Dual Readout Testbeam simulation

Sarah Eno 19 Dec 2024 SLAC HFCC workshop

Test beam simulation

We are building a publicly available code to do simulations of test beams and in general explore dual readout calorimetry in a stand-alone environment. The code is based in dd4hep (<u>https://dd4hep.web.cern.ch/dd4hep</u>), a wrapper for GEANT4. This is the official code for future colliders. Code developed here should be easy to port back and forth to the full detector simulation discussed later today by Wonyong Chung.

- First code simulated single crystals. Was developed by Mekhala Paranjpe and Sarah Eno. Used in the PbF2 paper https://www.sciencedirect.com/science/article/abs/pii/S0168900224010350
- Very useful for understanding odd angular dependence of light collection and realize the challenges of prompt light collection for Cherenkov light due to its characteristic angle
- Available at : https://github.com/Mekhpar/SingleCrystal_cosmic_ray/tree/main/compact





Array with HCAL

We have updated this to a flexible code allowing different configurations of HCAL + HCAL.

- ECAL currently has 2 crystal segments
- HCAL allows two options: a CMS-HCAL-like sampling calorimeter with scintillating and non-scintillating tile layers for active media and a IDEA-like fiber HCAL with scintillating and non-scintillating fibers in individual absorbers (either tube or square with circular hole).
- General user code at: gitlab
- Beta test version at: https://github.com/saraheno/DualTestBeam







Larger team

- U. Maryland general code development
- Baylor ECAL optimization studies
- Rutgers Dual readout correction for joint ECAL/HCAL test beam

Welcome to join

Working on this code can be a good first project for graduate students. We work in the "standalone simulations of ECAL plus HCAL" thread on the CalVision mattermost. We have weekly meetings, currently Fridays at 3:30 PM Eastern. We have a google sheets where we have a list of projects

https://docs.google.com/spreadsheets/d/159vRkuQ4VSZwLp4ARx5AZhcYsIpUfLfnX82SNIcR_Bw/edit?usp=sharing

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	A	В	С	D	E	F	G	н	1
2	Name	goal for next meeting			List of money plots for a paper		List of simulation upgrade goals port the uva electronics simulation into dd4hep the official way		
4	Sara Nabili	Correct ecal slices in Resolution.C code and resport energy deposition, and update my slides			electron resolution as a function of the impact position within a cell		port Mekhala's interface between crystal and photodetector into our code		
5	Sarah Eno	add optional material in front of calorimeter or maybe check the dual readout correction for mixed calorimeter. send yongbin emails from geant authors on non-conservation			containment versus lateral size electrons and pions		add material in front of the calorimeter		
6	Yusuf Aamir	fiber cal - energy resolution using formula for all histograms			electron resolution versus material between the crystals		check (and fix?) birks' law implementation in dd4hep		
7	Peter Miller	Effect of particle beam angle within cell on hcal fiber calibration (position and angle dependence)			dependence of resolution for electrons and pions on integration time		also do correctly the interface between the fibers and the photodetectors		
8	Kenichi Hatakeyama	Try to understand/debug results of gendet=2 with supporting structure. Study better the dimension and specs of the supporting structure			pion resolution as a function of the relative lengths of the two crystal segments		check and verify Sarah's code to do the dual readout correction for a setup with both an ecal and hcal (Resolution twocals.C)		
9	Jon Wilson	electron resolution for different support structures, screen grab showing material between the crystal (ddsim or geoDisplay visuals)			cherenkov collection efficiency for different wrappings and interfaces between crystal and photodetector		true model of sipmm, not "kill media"		
10	Alex Truitt	Energy resolution of the honey comb structure (the effect of adding them) on ECAL					add carbon fiber crystal holder in ECAL (this has already been done)		
11	Walker Hendricks	Energy resolution of the honey comb structure (the effect of adding them) on ECAI			electron energy scale for fiber calorimeter versus impact position within a cell and versus angle		add polarization effects		
12	John Paul Chou	Reading the Morco Lucchini's paper of New prespective on Dual Readout Calorimetry.			electron resolution versus material between the two crystal segments				
13	David Yu	Presently getting up to speed on basics. Plan to ramp up contributions after starting @Buffalo in Jan 2025 (with student/postdoc).			pulse shape simulations for each photodetector in the crystal calorimeter for electrons and pions				
14									
16					Ratio of detected: C light produced in interfaces / C light produced in crystal Study versus filter and matching mediums thickness.				
17					sigma_E/E curves for different gaps (e/gamma)				
18					sigma_E/E curves for different gaps (pi+/-)				
19									

Getting started

Instructions on getting started can be found at: https://foswiki.web.cern.ch/Calvision/DualCrystalDD4hep



Simulation with dual readout calorimetry

Setup the working area:

