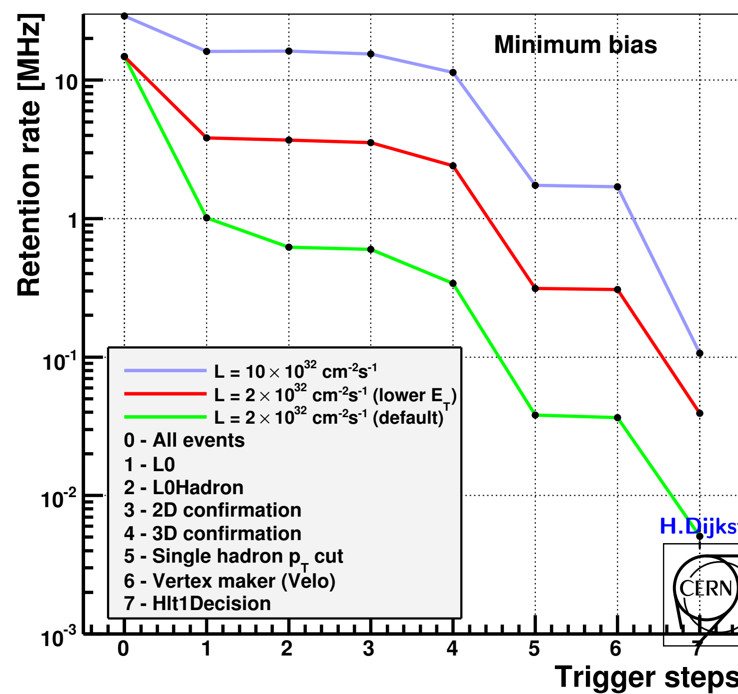
Upgraded Hadron Trigger and $B_s \to \phi\phi$

Preliminary Algorithm:

- as "now", i.e. High-E_T-seeds+VELO+tracking.
- Phase-I@2.10^{32}: get $> 2\times$ efficiency:
  - Hard→Soft trigger: 1→4 MHz rate.
  - $B_s \to \phi\phi$ efficiency $16\% \to\sim 55\%$.
  - Output rate: 5 →40 kHz.

- Increase luminosity: $10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - Input rate 15 MHz
  - $+$some high-L tuning to reduce rate.
  - $> 10\times$ better signal yield for $5\times$ increase in L.
  - Minimum Bias rate: 100 kHz.
  - Next: study to reduce to 10-20 kHz with additional tracking.





H.Dijkstra

Time Schedule

LHCb will have to upgrade synchronized with LHC and GPD schedule:

- 8 months shutdown 10/2012-6/2013 to install new IR in GPDs.
- 18 months shutdown 2017-6/2018 to replace GPD Inner Detectors.

Exploit the above two windows for a two phase upgrade scenario:

- Up till 10/2012: collect $\sim 9\text{fb}^{-1}$: data-doubling-time (DDT): 3 years.
- PHASE-I:
  - 10/2012-3/2014, of which 12 months access, to upgrade all FE to 40 MHz.
  - Run at lumi $< L^{\text{peak}} \sim 10^{33}$ till 2017.
  - $\int L^{2017} = 25$ fb^{-1} most with doubled hadron trigger efficiency!
  - 25% above the radiation limit for all detectors (but VELO).
  - DDT: 3 years in 2017.
- PHASE-II
  - 2017-6/2018 to upgrade detectors for high lumi and radiation.
  - Run at lumi $< L^{\text{peak}} > \sim 3 \times 10^{33}$ till 2022.
  - collect $\int L^{2022} \sim 110\text{fb}^{-1}$. (DDT: 5 years.)

LHCb and LHC-machine

- Now: run at $2-5.10^{32}$: limitation hadron-trigger.
- PHASE-I: run at $\approx 10.10^{32}$: limitation tracking efficiency (radiation)
- PHASE-II: run at $\lessapprox 50.10^{32}$: limitation probably (R&D..) upgraded tracking.

LHCb happy with LHC (without Super), needs (has $\beta^*=$ 1 m) optics to run at above lumies.

- PHASE-I/II lumi-limits due to number of pp-int/xing!!
- Needed: 25 ns! (50 ns will half our integrated luminosity!), and like
  - luminosity leveling for $L > 10^{33}$
  - long(er) luminous region

SLHC: LHCb does not need it but we like very much one of the discussed schemes:

- 25 ns bunches, but:
  - 50 ns $I^{\text{high}} \leftrightarrow I^{\text{high}}$ bunches
  - Interleave with 50 ns $I_{\text{low}} \leftrightarrow I_{\text{low}}$ bunches
  - GDP xings: $I^{\text{h}} \times I^{\text{h}},\ I_{\text{l}} \times I_{\text{l}}, I^{\text{h}} \times I^{\text{h}}$
  - LHCb xing: $I^{\text{h}} \times I_{\text{l}},\ I_{\text{l}} \times I^{\text{h}}, I^{\text{h}} \times I_{\text{l}}$ etc..

Note: no tune shift limitation for I^{h} bunches due interactions with I_{l} bunches.

Upgrade Summary

- -2013: ramp to $L \leq 5.10^{32}$, $\int L =\sim 9 \text{ fb}^{-1}$
- PHASE-I: 2013-2017 upgrade trigger: $L \sim 10^{33}$, $\int L =\sim 25 \text{ fb}^{-1}$
- PHASE-II: 2017-2022: upgrade detectors: $L \leq 5.10^{33}$, $\int L =\sim 110 \text{ fb}^{-1}$

- LHCb PHASE-I/II lumi-limits due to number of pp-int/xing!.
- Hence: we want as many xings/s (25 ns?) as possible. Doubling the bunch spacing (50 ns) will half our integrated luminosity.
- Second order "requests":
  - Luminosity leveling for larger ($L > 10 \times 10^{32}$) luminosity.
  - Long(er) luminous region = better.