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LHCb RICH Testbeam Analysis

This page summarises the efforts of the RICH TestBeam Analysis of the 2006 tests.

The data has been recorded using an early version of the official LHCb online framework using the UKL1 board.

The analysis is done using the official reconstruction software BRUNEL

Presentations and posters at international conferences or workshops

- **System Tests of the LHCb RICH Detectors in a Charged Particle Beam**
    - Speaker: *Hugh Skottowe*
    - Slides and proceedings
    - The 2008 IEEE Nuclear Science Symposium (NSS), Medical Imaging Conference (MIC) and 16th Room Temperature Semiconductor Detector Workshop
    - Dresden (Germany) 19-25 October, 2008
    - Conference webpage
- **The Performance of the LHCb Pixel Hybrid Photon Detectors in a 25ns Structured Test-Beam**
    - Speaker: *Davide Luigi Perego*
    - Slides and proceedings
    - The 2007 IEEE Nuclear Science Symposium (NSS) and Medical Imaging Conference (MIC)
    - Honolulu (USA) 27 October-3 November, 2007
    - Conference webpage
- **The operation of the LHCb RICH photon detection system in a charged particle test beam**
    - Speaker: *Sean Brisbane*
    - Slides and proceedings
    - 6th International Workshop on Ring Imaging Cherenkov Counters (RICH2007)
    - Trieste (Italy) 15-20 October, 2007
    - Workshop webpage

Tasks

Hit clustering and tracking (Hugh)

Tracking alignment (Andrew)

Mirror and HPD alignment (Chris E.)

Mirror and HPD alignment has been performed for the following testbeam runs:

N2: 3, 4

C4F10: 27, 28, 29, 30, 31, 32, 33, 34, 35, 55, 56, 66, 75, 76, 88, 89, 91, 92, 93, 94, 95

If further runs are needed, let me know!

How to use:

- Include the appropriate alignment options file in your software: Use Alignment_Data.opts for reconstructing testbeam data, Use Alignment_Sim.opts for simulating the testbeam and for digitising and reconstructing simulated data.
- In the alignment options file uncomment the lines corresponding to the testbeam run required.
- Check you are using the correct geometry database (DDDB_RiTB20071005.db or later).

Differences between the alignment options files

The testbeam simulation does not currently support the individual alignment of HPD Si sensors in Gauss. As a result, the Alignment_Sim file only contains mirror alignment conditions. The Alignment_Data file contains alignment conditions for both the mirror (determined from data) and the individual Si sensors inside each HPD (from the Scotland HPD testing).

Photon yields and beam composition from N2 runs (Tom)

Photon yields and beam composition from C4F10 runs (Erica, Davide, Tito)

Results from the analysis of most of the C4F10 runs (v3 DST file version) are available. A model for the expected distribution of the number of hits has been developed. A Poisson-distributed photoelectron yield is convoluted with a binomial function accounting for charge-sharing between adjacent pixels and a second Poisson parameterising the probability of two photons hitting the same pixel. The contributions of one, two and three particles per bunch to the function have been also considered. The fit range is fixed for all the runs between 5 and 30 photoelectrons. In the following table the average numbers of photoelectrons per radian Npe/Δ (Npe/rad) for all the HPD involved in the test are shown. Only runs with the nominal value of the TTCrx = 160 (corresponding to a Time Delay = 16.67 ns) have been considered; known bad runs are excluded in this computation. The average is quoted for all runs which involve the HPD, irrespective of the C4F10 concentration.

HPD	Npe/Δ (Npe/rad)
36	10.7 ± 0.2
88	8.3 ± 0.5
116	8.6 ± 0.3
117	8.5 ± 0.4
222	9.0 ± 0.5
223	8.9 ± 0.3
265	8.8 ± 0.3
282	9.4 ± 0.6
283	9.2 ± 0.6

Four sets of runs have been done varying the TTCrx value:

Run Number	Mirror Position	HPDs		
35-46	7	88	222	223
47-60	27	36	222	283
61-75	31	265	282	283
76-87	13	116	117	265

These runs can be used to study the performances of the HPDs as a function of the time delay (Time Scan). Click on the "Mirror Position number" to open the plot of the related Time Scan. The superimposed magenta dashed lines refer to the nominal Time Delay = 16.67 ns.

