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## TOTEM Ntuple

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TOTEM Ntuple

Description of the TOTEM ntuple structure.

Metadata part

branch: event_info.

```c
struct EventMetaData
{
    unsigned long run_no;                 ///< run number in form \([run number]\)*1E4 + [raw-data file index]
    unsigned long event_no;               ///< event number assigned by CMSSW (RawDataSource), counts from 1
    unsigned long daq_event_number;       ///< event number assigned by DAQ
    unsigned long long timestamp;         ///< timestamp of the event (UNIX timestamp), 1s resolution
    std::vector<unsigned int> optoRx_Id;  ///< ID of a given OptoRx (the index of the array)
    std::vector<unsigned int> optoRx_BX;  ///< bunch-crossing number reported by a given OptoRx
    std::vector<unsigned int> optoRx_LV1; ///< LV1 as reported by a given OptoRx
};
```

Trigger part

branch: trigger_data.

(the data from LoneG)

```c
struct TriggerData
{
    unsigned char type;                   ///<
    unsigned int event_num;               ///< incremental counter of triggers accepted by DAQ (thus event counter
    unsigned int bunch_num;               ///< the number of bunch(-pair) collided in this event
    unsigned int src_id;                  ///<
    unsigned int orbit_num;               ///<
    unsigned char revision_num;           ///<
    unsigned int run_num;                 ///< the run number (without the raw-file index extension)
    unsigned int trigger_num;             ///< incremental trigger counter
    unsigned int inhibited_triggers_num;   ///< incremental counter of triggers rejected by DAQ
    unsigned int input_status_bits;       ///< result of the trigger logic (each bit corresponds to
};
```

The meaning of the bits in `input_status_bits` above is defined by the following table:

<table>
<thead>
<tr>
<th>bit</th>
<th>trigger type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>RP220_Vert</td>
</tr>
<tr>
<td>1</td>
<td>RP220_Horiz</td>
</tr>
<tr>
<td>2</td>
<td>RP220_Cross</td>
</tr>
<tr>
<td>3</td>
<td>TTBB</td>
</tr>
<tr>
<td>4</td>
<td>CMS &amp; L1SA</td>
</tr>
<tr>
<td>5</td>
<td>T2_single arm</td>
</tr>
<tr>
<td>6</td>
<td>T2</td>
</tr>
<tr>
<td>7</td>
<td>T2_HighMultiplicity</td>
</tr>
<tr>
<td>8</td>
<td>T1</td>
</tr>
<tr>
<td>9</td>
<td>BC0</td>
</tr>
<tr>
<td>10</td>
<td>T2_LM</td>
</tr>
<tr>
<td>11</td>
<td>L1SA</td>
</tr>
</tbody>
</table>
Roman Pot part

Below, [RP] stands for RP numerical ID (e.g. 120 for 56-near-top). * RP Numbering Scheme:

![Numbering of Roman Pots.](image)

Digi section (misleading name, this branch refers to clusters)

branches: digi_rp_[RP].

```cpp
struct RPRootDumpDigiInfo {
    std::vector<int> numberOfClusters;  ///< number of clusters in a given plane (indexed from 0 to 9)
    unsigned int numberOfPlanesOn;      ///< number of planes with at least one cluster
    unsigned int uPlanesOn;             ///< number of U planes with at least one cluster
    unsigned int vPlanesOn;             ///< number of V planes with at least one cluster
    std::vector<int> planeId;           ///< plane ID for a given cluster (array index)
    std::vector<int> clusterSize;       ///< cluster size of a given cluster
    std::vector<int> centralStrip;      ///< central strip of a given cluster
};
```
Pattern-recognition section

branches: par_patterns_rp_[RP]. (parallel/road search algorithm)

branches: nonpar_patterns_rp_[RP]. (non-parallel/Hough-transform search algorithm)

Each of the branches has the following structure:

```cpp
class RPRootDumpPatternInfo {
    std::vector<RPRootDumpPattern> u, v; ///< arrays of recognized patterns in u and v projections
    bool fittable;                        ///< whether there is one (and only one) combined u-v pattern worth fitting
};
```