Code structure

ode ⊙ Issues \$1 Pull requests ⊙ Actions	🗄 Projects 🖽 Wiki ① Security 🗠 Insights 🕸	Settings
DualTestBeam Public		🖈 Pin 💿 Unwatch
🐉 master 👻 🐉 1 Branch 🛇 0 Tags	Q Go to file	file 👻 <> Code 👻
Sarah more automation	2652191 - 2 d	ays ago 🕚 261 Commits
Compact	more automation	2 days ago
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eve eve	first commit	2 years ago
include	first commit	2 years ago
scripts	first commit	2 years ago
src src	new emfrac variable in hit and start up upstrea	2 months ago
CMakeLists.txt	ha	2 years ago
README.md	first commit	2 years ago
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The xml files that contain much of the geometry information, code for analyzing the data, and scripts for running the jobs are in "compact".

The C++ code that actually builds the detectors is in "src"

Most geometry in 2 xml files, rest in code

Files	DualTestBeam / compact / SCEPCALConstants.xml [
^y master ^w Q. Go to file	Sarah lots of options		
Dec.HCALxml Overlay3.C	Code Blame Executable File - 80 lines (54 loc) - 3.5 KB 1 cdefine> 2	Files *********************************	DualTestBeam / compact / SCEPCAL_DRCrystal.xml Code Blame Executable File - 68 lines (45 loc) - 3.32 KB Raw (C) + 3.42 KB
ProcessResvE.sh ProcessResvE.sh ProcessResvE.sh ReadMM md	4 5 6 7 <[photodetector thicknesses> 8 <constant name="Millikief" value="0.001cm"></constant> <[should be 0.1 mm> 9 <constant name="Usetmandth" value="0.001cm"></constant> <[should be 1>	Q Go to file SCEPCALConstantsS2.xml SCEPCALConstantsS3.xml	31 cdmensions width="DRcrystalwidth" z_length="DRcrystallength1+DRcrystallength2+DRcrystalgapl+2*killthick" repeat="DRcrystalbsi /> 33 34 35 36 37 37 37 38 38 39 39 30 30 30 30 30 30 30 30 30 30 30 30 30
 Resolution.C Resolution_twocals.C 	<pre>11 cconstant name="Upstreamoffset" value="-50.0*cm"/> <!-- distance in front of ecal for start of 12 13 <! constants for dual readout crystal calorimeter--> 14 cconstant name="DBcrystalhddth" value="1.0*cm"/> <!-- should be 1--></pre>	SCEPCAL_BOUND.xml SCEPCAL_DRCrystal.xml CSCEPCAL_DRCrystal.xml	38 for example, there may be 10 layers with one thickness of Pb and scint and 20 with another set of thicknesses. 39 each of these repeating things is a "layer". (so in this example, two "layers") 40 within a layer is a slice os the Pb and scint are slices 41 the assembled two is a Slice.
ResvE.C SCEPCALConstants.xml SCEPCALConstants2.xml	<pre>15 <constant name="DRcrystallength1" value="5.0*cm"></constant> 16 <constant name="DRcrystallength2" value="5.0*cm"></constant> 17 <constant name="DRcrystalgap1" value="0.001*cm"></constant> 18 <constant name="DRcrystalgapamat" value="DRcrystalgap12"></constant></pre>	SCEPCAL_DRriber2.xml SCEPCAL_DRriber2.xml SCEPCAL_DRSampling.xml	<pre>42 creation assessment (come is a stare 42> 43 43 44 (structure> 45 choney name="boney" thickness="DBCrystalhont" material="NS Polystymene" vise"CrystalEcalHonevVis" sensitive="ves"/> 45 choney name="boney" thickness="DBCrystalhont" material="NS Polystymene" vise"CrystalEcalHonevVis" sensitive="ves"/></pre>
SCEPCALConstants3.xml SCEPCALConstants4.xml	<pre>19 <constant cm"="" name="DRcrystalgapt" value="0.001"></constant> 20 <constant drcrystalgapt"="" name="DRcrystalhont" value="0.999"></constant> 21 22 <constant name="DRcrystallength" value="DRcrystallength1+DRcrystallength2"></constant> <!-- should be 20 n</pre--></pre>	SCEPCAL_DRSampling2.xml SCEPCAL_DRUpstream.xml SCEPCAL_FCAL_yml	46 47 48 49
SCEPCALConstantsBigEcal.xml SCEPCALConstantsBigEcalR.xml SCEPCALConstantsBigEcalR2.xml	23 24 25 26 <constant name="DRcrystalNsize" value="45"></constant> should be 45	SCEPCAL_EdgeDet.xml SCEPCAL_HCAL.xml	50 cstaves vis="Invisible"/> 51 clayer repeat="1" vis="Invisible"> 52 cslice material = "ENBAG" thickness = "killthick" sensitive="yes" limits="cal_limits" vis="CrystalEcalSensitiveVis" 53 cslice material = "ENBAG" thickness = "ORCrystalBength" sensitive="yes" limits="cal_limits" vis="CrystalEcalSensitiveVis"
SCEPCALConstantsBigEcalR3.xml	<pre>27 28 <{ gap between ecal and hcal> 28 <constant mm"="" name="EcalHcalgap" value="0.1"></constant> <{ should be small 0.1 mm></pre>	SCEPCAL_HCAL2.xml	54