Cherenkov angle resolution (Andrew, Hugh)

Simulation using GAUSS and BOOLE (Nick)

A simulation with the tracking HPDs included is now completed and will be included with the next software Tarball. The tracking HPDs are assigned the same L0IDs as in the real data (131 & 126) so the same tracking algorithms should be able to be used on simulated data. Options will also be available for the ParticleGun allowing a pion- beam with impurities (10% electron, 7% Kaon, 3% Proton) and with multiple particles per event (poissonian, with mean settable in options file) to be generated.

Changing the beam composition could have effects on Cherenkov resolution, and multiple particles per event will affect the # hit distribution.

The following data sets are currently available on CASTOR, and can be found at: /castor/cern.ch/user/n/nstyles/testbeam-simdata:

sim001.sim/digi001.digi: pure pi- beam, single particle, travelling along single fixed path parallel to z-axis. Vertex at x=-305 mm, y=7 mm, z=8000 mm.

sim002.sim/digi002.digi: pure pi- beam, single particle, travelling along multiple paths parallel to z-axis. Vertices over range x=-300 mm to -320 mm, y=0 mm to 20 mm, z=8000 mm.

sim003.sim/digi003.digi: impure pi- beam, multiple particles (mean particles/event = 1.1), travelling along multiple paths parallel to z-axis. Vertices over range x=-300 mm to -320 mm, y=0 mm to 20 mm, z=8000 mm.

sim004.sim/digi004.digi: pure pi- beam, single particle, travelling along multiple paths parallel to z-axis. Vertices over range x-302 mm to -312 mm, y=2 mm to 12 mm, z=8000mm.

All of the above are N2 runs, with the Cherenkov ring positioned on HPD 461. C4F10 runs will be made available once a correct mirror position for this radiator is obtained from the alignment. *NB all of these data files were produced with a particle momentum of 450 GeV. This is not correct, as the momentum of the beam particles was 80 GeV; however this should not affect the cherenkov angle as we are already saturated by 80 GeV.*

Currently, hits are not produced over the entire tracking sensor due to an active radius applied in Boole to remove hits that could not have come from photo-electrons. If this proves to be problematic, this may be changed for the next tarball.

The latest version of the simulation included in the last tar-ball is based on Gauss v30r2 and Boole v14r0. These releases break DC06 compatibility, so there may be some differences between results obtained with this version compared to previous versions; this should be investigated. When compiling, warnings will appear about conflicting Gaudi releases, this is a known feature and can be ignored. In order to simulate C4F10 events, new versions of the structure and geometry xml files for the 'AfterMagnet' region are required; these can be found at /afs/cern.ch/user/n/nstyles/public and should be copied into the folder Gauss_v30r2/Det/XmlDDDB/DDDB/AfterMagnet to replace the versions currently there. For using Boole, you should check the you have the lastest version of the sql database, and change DefaultTAG from "N2" to "C4F10" in 'v200601.opts'.

(Antonis)

List of HPDs

Column	chip #	HPD number	L0 ID	PDTF PC Im Rad [um]	QE dE (sum)

0	8_127	H525014	100	6358	0.80
0	8_115	H518004	101	6435	0.79
0	8_185	H542003	150	6689	0.79
0	8_191	H542001	151	6641	0.82
0	8_194	H539010	76	6467	0.84
0	8_123	H525002	77	6552	0.89
0	8_114	H525004	116	6652	0.81
0	8_133	H521005	117	6616	0.84
0	8_113	H525015	88	6607	0.85
0	8_118	H516005	89	6521	0.72
0	8_160	H527008	108	6525	0.78
0	8_110	H518001	109	6213	0.87
0	8_128	H525011	166	6661	0.82
0	8_157	H524006	167	6420	0.90
0	8_170	H518009	60	6567	0.86
0	8_130	H521008	61	6521	0.84
1	8_180	H527002	266	6698	0.79
1	8_121	H516020	267	6387	0.87
1	8_107	H518002	256	6483	0.91
1	8_112	H516018	257	6605	0.74
1	8_96	H516014	176	6472	0.82
1	8_99	H516009	177	6306	0.86
1	9_121	H610003	264	6476	0.94
1	9_177	H612003	265	6502	0.88
1	8_104	H516012	222	6410	0.91
1	8_122	H516019	223	6569	0.84
1	8_197	H539003	146	6652	0.83
1	8_134	H524003	147	6707	0.84
1	8_156	H525011	250	6613	0.77
1	8_98	H518005	251	6465	0.84
1	8_119	H524005	178	6377	0.68
1	8_108	H518003	179	6403	0.85
6	9_49	H549013	162	6622	0.83
6	9_111	H550011	163	6777	0.99
6	9_71	H541015	86	6656	0.95
6	9_66	H550021	87	6697	0.98
6	8_196	H541012	78	6737	0.71
6	9_68	H542018	79	6616	0.79
6	9_55	H550008	282	6598	0.84
6	9_60	H549011	283	6636	0.89
6	9_70	H542015	36	6702	0.97
6	9_106	H549008	37	6464	0.86
6	9_56	H550009	18	6727	0.79
6	9_75	H550019	19	6740	0.95
6	9_74	H542010	14	6645	0.88
6	9_61	H550013	15	6480	0.95
6	9_104	H545001	156	6726	0.93
6	9_67	H550016	157	6756	0.97