The u and v array elements (linear patterns) are described by:

```cpp
class RPRootDumpPattern {
    double a; ///< slope in rad
    double b; ///< intercept (at the middle of the RP) in mm
    double w; ///< weight
};
```

Track section

branches: track_rp_[RP].

```cpp
class RPRootDumpTrackInfo {
    bool valid;                       ///< whether track fit is valid
    double x, y, z;                   ///< track fit interpolated to the middle of the RP
    double chi2;                      ///< fit chi square
    double chi2ndf;                   ///< fit chi square divided by the number of degrees of freedom
    unsigned int entries;             ///< the number of contributing hits
    double res_x, res_y;              ///< seem not used
    std::vector<int> u_sect, v_sect;  ///< list of active trigger sectors calculated from (strip) data
    int u_sect_no, v_sect_no;         ///< sizes of u_sect and v_sect vectors
};
```

Multitrack section

branches: multi_track_rp_[RP]

Each of the possible track (u-v) combinations is listed in the following array:

```cpp
vector<RPRootDumpTrackInfo>
```

Single-proton reconstruction section

branches: rec_prot_[left/right].

```cpp
class RPRootDumpReconstructedProton {
    bool valid;
    double thx, thy, phi, t, tx, ty, xi, x0, y0, chi2, chindf;
};
```
Proton-pair reconstruction section

branch: rec_prot_pair.

```cpp
struct RPRootDumpReconstructedProtonPair {
  bool valid;
  double thxr, thyr, xir, phir;
  double thxl, thyl, xil, phil;
  double x0, y0, z0, chi2, chindf;
  double tr, txr, tyr;
  double tl, txl, tyl;
  double t;
};
```

T1 part

T2 part

```cpp
std::vector<int> Pad_row;            //pad row (0..24)
std::vector<int> Pad_col;             //pad column (0..63)
std::vector<int> Pad_det;             //symbolic id of the detector containing the pad:
  //0..9: planes in the Plus Near quarter;
  //10..19: planes in the Plus Far quarter
  //20..29: planes in the Minus Near quarter
  //30..39: planes in the Minus Far quarter
std::vector<int> Strip_row;           //strip row(0..255)
std::vector<int> Strip_col;            //strip column (0..1)
std::vector<int> Strip_det;            //symbolic id of the detector containind the strip, same
std::vector<double> TrkEta_XY;    //track eta calculated from the polar angle where the XZ and YZ
std::vector<double> TrkZmin_XY;  //Z value of the minimum approach disctance of the track from the
std::vector<double> TrkRmin_XY;  //the corresponding distance.
std::vector<double> TrkAx;            // slope of the track projection in the XZ plane
std::vector<double> TrkAy;            // slope of the track projection in the YZ plane
std::vector<double> TrkX0;            // intercept of the track projection in the XZ plane
std::vector<double> TrkY0;            // intercept of the track projection in the XZ plane
std::vector<double> TrkPhi;           // phi of the track obtained using the TrkAy and TrkAx.
  // For secondaries can be different from the
std::vector<double> TrkChi2XProb;          //Chi2-X probability (goodness of the XZ projection fit
std::vector<double> TrkChi2YProb;          //Chi2-Y probability (goodness of the YZ projection fit
std::vector<double> TrkClass1HitCounter;   //Number of class1 Hit (1 strip cluster and 1 pad clu
std::vector<double> TrkHitCounter;         //Number of class1 hits + number of cluster pad (with
std::vector<double> TrkThetaR_RZFit;  // Trk Polar angle obtained with a linear fit on the (r,Z
std::vector<double> TrkEta_RZFit;        // Trk Eta obtained from TrkThetaR_RZFit
std::vector<double> TrkPhi_RZFit;        // Trk Phi obtained with a constant fit of the (phi,Z) fit
std::vector<double> TrkZ0_RZFit;         // Crossing Point between Trk and the Z Axis, obtained
std::vector<double> TrkBX_RZFit;        // Track Y @ Z=0 obtained with an extrapolation of the
std::vector<double> TrkBY_RZFit;        // Track Y @ Z=0 obtained with an extrapolation of the
unsigned int NumPadCluH0; //Num pad cluster in the whole PN
unsigned int NumPadCluH1; //Num pad cluster in the whole PF
unsigned int NumPadCluH2; //Num pad cluster in the whole MN
unsigned int NumPadCluH3; //Num pad cluster in the whole MF
std::vector<int> TrkNumHitInH0;  //Number of hits from the quarter PN,
std::vector<int> TrkNumHitInH1;  //Number of hits from the quarter PF,
```
std::vector<int> TrkNumHitInH2;  //Number of hits from the quarter MN,
std::vector<int> TrkNumHitInH3;  //Number of hits from the quarter MF,
std::vector<double> TrkEta2;   //Eta of the track obtained as an average of the hit eta (assuming the vertex at (0,0,0))
std::vector<double> TrkChiProb;            Track Chi2 probability
std::vector<double> ProbChi2R_rz;        Track Chi2 probability for the RZ fit
std::vector<double> Chi2Rreduced_rz;   Reduced Chi2 for the RZ fit
std::vector<double> HitPhi;      // Phi position of all the Hits (degree)
std::vector<double> HitR;        // R position of all the Hits (mm)
std::vector<double> HitType;     // 0-> only pad; 1-> only strip 2->Class 1 Hit (superimposition pad/strip)
std::vector<double> HitNumPad;   // Cluster Pad Size
std::vector<double> HitNumStrip;  // Cluster Strip Size
std::vector<double> TrkEntryX;   // Track X Entry point
std::vector<double> TrkEntryY;   // Track Y Entry point
std::vector<double> TrkEntryZ;   // Track Z Entry point
std::vector<double> TrkExitX;     // Track X Exit point
std::vector<double> TrkExitY;     // Track Y Exit point
std::vector<double> TrkExitZ;     // Track Z Exit point