Code structure

- src 📄
- DRCrys_geo.cpp
- DRFiber_geo.cpp
- DRFtubeFiber_geo.cpp
- DRSamp_geo.cpp
- DRUpstream_geo.cpp
- DualCrysCalorimeterDump.cpp
- DualCrysCalorimeterHit.cpp
- DualCrysCalorimeterHit.h
- DualCrysCalorimeterSDAction.c...
- EdgeDet_geo.cpp

- ← → C 25 github.com/saraheno/DualTestBeam/blob/master/src/DRCrys_geo.cpp
- 🔡 📔 🗅 assoc. chair 🕒 camps 🗅 futureAccel 🗅 CMS 🙋 Install gcc 4.9 at ub... 🗅 computer general 🗅 d0 🗅 fashion 🗅 Fred School 🗅 grammar 🗅 hep general

Files
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DRCrys_geo.cpp
DRFiber_geo.cpp
DRFtubeFiber_geo.cpp
DRSamp_geo.cpp
DRUpstream_geo.cpp
DualCrysCalorimeterDump.cpp
DualCrysCalorimeterHit.cpp
DualCrysCalorimeterHit.h
DualCrysCalorimeterSDAction.c
EdgeDet_geo.cpp
CMakeLists.txt
C README.md

DualTestBeam / src / DRCrys_geo.cpp					
Code	Blame Executable File · 298 lines (191 loc) · 8.99 KB				
26	<pre>static Ref_t create_detector(Detector& description, xml_h e, SensitiveDetector sens) {</pre>				
145					
144					
145					
140					
147					
149					
150	// loop over the sets of layer elements in the detector.				
151	double z bottoml = -hzmax:				
152	int 1 num = 1:				
153	<pre>for(xml coll t li(x det, U(layer)); li; ++li) {</pre>				
154	<pre>std::cout<<"DRCrys layer (layers contain slices of material)"<<l_num<<std::endl;< pre=""></l_num<<std::endl;<></pre>				
155	<pre>xml_comp_t x_layer = li;</pre>				
156	<pre>int repeat = x_layer.repeat();</pre>				
157	// Loop over number of repeats for this layer.				
158	<pre>for (int j=0; j<repeat; j++)="" pre="" {<=""></repeat;></pre>				
159	std::cout<<"DRCrys layer "< <li<<" "<<j<<std::endl;<="" repeat="" td=""><td></td></li<<">				
160	<pre>string l_name = _toString(l_num,"layer%d");</pre>				
161	<pre>double l_hzthick = layering.layer(l_num-1)->thickness()/2.; // Layer's thickness.</pre>				
162	<pre>std::cout<<"half thickness is "<<1_hzthick<<std::endl;< pre=""></std::endl;<></pre>				
163					
164	<pre>// find top and bottom lengths at this position and center</pre>				
165	// relative to tower bottom				
166	<pre>double z_topl=z_bottoml + 2.*1_hzthick;</pre>				
167	<pre>double z_midl=z_bottoml + 1_hzthick;</pre>				
168	<pre>Position l_pos(0.,0.,z_midl); // Position of the layer.</pre>				
169	<pre>std::cout<<" placed at z of "<<z_midl<<std::endl;< pre=""></z_midl<<std::endl;<></pre>				
170					
171	dd4hep::Box l_box(hwidth,hwidth,l_hzthick);				
172	dd4hep::Volume l_vol(l_name,l_box,air);				
173	<pre>DetElement layer(tower_det, l_name, det_id);</pre>				
174	11 for the set of the				
175	// Loop over the sublayers or slices for this layer.				
176	<pre>int s num = 1;</pre>				

C*

Resolution.C

Makes a wide variety of relevant plots (some examples)



Most pressing needs

- Proper interface between crystal and photodetectors (port from single crystal code)
- Proper simulation of electronics (port from stand alone code by Ledoskoy et al)
- Proper Dual correction implementation for joint calorimeter

Conclusions

- We have a nice sandbox for playing with dual readout calorimetry
- However it still needs development to be ready to be an accurate simulation to help us understand and optimize our array test beam, both with and without a backin HCAL
- dd4hep does have a pretty high entry barrier, but coming to our meetings and working with our team can help overcome this.