Charge sharing in dark-count/LED runs (Sean)

Charge sharing occurs when a significant number of the electron/hole pairs created by a single photoelectron are spread between adjacent pixels in the HPD. Data from LED runs was used to estimate this effect (to the 1% level or better). The charge sharing breakdown by HPD number (==2*L0 board number+L0 HPD position) follows. Those percentages flagged in orange may have a significant irreducible ion feedback rate reducing the precision of the charge sharing estimate, or have very low statistics in the LED runs.

HPD	ChargeShare %	HPD	Charge Share %
100	3%	223	2.4%
101	2%	250	No Data
108	3%	251	No Data
109	4%	256	3%
116	1.6%	257	3%
117	1.6%	264	No Data
146	3.3%	265	2.4%
147	2%	266	2.3%
14	2.7%	267	2.5%
150	5%	282	3.0%
151	2%	283	2.5%
156	2.5%	36	1.4%
157	2%	37	2.5%
15	3.5%	60	No Data
162	2%	61	No Data
163	2.9%	76	3.2%
166	8%	77	3.4%
167	No Data	78	2.9%
178	7%	79	2.8%
179	No Data	86	3.0%
18	3.1%	87	3%
19	2.6%	88	2.7%
222	4%	89	4.2%

Software

The test-beam analysis and simulation is based on the official LHCb software environment, i.e.

- BOOLE for reconstruction and analysis
- Panoramix for visualisation
- Gauss and BOOLE for the simulation

Software versions

However, some files need to be adapted to the special test-beam setup and are not part of the official LHCb software repository. A summary of all needed updates together with some links to tar-balls containing all software is given below. All files are available from CASTOR from the directory `/castor/cern.ch/lhcb/testbeam/lhcbrich`

- [Version 2006-Nov-17] GAUSS, BOOLE, BRUNEL (15 MB)
- [Version 2006-Nov-17] Panoramix (6 MB)
- [Version 2006-Dec-13] BRUNEL (113 MB)

- [Version 2006-Dec-14] all packages (122 MB)
- [Version 2007-Jan-21] all packages (164 MB)
- [Version 2007-Jan-29] all packages (60MB)
- [Version 2007-Apr-18] all packages (74MB), includes updates to simulation from Nick
- [Version 2007-May-31] all packages (20MB), filename *cmt-testbeam-new_area_20070531.tgz*
- [Version 2007-Aug-09] all packages, including Brunel v31r8, filename *cmt-testbeam-new_area_2007Aug09.tar.bz2*
- [Version 2007-Oct-22] all packages, (90MB), filename *cmt-testbeam-new_area_20071022.tar.bz2* includes: Gauss v30r3 (using SqlLite), Boole v14r5, Panoramix v15r6, Alignment options from Chris
- [Version 2007-Nov-07] all packages (103MB), filename *cmt-testbeam-new_area_20071107.tgz*, includes latest Boole (from Nick), alignment options (from Chris)
- [Version 2007-Nov-27] all packages (100MB), filename *cmt-testbeam-new_area27Nov2007.tar.bz2*, includes Gauss v30r4, Brunel v32r0, alignment options (from Chris), new DDDB (from Antonis) *[Final Version] TestBeam2006_cmtuser.tar.bz2