Warning: to limit the size of the ntuple, it is possible that some field (hit, pad, strip collections) are missing.

Fetching data from Ntuple

**Totem files**

TFile *totemFile = TFile::Open(totemFileName.c_str()); //opening input files
TTree *tree_totem = (TTree *) totemFile->Get("TotemNtuple");
checkAndGetBranch(tree_totem, "trigger_data")-&gt;SetAddress(&trigData);
int totemSize = tree_totem-&gt;GetEntries();
for (int tot_i = 0; tot_i &lt; totemSize; tot_i++) {
  tree_totem-&gt;GetEntry(tot_i);
  cout &lt;&lt; Data in trigData &lt;&lt; tot_i &lt;&lt; is equal &lt;&lt; trigData[&$594$];nameOfTheDataFromTrigData;
}

**CMS files**

TFile *cmsFile = TFile::Open(cmsFinalFileName.c_str());
TTree *tree_cms = (TTree *) cmsFile-&gt;Get("evt");
MyEvtId *evtcmsUA = nullptr;
checkAndGetBranch(tree_cms, "evtId")-&gt;SetAddress(&evtcmsUA);
int cmsSize = tree_cms-&gt;GetEntries();
for (unsigned int cms_i = 0; cms_i &lt; cmsSize; cms_i++) {
  tree_cms-&gt;GetEntry(cms_i);
  cout &lt;&lt; Data in evtcmsUA &lt;&lt; cms_i &lt;&lt; is equal &lt;&lt; evtcmsUA[&$594$];nameOfTheDataFromEvtcmsUA;
}

**Checking and getting branch(checkAndGetBranch method from example above)**

TBranch *checkAndGetBranch(TTree *tree, string branchName) {
  TBranch *branch = tree-&gt;GetBranch(branchName.c_str());
  if (!branch) {
    string dotBranchName = branchName + ".";
    branch = tree-&gt;GetBranch(dotBranchName.c_str());
  }
  if (!branch) {
    tree-&gt;Print();
  }
error(" No data branch " + branchName + " found in input file!");
}
return branch;
}