Instructions

Analysis

The data is analysed using TestBeam.exe in the package Rich/TestBeam package. Go to the `cmt` area of this package, setup Brunel via `BrunelEnv v30r14` and `source ./setup.(c)sh` . The main option file for the test-beam analysis is `TestBeamAnalysis.opts` in the `options` area of the same page. The following algorithms are currently used:

- `RichFixedTestBeamTrackAlg/CreateTrack` create a single (ideal) track per event, not using the tracking HPDs (mainly used for simulation studies with using the ParticleGun to shoot one particle through the detector)
- `RichClusteredTestBeamTrackAlg/CreateTrack` create clusters from hits in the tracking HPDs, create tracks from these clusters (used for data analysis)

Simulation

To simulate events with the test-beam setup, Gauss is used in conjunction with the ParticleGun. One pion is shot through the detector with fixed momentum and direction (N.B. hits in the tracking HPDs are are not simulated at present). To simulate new events:

- Go to the `cmt` area of the `Sim/Gauss` package
- Setup `GaussEnv v25r6` and `source setup.(c)sh`
- Build Gauss if not yet done
- Run Gauss via `../slc3_ia32_gcc323/Gauss.exe ../options/Gauss.opts`. You may want to edit `ApplicationMgr.EvtMax` and the setting in `ParticleGun.opts`
- This produces `Gauss.sim` and `NewCatalog.xml` and some monitoring histograms)
- Now go to the `cmt` area of the `Digi/Boole` package
- Setup `BooleEnv v12r9` and `source setup.(c)sh`
- Build Boole if not yet done
- Run Boole via `../slc3_ia32_gcc323/Boole.exe ../options/v200601.opts`
- This produces `Boole.digi` and `NewCatalog.xml` (and some monitoring histograms). The .digi file can then be analysed with TestBeam.exe

Visualisation

The events (both real data and simulation) are visualised using Panoramix.

- Go to the `cmt` area of the `Vis/Panoramix` package

- Setup `PanoramixEnv v13r10` and `source setup.(c)sh`
- Build Panoramix if not yet done
- Run Panoramix via `../slc3_ia32_gcc323/Panoramix_main.exe ../options/testbeam.opts` (N.B. this includes the TestBeamAnalysis.opts from TestBeam.exe). If you want to visualise the simulation output of Gauss, use `../options/tr_test_sim.opts`

`N.B.` Make sure that the following options in `scripts/python/panoramixmodule.py` are commented out:

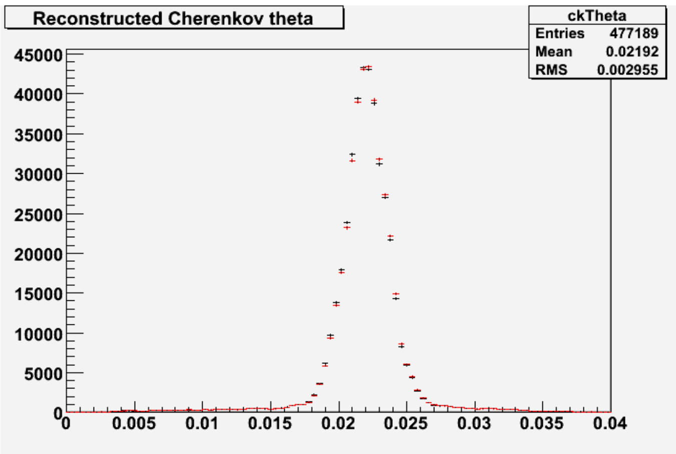
```
TrackHerabExtrapolator     = appMgr.toolsvc().create('TrackHerabExtrapolator',  interface='ITrackE
TrackLinearExtrapolator    = appMgr.toolsvc().create('TrackLinearExtrapolator', interface='ITrackE
MCDecayFinder              = appMgr.toolsvc().create('MCDecayFinder',           interface='IMCDeca
MCDebugTool                = appMgr.toolsvc().create('DebugTool',               interface='IDebugT
TrackMasterFitter          = appMgr.toolsvc().create('TrackMasterFitter',       interface='ITrackF
```

Switching off the "fudge factor"

The Gaudi-based reconstruction software has an inbuilt "fudge factor" which shifts the mean of the Cherenkov angle by a small amount to the correct value. This shift is very small and is used to handle tiny residual effects which are not handled otherwise. The effect for the TestBeam setup is tiny indeed, however, as it's tuned for the full LHCb detector description and setup, it may be best to switch it off. This link points to the documentation of the fudge factor. It can be switched off by adding the following linen to `TestBeamAnalysis.opts` or `RichPhotonsFromReco.opts` (which is included by the main options file)

```
ToolSvc.Offline.RichPhotonCreator.PhotonParams.CKThetaQuartzRefractCorrections = {0,0,0};
```

The plot below illustrates the effect



The black histogram is with the "fudge factor" switched on, the red when it is switched off. The mean (of the histogram) changes slightly from 21.92 to 21.96 when switching the factor off

Data

All data has been copied to CASTOR. The Excel file attached to this page summarises some details regarding each run of data-taking.
The orignial MDF files are in */castor/cern.ch/lhcb/testbeam/lhcbrich/2006*. These files have been rebuilt to correct various deficiencies and at the same time to convert from the old MDF v1 format to v3 format. The v3 MDF files can be found at */castor/cern.ch/lhcb/testbeam/lhcbrich/2006_mdf/*. They should be used in preference to the old files for any new DST production or analysis that uses the MDF files directly.
The files converted to the DST format can be found in */castor/cern.ch/lhcb/testbeam/lhcbrich/2006DST* . The DST files created from the original MDF files taken during the beam-test are called run_xxxx.dst, the ones created from the MDF files converted to the v3 format are called run_xxxx.dst_v3.

"bad runs"

The following runs should be treated with special care:

- 1: HPD 86 is out of synchronisation (with the bunch crossing ID in the L0 header words for that HPD being different from all other HPDs, including its partner on the L0 board. 86's bxID in fact seems to match up with the bxID of other HPDs in the previous event)
- 15-25 Event rebuilding did not work properly leading to apparently "missing" HPDs and therefore more HPDs than expected having zero hits. The data are not actually missing.
- 61 & 63 do not exist. The data were re-taken under different run numbers.
- 84- From this run onwards HPD 265 always has bunch ID = 0 though the number of hits looks OK.
- 92-95 are tests of higher trigger rates.
- 96-100 are tests of sending several almost consecutive triggers (e.g. 15 triggers within 30 clock cycles, with one being sent every other clock cycle), of which only the first of each set is necessarily correlated with coincident signals in the trigger scintillators.

In addition, the tracking data in the following runs are probably unusable:

- 13-15 (desynchronization between trackers)
- 16 (no tracking)
- 30-36 (desync. between trackers; run 36 also seems to have rows of pixels for some events (from 73865 onwards or maybe earlier too?) and other runs may have that problem too, as yet unseen)
- 37 (no tracking)
- 38-55 (desync. between trackers; also seem to have many inefficient pixels)

Environmental Conditions

Environmental conditions from 28/9/06 to 01/10/06

- Radiator temperature
- Atmospheric pressure (from CERN Gamma Irradiation Facility)

Details on demagnification law (from Thierry)

The HPD electrode voltages had been for years set as follows:

- photocathode: -20kV
- 1st electrode: -19.700kV
- 2nd electrode: -16.417kV
- anode: 0kV

The corresponding de-magnification law is illustrated in the first attached plot called "Previous_optics.pdf". This plot shows the fit results for a quadratic law.

Following the integration of HV monitoring lines, and the implementation of a redundant resistive HV splitter, the HPD electrode voltages in the final system are set as follows:

- photocathode: -20kV
- 1st electrode: -19.714kV
- 2nd electrode: -16.478kV
- anode: 0kV

The corresponding de-magnification law is illustrated in the second attached plot called "Final_optics.pdf". This plot shows the fit results for a quadratic law.

The third attached plot called "Both_optics.pdf" shows the superposition of the 2 laws. The final one results in a slightly larger image on the pixel chip, for a given image on the photocathode.

Please keep in mind that the law relates photocathode radial coordinates (as measured from the tube axis) to anode radial coordinates. As such, it does NOT include the refraction effects at the quartz window.

The estimate of the Point Spread Function for both optics is shown on the fourth attached plot called "PSF_HVsplitter.pdf". This estimate is the result of a MC simulation with simplified hypotheses on the energy spectrum and emission angle of the photoelectron for incoming photon energies of 2eV and 4eV, assuming a photocathode threshold energy of 1.5eV. As such, it definitely is not what the real situation is.

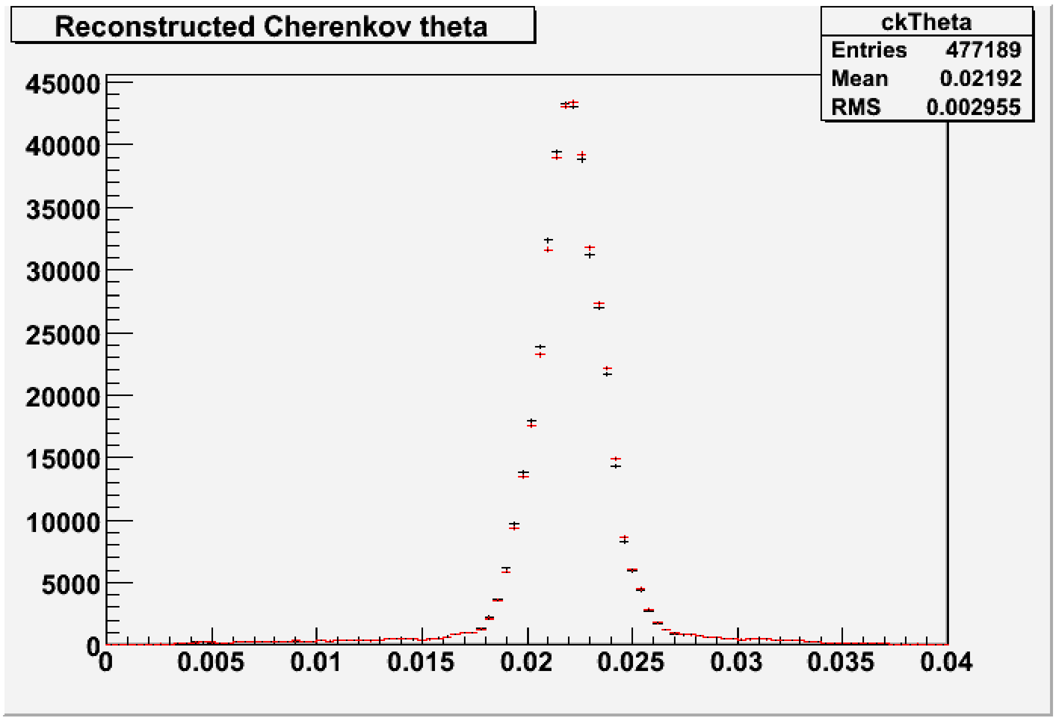
Finally, please bear in mind that all effects described here assume a tube with perfectly made mechanics, and exact electrode voltage values. This is definitely not the case in practice. Also, the presence of a stray magnetic field will distort and blur the images.

paper

We should aim to summarise the analyses of the beam-test in a published paper. It would be good if we could send the paper to the journal by fall, completing the internal review over the summer. Please start filling in the sections with your analyses. The tar-ball with all files is attached to the TWiki.

-- Main.ukerzel - 21 Jan 2007

- Both_optics.pdf: Both_optics.pdf
- Final_optics.pdf: Final_optics.pdf
- Previous_optics.pdf: Previous_optics.pdf
- PSF_HVsplitter.pdf: PSF_HVsplitter.pdf
- l0-id-numbers.txt: L0 ID numbers
- Rich_TBSep06Paper_20070530.tgz: Draft version of TB paper, 30 May 2007
- RichTestBeam2006Paper_2007June11.tgz: RichTestBeam2006Paper_2007June11.tgz
- Fudge factor on / off:



- RichTestBeam2006Paper_2007July31.tgz: TB analysis paper, snapshot 31 July 2007
- RichTestBeam2006_2007Aug31.pdf: Snapshot of TB paper from 31 Aug 2007
- T_SSB.xls: Radiator temperature
- TestbeamAtmPtessure.xls: TestbeamAtmPtessure.xls
- Lhcbnote_2007_134_071102.pdf: HPD technical description from Thierry
- Alignment_Data.opts: Alignment conditions for testbeam data
- Alignment_Sim.opts: Alignment conditions for testbeam simulation
- testbeam_total2.xls: Mirror reflecitivity measurement

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